Problem Solving in Endodontics
Prevention, Identification, and Management

5th Edition

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with 1663 illustrations
The discipline of endodontics seems to be at the crossroads in its evolutionary process and growth as a specialty of dentistry. Over the past few years, the practice of endodontics has been enhanced by remarkable technologic innovations and evidenced-based research. A wealth of new information has led to a better understanding of the biological basis for treatment, which has resulted in improved clinical treatment and more predictable outcomes. Interest in the provision of quality endodontic procedures and tooth retention remains foremost with many dental practitioners.

At the same time, however, our educational processes within this discipline are ailing. Recruitment to full-time faculty positions in endodontics has been a major challenge, especially from the ranks of recent graduates of endodontic specialty programs in the United States and Canada. The same is true in many countries around the world. The modest success of filling some teaching positions from the ranks of the retired military is offset by the comparatively short career potential of these people. Furthermore, many of these individuals are choosing a more lucrative “second career” in private practice. Moreover, whereas part-time faculty do play a role in the educational process, most do not possess pedagogic expertise. Teaching, therefore, may often be empirically-based, which at times can undermine even the most sophisticated and well-structured curricula. Despite the addition of many foreign trained educators in the United States and elsewhere, numerous faculty positions remain unfilled with no prospects in the offing. In some schools, endodontic departments have lost autonomy and have been consolidated into megadepartments, which ultimately weakens the position of endodontics in the competition for curriculum time. Who then will teach the students of tomorrow?

The astute observer will also note that over the course of recent years there has been the loss of many enduring and influential figures in endodontic education. Not only are these individuals remembered for their inspirational teaching but also for their self-sacrificial commitment to excellence in all aspects of endodontics. An attempt at a complete list would be futile as the definition of “great” is elusive. Nevertheless, today one wonders who are the leaders that can replace Irving Naidorf, Gerry Harrington, I.B. Bender, Sam Seltzer, Hank Van Hassel, Don Arens, Harold Gerstein, Tom Mullaney, Gene Natkin, Thom Dumsha, and Ed Osetek? Who will be the stalwarts of the future or have we seen the twilight of the “endodontic professor?” Who will be remembered for their intellects, the rigor of their educational programs, and their enduring influence on students? Who will bring the necessary passion to the teaching of endodontics and the inquisitive energy to the research that is essential within this discipline?

Unlike many popular novelists or screen writers of our time, we did not conclude the previous editions of this book with visions of a “sequel” or plans for the “next installment.” The impetus for the creation of a fifth edition arose gradually during many think tank endeavors and reflective sessions in the years since the publication of the fourth edition. It is obvious that there have been significant contributions from research that have impacted on current practice. Some concepts that were novel at the time of the fourth edition are now fully integrated into modern theory and practice. Other prompts came from readers and commentaries on our previous efforts. Our own experience and observations have led to certain additions and changes as well as an increasing need to present the information within from a global perspective. For example, tooth numbering systems differ widely throughout the world. Since this book has achieved a surprising and gratifying international presence, revisions were required to rename each tooth using international standardized terminology, e.g., maxillary first molar, etc. In the same way, we have attempted to use diction that will be as clear as possible to nonnative English readers.

Many excellent endodontic texts currently available are anthologies of chapters written by a multitude of different and varied authors. A distinct disadvantage of this approach is the paucity or lack of communication among writers. The fifth edition of Problem Solving in Endodontics is the product of two of the original authors. The intense collaboration during the long creative process has resulted in a uniquely cohesive and integrated text. For example, concepts and figures are frequently cross referenced from other chapters where additional information will be helpful. A cursory examination of the table of contents will reveal a complete restructuring of the text material into sections of related topics. There are several completely new chapters. Every chapter carried forth from the previous edition has been almost completely rewritten.

In terms of content, the first obvious change is the expansion of diagnosis in this edition. It has become clearer
that problem solving must include a more complete process of diagnosis. Observations of referred cases in the private practice experience of the authors underscore diagnostic and treatment planning errors which in some cases, have led to a succession of calamities in treatment. Occasionally, endodontic treatment was completely unwarranted. Our objective in expanding the diagnostic section is to give the reader a diagnostic process that can confirm or rule out pathoses related to issues of the pulp and supporting periodontium in the vast majority of clinical situations. Likewise, it was not our intention to be encyclopedic. Rare conditions are omitted as we believe the practitioner provides better service by ruling out the most common possibilities and referring the patient when a diagnosis cannot be reached. For our international audience, we have included as many alternate diagnostic and treatment procedures as possible so that proper diagnosis can be done with the materials available.

A second major expansion is the section on surgical procedures. The ability to treatment plan and perform a multiplicity of surgical procedures are hallmarks of the specialty of endodontics, and therefore it will be obvious that tooth retention is a paramount objective of this text. The discussion of periapical surgery is intentionally limited to the anterior teeth and it is presumed that readers who will use this text for acquiring surgical techniques will be novices. The text is written with this in mind and with increased attention to detail. Periapical surgery on posterior teeth is a subject that requires extensive surgical experience and is not within the scope of this text.

A third addition in content consists of references throughout the text. The amount of research since the previous edition is staggering. We have endeavored to include as many of the relevant sources as possible to support the advocated philosophy. Whenever possible, evidence-based or best evidence references are cited to support the clinical choices. Furthermore, because textbooks can often be out of date by the time they go through the gymnastics and gyrations of publishing, a recommended additional reading list is included with updates added as close as possible to the final process of publication. It is anticipated that references will be website based and usable for academicians and lecturers.

Fourth, entire chapters are spent on irrigation and disinfection and on working length determination, with extensive literature assessments and clinical directives, because of the importance that these two entities play in the achievement of success. Furthermore, issues of diagnosis and treatment of tooth hypersensitivity along with vital pulp therapy have been expanded and put into clinical perspective, as well as techniques to revitalize the compromised tissues in teeth with immature apical development—often referred to erroneously at this early stage of its evolution as “regenerative endodontics.” In doing so it should be understood by the reader that endodontic therapy does not equal root canal treatment, as this discipline encompasses many diagnostic and treatment modalities.
Acknowledgments

A text of this nature requires the input from many interested and loyal supportive individuals who believed in the passion and commitment of the authors.

PEL would like to express appreciation for the immeasurable contribution made by his daughter, Jennifer Ludwigson in the production of digital images, location of charts and records, and willingness to be a subject in clinical photographic demonstrations. Thanks also to Lorrie Ebergson, who has the most amazing memory for cases and patient names. Thanks to Diane Edson for setting up photographic demonstrations and sometimes being the subject as well. Thanks to Joe Ludwigson for help with the skull photography. I appreciate the cases provided by the colleagues who are referenced in the legends. Finally thanks to my wife Kathy, for long-suffering patience and grace throughout the project.

JLG would like to express appreciation to all of his former graduate students and to all the professionals, globally in 51 countries, that he has had the honor and privilege to teach and guide in the achievement of quality, predictable endodontic procedures. I have learned from you in the process and furthermore you have kept my passion for teaching alive and well. I would also like to thank the endodontic staff members at the Medical College of Virginia, University of Maryland at Baltimore and Baylor College of Dentistry for their support in my vision of endodontic excellence during my 27 years of full-time teaching. Gratitude goes out to the enthusiastic and supportive dental assistants and administrative staff that have assisted me in the practice of endodontics. Finally, for the many hours of patience, understanding, and support provided to me by my wife Marylou, I express my deepest gratitude.

We also wish to thank John Dolan, Executive Editor, for believing in us and using a gentle prod to move us forward with this edition; to Brian Loehr, Developmental Editor, for his creative ideas and excitement in the editing of this text and preparation of the layout and presentation of the messages within; and Rachel McMullen, our Senior Project Manager, for keeping on schedule and ensuring that we always strove for excellence every step along the way.
Dedication

It is both a privilege and honor for the two authors of this text to dedicate this vastly revised edition of *Problem Solving in Endodontics* to Dr. Sonia Ferreyra of Córdoba, Argentina. We have come to recognize that Sonia is an individual with a unique vision for dental education and the will to bring it into reality. Early in her teaching career, she was recognized by her peers and her students for her ability to incorporate the science of dentistry with the highest standards of clinical care. Gradually, the needs and requests of her postgraduate students led to a formalized program of study that now encompasses a 30-month curriculum focusing on the areas of endodontics and dental trauma.

Today, Dr. Ferreyra is the President of FUNDECO, a Scientific Foundation for Continuing Education in Dentistry in Argentina. She established this Foundation in 2002 with the goal to educate highly qualified dental professionals in formative knowledge and clinical skills. Her vision “to save teeth” includes education, patient care, and clinical research, which is most laudable in this day and age. In addition to continuing educational programs at the highest possible level, FUNDECO has established school educational programs, sports educational programs, and emergency unit programs to manage dental trauma in local hospitals. Under her astute guidance, treatment protocols and rehabilitation programs for patients have been developed with services provided free of charge. She has initiated research programs that would contribute to the ultimate delivery of quality and predictable clinical care to the community at large. She has been directly responsible for 359 postgraduate students, of which 185 have successfully completed their studies and remain active with the workings of the Foundation. Another 174 are presently in various stages of their educational and research pursuits. She continues to influence dental professionals in Uruguay, Paraguay, Chile, Argentina, and Spain.

Sonia has become a beacon of hope for many dental professionals and a life-line to tooth retention and quality oral health care for so many residents of these countries in South America. She is passionate about her mission; deliberate in choosing her students; unrelenting in her pursuit of science and both educational and clinical excellence; and compassionate and caring in all of her undertakings. She is loved by all of her students and through both good times and challenging times in the establishment of FUNDECO, she has endeared herself to so many dentists, imbuing them with her wisdom, her impeccable values, and her staunch professional integrity. Dr. Ferreyra holds both a DDS and PhD degree and is a member of both the American Association of Endodontists and International Association of Dental Traumatology.

For JLG as a contributor to Dr. Ferreyra’s efforts for the past 10 years, this has been an amazing and rewarding relationship, especially during the evolution and growth of her Foundation. For PEL, the past 5 years of contributions have expanded his horizons and his love for teaching on all levels, spurred on by the thirst for knowledge and enthusiasm displayed by all of Sonia’s students. Together, we are both humbled and proud to dedicate our efforts to this extraordinary and enthusiastic young lady, who is both a true “amiga” and an inspiration for so many colleagues. Sonia we salute you and thank you for your immense contribution to endodontics and dental trauma.

James L. Gutmann
Paul E. Lovdahl
Es un honor y privilegio, como autores de este libro, dedicar esta ampliamente revisada edición de “Resolviendo Problemas Endodónticos” a la Dra. Sonia Ferreyra de Córdoba, Argentina. Hemos llegado a reconocer, que Sonia es una persona con una visión única por la educación odontológica y el deseo de llevarlo a la realidad. Temprano en su carrera de docente, fue reconocida por sus colegas y estudiantes por su habilidad de incorporar la ciencia odontológica con los más altos niveles de cuidado clínico. Gradualmente, las necesidades y demandas de sus alumnos de post-grado, resultaron en un programa formal de estudio, que hoy en día consta de un currículo de 30 meses de duración, enfocado en áreas de endodoncia y trauma dental.

Hoy, la Dra. Sonia Ferreyra es la presidenta de FUNDECO, una Fundación científica para Educación Continuada en Odontología en Argentina. Ella estableció esta Fundación en el año 2002, con el propósito, de formar odontólogos altamente calificados, en conocimientos formativos y habilidades clínicas. Su visión de “salvar dientes” incluye, educación, cuidado del paciente y investigación clínica, la cual es elogiable en estos tiempos. Además de programas educación continuada del más alto nivel, FUNDECO estableció programas educativos en escuelas, programas educativos de deportes y programas de unidades médicas para poder manejar el trauma dental en hospitales locales. Bajo su astuta guía, han sido desarrollados protocolos de tratamiento y de programas de rehabilitación con servicios prestados sin costo alguno para el paciente. Ella ha iniciado programas de investigación que contribuirán en grande la entrega de calidad y cuidado clínico predecible para una amplia comunidad. La Dra. Sonia Ferreyra es directamente responsable de 359 egresados de Post-grado, de los cuales 185 han completado satisfactoriamente sus estudios, y se encuentran activos trabajando con la Fundación. Otros 174 están actualmente en varias etapas de sus carreras educacionales y de investigación.

Ella continúa influenciando a odontólogos en Uruguay, Paraguay, Chile, Argentina y España.

Sonia se ha convertido en faro de esperanza para muchos odontólogos, y en una línea de vida, para la retención de dientes y calidad en el cuidado oral para muchos residentes de estos países en Sur América. Ella tiene pasión por su misión; selecciona muy bien a sus estudiantes; persistente en su destino, en cuanto a la investigación científica y en su búsqueda de la excelencia educacional y clínica; también en cuanto al cuidado compasivo de sus pacientes. Es una doctora muy querida por sus alumnos y en todo momento ya sea bueno o desafiante en FUNDECO, ella se ha puesto siempre en disposición muchos Odontólogos, enseñándoles de su experiencia y sabiduría, con valores impecables y su gran integridad profesional. La Dra. Ferreyra posee 2 diplomas, uno como Odontóloga y otro de PHD, es miembro de la Sociedad Americana de Endodoncia, y de la Sociedad Internacional de traumatología dental.

Para JLG como contribuyente a los esfuerzos de la Dra. Ferreyra durante los últimos 10 años, esta ha sido una relación de gran satisfacción, especialmente durante la evolución y el crecimiento de su Fundación. Para PEL, los últimos 5 años de contribuciones han expandido sus horizontes y su amor por enseñar a todos los niveles, empujado por la sed de conocimiento y el entusiasmo demostrado por todos los alumnos de la Dra. Sonia. Juntos, nos sentimos al mismo humildes y orgullosos de dedicar nuestros esfuerzos a esta extraordinaria y entusiasta joven mujer, quien significa una verdadera amiga y una inspiración profunda para muchos colegas. Sonia, te saludamos y te agradecemos por tu inmensa contribución a la endodoncia y al trauma dental.

James L. Gutmann
Paul E. Lovdahl
New to this Edition

To help you make the best clinical decisions, this edition contains new chapters and new sections on diagnosis and treatment planning!

Expands the endodontists’ capabilities into differential diagnosis.

Use of new material in vital pulp therapy.

The Surgery section has been expanded with new case studies, and more in-depth coverage of indications and applications for surgeries!
New Illustrations!

Drawings and radiographs that identify clinically-important and potential anatomic problems.

Controversies in the biologic and clinical aspects of working length determination
Chapter 1

Problem Solving in the Diagnosis of Odontogenic Pain

“A few moments’ consideration of the original cause of trouble at the apex of roots enables us to realize what is required to be accomplished in the way of successful treatment. If the original cause is admitted to be irritation from decomposing pulp, its removal will in most cases affect a cure.”

W. Whitehouse, 1884

Making an accurate endodontic diagnosis is a problem for many dentists. The solution to this problem is neither easy nor lends itself to a method that can be reduced to a series of simple steps. A further complication is that most clinicians find it difficult to challenge long-held concepts and practices and resist the notion that these beliefs may be biased. Their experience, under examination, may be limited. There is also a tendency to place trust in authorities without asking how these authorities came to be dominant influences in clinical thinking and practice. When attending a continuing education course, it is not unusual to have thoughts, such as “I already know this,” or “I have heard this before,” or “There is nothing new to be learned here.”

Dentists attend continuing education courses or read professional literature with the intent to improve their knowledge and abilities. In reality, most of the information in a course may not be new to an experienced clinician. What is often missed by clinicians, however, is the importance of detail, relative significance of concepts, and how this unique information can enhance their diagnostic acumen and clinical data gathering. Upon returning to the practice of dentistry, the information presented in the educational experience is often forgotten, and the clinician is destined to repeat the same errors they have been perpetuating for years. In an attempt to minimize this nonproductive process, and in the hope that ingrained patterns of erroneous thinking in the diagnosis of pulpal and periapical pathosis states will be clarified, simplified, and enhanced for the dental clinician, this chapter will provide detailed diagnostic methods used by the authors and most endodontic specialists.
Most concepts may already be familiar; the intent of this chapter is to provide a context for each method or test that will emphasize its unique importance in a problem-solving format. Not all diagnostic tests, examination methods, weighing of historical information, or patient subjective data are relevant to every case. Through clinical examples, the value of each approach will be emphasized to assist the clinician in reevaluating the entire diagnostic process and the incorporation of a realistic and meaningful approach to making a final diagnosis.

Taking an Accurate Dental History

The most common complaint that brings people to the dentist is pain. It is usually an acute problem termed “an emergency” by the patient, who typically characterizes it as being swollen, having pain to biting, being unable to tolerate temperature changes, or the statement, “I have an infection in my tooth.” Occasionally the dental problem is the result of trauma that is usually obvious by appearance; or the patient arrives with complaints of vague or nonlocalized pain. In some cases, pain may not be a reason for the dental consultation at all. The specific nature of the problem is sorted out during the consultation interview, where patient statements and other critical information are collected. In addition to revealing much information about the dental problem, this initial contact, if done in an open and nonthreatening manner, will usually disclose patients’ expectations, previous experiences, fears, and their understanding of the nature of their dental problem.

Because pain is so variable and its perception so subjective, history taking will require gathering and interpreting appropriate information. Patients frequently have strongly held preconceptions that may not be true or relevant. For example, often they believe they know which tooth is causing the problem. The clinician must be able to distinguish information that is useful, such as “I cannot bite on this tooth,” from that which is subjective, such as “The pain hurts me in these three teeth.” It is highly unlikely there are three teeth creating the patient’s problem, but it is quite common for pain to be referred to an area larger than the area of the offending tooth. A few pertinent questions to obtain greater insight into the patient’s specific problem may include:

- “Can you recall what you were experiencing prior to the treatment performed by the other dentist?”
- “When do you feel this pain?”
- “Is it a constant pain? If not, describe when or how it occurs and how long it might last.”
- “Has the pain occurred more frequently or lasted longer in the past few days or weeks?”
- “Is the pain stimulated by something hot or cold?”
- “Is there a time of day when the pain seems to be worse?”
- “Does the pain awaken you at night?”
- “How would you describe the pain? Is it dull? Is it sharp, like an electric shock?”

At this point, it is appropriate to ask the patient about any physical perceptions or concerns.

- “Have you noticed any swellings, or do you feel swollen in any specific area?”
- “Is there an area of your face that is tender to touch?”
- “Are there any teeth that hurt or are uncomfortable when you chew or after you have eaten?”
- “Do any of your teeth feel loose, or are you biting on any tooth sooner than other teeth?”

Interpretation of Historical Data and Subjective Findings

Interpreting historical data and subjective findings usually occurs simultaneously as they are secured, and these initial impressions usually direct the subsequent questioning. As a broad overview, let us consider these questions in the order they have been presented. Responses to the initial questions about the basic dental complaint can often lead directly to a clinical examination and a rapid diagnosis. If the problem were an acute abscess, for example, the patient would probably give enough information in the first two or three sentences to make a tentative diagnosis of abscess. Subsequent questioning would then concentrate on the presence of physical signs and symptoms of infection. It would remain to be determined if the abscess is of pulpal, periodontal, or other etiology.

Patients who have been experiencing chronic pain problems may not be feeling any pain at the moment of examination but can describe the chronic nature of it in detail. Endodontic problems can develop episodically over a period of time but will most often show a pattern of decreasing periods of comfort and increasing periods of
discomfort. This may even be followed by periods of complete comfort.

The overall time frame for tooth problems is much shorter than for myofascial pain problems, which often come and go over a period of years. It is helpful to find out if there have been periods of complete resolution. This kind of history is also consistent with myofascial pain related to nocturnal bruxing or clenching, which is discussed in Chapter 6 on nonodontogenic pain. Within this diagnostic theme, it is common to awaken in the morning with facial pain. Both endodontic problems and myofascial pain problems can awaken patients from sound sleep, which is one of the few relatively objective measures of the severity of pain. Other typical symptoms of myofascial pain problems may mimic endodontic pathosis as well. As will be discussed in detail in Chapter 6, patients who have developed trigeminal neuralgia may experience severe and debilitating episodes of electric shock-type pain but are curiously never awakened from sleep with pain.

If the patient has not experienced appreciable pain, responses to the probing questions during data gathering often focus on a nodule or “bump” noticed on the mucosal surface or an area that is noticeably tender to touch. These findings may indicate a developing periapical lesion or a draining sinus tract. Other possibilities could include a wide range of possibilities, from a normal but previously unrecognized exostosis to a small swelling associated with blocked ducts of minor or major (Stensen’s duct) salivary glands. Diagnosis and treatment of many of these etiologies is beyond the intended scope of this book. Our purpose here is to rule these out as having a pulpal or periapical origin or focus.

Finally, some patients who come for a routine examination are found to have a clinical lesion of possible pulpal or periapical origin or a radiographic lesion discovered on the routine radiographic survey (see Chapters 2 and 3). It is still important to inquire about any history associated with these lesions. Many people may recall episodes of pain or local swelling in the past that may assist in clarifying these findings and providing a more accurate diagnosis. On the other hand, the radiographic lesion or interpretation of such may not be of pathologic origin.

Clinical Examination: Objective Findings

Visual Inspection

Clinical examination specifically for an endodontic diagnosis will focus on two areas: causative factors in the teeth (pulpal inflammation, infection, etc.) and signs of periapical pathosis in the soft tissues due to spread of an inflammatory/infectious process from the pulp. All of the teeth on the side of pain should be visually inspected. Gross caries is an obvious etiology for painful symptoms. Occasionally in a case of spontaneous pain, gross caries may be observed in a tooth, almost invariably a molar, in the opposing arch from where the pain has been felt. Further testing in such a case often indicates that the teeth in the area of felt pain are normal, whereas the opposing carious tooth is the source of the referred pain.

Clinical Problem

Problem: A 52-year-old male was seen on an emergency basis. His chief complaint was of acute, spontaneous pain episodes in the mandibular left molar area (Fig. 1-1, A). Visual examination revealed no caries or fracture lines in either the left maxillary or mandibular teeth. There was a very large amalgam restoration in the mandibular first molar, which was the area where the patient felt the pain was originating. Thermal sensibility (pulp) tests, however, elicited normal responses from all teeth in this area.

Solution: Failure to reproduce the patient’s chief complaint during the examination of this quadrant of teeth resulted in conducting further tests in other areas of the left side. Further tests were then conducted on the opposing teeth. The heat test elicited an acute, severe painful response on the maxillary second molar. A radiograph of this area revealed gross caries (see Fig. 1-1, B). Although there was no visual evidence of caries clinically, on removal of the occlusal composite resin, gross marginal leakage was apparent. Root canal treatment was indicated only on the maxillary second molar.

FIGURE 1-1 A, Left mandibular molars respond normally to thermal tests. B, Maxillary second molar with evidence of gross caries.
Another important process in the clinical examination is to search for the presence of coronal fracture lines. The majority of fractures occur in a mesial-distal direction, and frequently these are obscured by coronal restorations (Fig. 1-2). It is often possible to observe them only on the intact marginal ridges, but they may extend to or below the level of crestal bone on the interproximal surface (Fig. 1-3). Fractures may also be observed on the buccal or lingual surfaces. Two fracture lines on different surfaces may be evidence of a complete cusp fracture. For example, the combination of a deep lingual fracture line in the lingual groove of a mandibular molar and a fracture line on the distal marginal ridge distal could indicate the fracture of the distal lingual cusp, which is a common factor in the initiation of pulpal inflammation (Fig. 1-4).

The soft tissues should be examined for physical signs of redness and swelling that may indicate that the periapical tissues have become inflamed or infected. Typically these specific physical signs would be evidence of a sinus tract, local swelling over the apices, or regional swelling (Fig. 1-5). Discoloration and edema may also be clues in a site of recent acute infection. In view of the original complaint of the patient, the clinician must be careful to avoid being misled by the accidental discovery of additional problems. For example, if the original complaint included a current history of acute thermal sensitivity, the visual observation of a sinus tract in the alveolar mucosa or attached gingiva on a single-canal tooth may be evidence of a pulpal problem, but it would probably not be the source of the symptoms for which the patient is seeking treatment. In this situation, the patient may have at least two distinct problems.
Occasionally there may be signs of infection that are likely to be the source of the patient’s complaint but unlikely to be of pulp or periapical origin. Pericoronitis around a partially erupted third molar is usually recognizable owing to its location; an endodontic problem with the second molar may have to be ruled out (Fig. 1-6). Much more common are periodontal abscesses, which may be more difficult to differentiate from periapical abscesses if periodontal disease is evident throughout the dentition. This diagnostic problem will be discussed further in the subsequent section on periodontal probing.

The clinical examination is conducted with a series of instruments and techniques that might be considered the “tools of problem solving.” Each test or assessment technique can reveal a clue that may impact or confirm the ultimate diagnosis. Seldom will it be necessary to do all of the tests or techniques listed, but it is equally important not to jump to conclusions too early in difficult diagnostic cases. The process of clinical examination is intended to both identify the source of the symptoms or observed pathosis and to rule out pathosis on adjacent teeth. It may be difficult in some cases to reproduce reported symptoms, but it often will be possible to reach a confident opinion about the normality of certain teeth, thereby reaching a diagnosis through the process of elimination.

During a clinical examination, data are gathered using a multitude of tests and evaluative procedures. While some tests will focus on the status of the pulp, others will be used to ascertain the extent of the spread of pulp inflammation or infection to the supporting periodontium. At times, it is difficult to separate information that is pulparly related from information related to extension of the disease process or periapically related. It is the intent of this first chapter to focus on the gathering of key information that will initially provide evidence of pulpal status. Other findings gleaned in this problem-solving process must be correlated and integrated with a thorough examination of the supporting periodontium, along with quality radiographs. These data will then be integrated into a periapical diagnosis that will be addressed in Chapter 3.

**Use of the Explorer**

For diagnostic purposes, the No. 23 explorer or the DG16 endodontic explorer (both explorers can feature a No. 17 tip when the instruments are double ended) are useful for the detection of caries, open restorative margins, fractures, loose cusps, and fracture lines (Fig. 1-7). Interproximally, the extent of caries buccal lingually can be ascertained. If a cracked tooth is located in the area of pain, it is useful to explore the interproximal surface of the tooth with a fine
No. 17 explorer (Fig. 1-8). Often it is possible to feel the presence of a deep fracture line and follow it vertically along the proximal surface. Obviously, the more apical the fracture is felt, the more likely there is pulpal involvement. If the fracture extends below crestal bone, periodontal breakdown may also occur, a finding with serious prognostic implications. This will be discussed in more detail in the section on periodontal probing and also in Chapter 3 on radiographic interpretation.

**Palpation**

One of the most informative but often overlooked evaluative procedures of the clinical examination is palpation. While not crucial for a pulpal diagnosis, for teeth with pulpal necrosis, palpation soreness or pain may reveal the presence of inflammation associated with periapical periodontitis. Reflecting on the anatomy of this environment is important in the interpretation of findings in this examination. Teeth with roots that lie close to the surface of the alveolar process will more likely exhibit palpation sensitivity or tenderness. Roots covered by relatively thin labial plates of bone or no bone at all are usually in the maxilla, with the apices of the central incisors, the canines, the buccal root of the first premolar, and the buccal roots of the molars often located anatomically superficial to the bony surface. Examination of teeth in human skulls indicates that fenestration of the apex or sections of the root surface is common in the absence of pathosis (Fig. 1-9). Periapical lesions of teeth in other areas are less likely to exhibit palpation tenderness, owing to the thickness of the buccal plate or the external oblique ridge in the case of the mandibular molars (Fig. 1-10). Nevertheless, in conditions of an acute periapical abscess, palpation tenderness, local swelling, and drainage through the gingival sulcus are not unusual even where the buccal bone is very thick.

**Percussion**

Pain or tenderness to tapping on a tooth (percussion) is not crucial to a pulpal diagnosis but is symptomatic of...
three other conditions. It may be a sequela of trauma, which applies to virtually all anterior teeth and is easy to identify by the history. A root canal procedure may not be indicated, because there may be no pulpal damage. Sensitivity testing (formerly known as vitality testing) would be indicated. There may or may not be concomitant palpation tenderness with traumatized teeth, but if palpation tenderness is found, it will usually not be confined to the region over the apex.

Second, tenderness to percussion may be the result of periapical inflammation due to either a necrotic or an acutely inflamed pulp. In these cases, concomitant palpation tenderness may or may not be found only over the apices. Depending on the acuteness or chronicity of the underlying pathosis, both the percussion tenderness and concomitant palpation tenderness can be either mild or extremely acute. Included in this category are teeth that have coronal fractures, since it is the pulp that becomes painful from the flexing of the cracked cusp. However, sensibility tests would be necessary to establish a pulp diagnosis.

Third, tenderness to percussion may be a symptom of occlusal trauma, most often the result of nocturnal clenching or bruxing. The presence of a concomitant tenderness to palpation with this condition is rare. Furthermore, the pulps of affected teeth respond normally to sensibility testing. It is common to find more than one tooth equally sensitive and a history of episodes of discomfort separated by intervals of complete comfort. The reader is referred to Chapter 6 for additional information on this topic.

Percussion testing can be done using the handle of a mouth mirror to tap several teeth in the opposite dental arch along their long or vertical axis (occlusal direction) to establish in the patient’s mind the condition of normality (Fig. 1-11, A). Ideally a contralateral tooth from the tooth in question should be chosen; if available, a previously root-treated, symptom-free tooth may be used. Every effort should be made to “standardize” the degree of force used as each tooth is tapped, even though it is not possible to measure the force.

Following percussion of the teeth along the vertical axis of the tooth, the teeth are also tapped with the mirror handle on the inner slopes of the cusps (on posterior teeth) and at 90 degrees to the long axis of the tooth (see Fig. 1-11, B). A traumatically injured tooth and a tooth with periapical periodontitis will be sensitive in any direction. Teeth that have become sensitive to percussion from bruxism may be sensitive to percussion in only one direction. If the tooth responds normally to percussion tests when performed occlusally but is sensitive to lateral percussion, the underlying cause is most likely an occlusal prematurity or wear pattern in lateral excursion. Visual assessment will often identify smoothed, flattened cusps or marginal ridges when wear facets are present. If the tooth is sensitive in an occlusal direction, the prematurity or wear pattern is usually in the centric contacts. Articulating paper is often helpful in surveying the occlusal contacts. Treatment for this problem is described in Chapter 6.

**Bite Pressure Test**

This is a corollary test to the percussion test. At times, patients describe an inability to chew comfortably on a side or a tooth. It is often difficult to reproduce this symptom with the percussion test. A bite pressure test is performed by having the patient bite directly onto a device or material placed between the teeth. This is done tooth by tooth. Do the test first on the opposite side to inform the patient what is expected and what is normal. Various materials have been used for this purpose. The wooden handle of a cotton applicator, the cotton end of a cotton applicator, an orangewood stick, the commercially available “Tooth Slooth” (Professional Results Inc., Laguna Niguel, CA, USA), and temporary dental stopping have all been recommended (Fig. 1-12). Most clinicians prefer a semi-hard gutta-percha type stopping material or orangewood stick. Additional information about this test is described in Chapter 6.

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**FIGURE 1-11** A, Percussion in the vertical axis of tooth. B, Percussion perpendicular to vertical axis of tooth.
Periodontal Probing

The value of periodontal probing in diagnosing and differentiating problems of pulpal or periapical origin cannot be overemphasized. Loss of periodontal attachment has a significant influence on the prognosis of treatment and the prognosis for tooth retention. Periodontal probing should begin with the symptomatic tooth. Acute periapical abscesses will occasionally drain spontaneously through the sulcus, and upon probing in the area of swelling, purulent drainage will ensue. In most cases, the attachment will return rapidly after the initial removal of the infected pulp tissue from the root canal, often within 1 week (Fig. 1-13).

For the purposes of routine periodontal examination, the sulcus depth is usually measured and recorded at the mesial, midtooth, and distal points on both buccal and lingual surfaces. During an endodontic evaluation, however, probing should be as circumferential as possible in 1-mm increments. This technique will characterize the physical architecture of any infrabony defect associated with attachment loss. It is diagnostically important to know if the defect is narrow or wide across the circumference of the root and to determine whether the defect has a precipitous architecture or a rather gradual pattern of probing to the deepest point. Periodontal pockets tend to have a steplike or gradual architecture. They are shallow at the limits and step gradually to the deepest level (Fig. 1-14, A).

The most common cause of attachment loss is periodontal disease. It is possible to confuse an acute periapical abscess with an acute periodontal abscess. If the symptomatic tooth

**FIGURE 1-12** Bite pressure test with a wooden stick. See Chapter 6 for alternative techniques.

**FIGURE 1-13** A, Local swelling associated with an acute periapical abscess. B, Prodings are normal circumferentially except for a narrow 10 mm defect in the furcation. C, Post treatment radiograph indicating the bone loss associated with the apical lesion on the distal root. D, Three and a half weeks after treatment. The symptoms and the swelling have resolved completely. Prodings indicate complete periodontal reattachment in the area of the former defect.
but will be distinguished chiefly by the fact that the tooth will have had a root canal procedure. Vertical root fractures of teeth without previous root canal treatment are rare. Though symptomatic, many such defects will be discovered only on probing, because they lack radiographic signs of pathosis, including a periapical lesion. Another clinical finding unique to vertical fractures is the consistent location on either the midfacial or the midlingual surface of the involved root. If the root is fractured completely through, this probing pattern will be found on both buccal and lingual sides (see Fig. 1-14, B).

Chapters 3, 4, and 19 explore the topic of fractures more fully, but from a diagnostic standpoint, the probing pattern virtually defines the presence of fracture. Whenever a defect is present for which the diagnosis may be unclear, surgical exposure is a procedure that may reveal the cause, especially following a previous root canal procedure.

Many defects will be discovered interproximally. A deep mesial-distal coronal fracture extending below crestal bone will cause the formation of a narrow periodontal pocket only present at the site of the fracture line. Problings 1 mm to either side may be normal. The difficulty of probing in a vertical direction in the interproximal space can make this discovery a challenge if the periodontium is healthy. Anesthesia is sometimes necessary for this clinical evaluation. Some defects of this type will not be evident on radiographs, so the probrings may be the only objective evidence found. This is critical to the diagnosis, since a deep, narrow interproximal defect would suggest a poor long-term prognosis that may be best managed by extraction.

The fracture illustrated in Fig. 1-3 has an associated interproximal periodontal defect. Probrings confirmed that the defect extended well below the general crestal bone level of the area, and the tooth was extracted.

**Mobility**

Mobility is most often found on teeth with advanced periodontal disease. It can also occur in cases of acute periapical
abscess and occasionally, occlusal trauma.\textsuperscript{10} During the examination, note any mobility and check the occlusion. Regardless of etiology, occlusal reduction should be done in all cases of teeth having excessive occlusal contact, although its value has been questioned.\textsuperscript{9,25} Heavy occlusal contact will remain a contributing factor for postoperative pain and prolonged healing time.

**Radiographic Interpretation**

Chapter 3 on radiographic interpretation will cover a broad range of topics that digress from the issue at hand: odontogenic pain. Nevertheless, it is essential to the development of a pulpal and periapical diagnostic system to include a discussion of some important concepts regarding the value of radiographs. First, \textit{it should not be the expectation that every pulpally involved tooth will have radiographic signs of pathosis.}\textsuperscript{2} It is impossible to determine the condition of the pulp itself on a radiograph. The only changes to be discovered radiographically in these cases are those representing the loss of hard tissue, usually bone surrounding the apex. Periapical pathosis is, in turn, a consequence of pulpal necrosis and (occasionally) extreme pulpal inflammation. Routinely, teeth with pulpal symptoms (i.e., discomfort to thermal changes, etc.) will not have radiographic changes, yet they still require a root canal procedure. This is of crucial diagnostic significance.

**CLINICAL PROBLEM**

**Problem:** A 50-year-old female with a 2-month history of acute pain to heat in the maxillary left quadrant was referred to an endodontist. The symptoms began slowly, and initially the woman felt only mild pain of brief duration. The symptoms had progressively become more acute. The patient was now experiencing spontaneous pain almost continuously. She stated that her dentist has been unable to diagnose the problem because nothing has appeared on any of the several radiographs taken during this time (Fig. 1-15, \textit{A}).

**Solution:** The diagnosis of this case will never be made on the basis of a radiograph. In almost all cases, there are no radiographic changes in cases of thermal sensitivity. The diagnosis will always be made on the basis of thermal tests and clinical examination. In this case, though the molar teeth were heavily restored and likely candidates for endodontic involvement, the tooth causing the problem proved to be the second premolar (see Fig. 1-15, \textit{B}).

**FIGURE 1-16** Typical appearance of a periapical lesion.
Inflammation and infection of the periapical tissues are the result of necrotic tissue products and bacteria that emanate from the apical foramen and sometimes from lateral canals that can be present at a separate location on the root. The same process occurs in cases of failure of previous root canal treatment. This disease process will cause eventual resorption of the surrounding bone. It is the loss of bone that produces the characteristic radiolucency observed in the periapical area (Fig. 1-16). In some cases of acute periapical abscess, there are no radiographic changes even though there may be swelling and acute pain. These situations can be explained by the suddenness of onset. Radiographic evidence of apical bone resorption will require as much as 7 days or more to occur after the onset of an acute periapical abscess. In these cases, while no lesion is observed at the time of emergency treatment, a lesion may be present at a subsequent appointment when the tooth is comfortable and ready for completion of the treatment. The reader is referred to Chapter 3 for a discussion of the radiographic progression of periapical pathosis.

Differential Tentative Diagnosis

A differential diagnosis is an intermediate step in the diagnostic process. Diagnostic possibilities are narrowed to two or three plausible choices, and other possibilities are eliminated. This concept can apply to etiologic entities such as periodontal abscesses or vertical root fractures. Identification of the final diagnosis from the narrowed list will require a further but more focused examination. For endodontic cases, a frequent problem is identifying the correct tooth. After evaluating radiographs and doing the clinical examination, further testing is often required, but the area of interest will be more limited.

Sensibility (Vitality) Testing

Theory

Fortunately for dentistry, pulpal diagnosis has the benefit of some reasonably reliable tests. However, the value of these tests has been questioned to some extent as to their direct correlation with the disease process as a whole. Tests for the measurement or assessment of the depth of cracks in teeth do not exist. Hot, cold, and electrical stimulation have existed in dentistry for a very long time. Historically, the last test to arrive was the electric pulp tester, invented in 1867. Curiously, with all the developments in modern technology, no new testing methods have been refined for clinical application, and a problem or disconnect actually exists with all presently used tests. Whereas the desire of the clinician is to know the physiologic condition or relative health of the pulp tissue, the tests provide only an indirect assessment through stimulation of the nerve tissue or possible blood flow. Fortunately, although the pulp is a complex tissue composed of fibrous connective tissue, vascular supply, nerve supply, and odontogenic cells, there seems to be a reasonable correlation between the way the nerves react to sensibility tests and the health or pathologic condition of the pulp as a whole. Research approaches during the middle of the 20th century sought to correlate clinical symptoms with the histopathologic status of the pulp. However, all histopathologically defined conditions were found to have a wide variety of clinical signs and symptoms. A clinically based diagnostic system emerged based on symptoms alone. Diagnostic pulpal entities were defined clinically and primarily by responses to thermal tests. This system, with some modifications, has withstood the test of time and clinical practice.

There are two valuable aspects to thermal testing. First, the pulp either responds or it does not. This positive or negative aspect to the response indicates whether there is vital tissue, or specifically, vital neural tissues in the root canal. In this sense, the value of the thermal test is the same as the electric pulp test. In fact, if a tooth responds to either hot or cold, the electric pulp test may be redundant. As a consequence, electric pulp testing has value only with teeth that are unresponsive to thermal tests. The same qualifications apply to the value of a test cavity.

The second value of thermal testing is the qualitative aspect of the response. It is not only whether the pulp responds but also how it responds. This testing always begins with establishing what is normal for the patient by testing multiple teeth outside the symptomatic area. Ideally this is done by testing the tooth contralateral to the tooth in question and the teeth on either side of the suspected tooth. Responses of the symptomatic tooth are evaluated in comparison to the other tested teeth. This is extremely important when there are no clinical signs of pathosis other than a history of sensitivity. The magnitude of response and the duration have significant meaning in determining the status and prognosis of the pulp. Generally, the magnitude of the response is less important than the duration. Any test response which lasts 10 seconds or longer is considered abnormal and the status of the pulp is unlikely to improve. Theoretically this is a sign of irreversible pulpal degeneration. Teeth responding in this manner are indicated for root canal treatment.

Ideally, the object of thermal testing is to reproduce symptoms reported by the patient. Most of the time this will occur, and the diagnosis will be established rapidly. In many cases, however, this will not be possible. Degeneration of the pulp is a dynamic process in which the symptoms tend to change over time. Symptoms felt a week prior to the visit may no longer be felt at the time of examination. Nevertheless, it is extremely unlikely that the pulp has recovered to complete normality. In these cases, any abnormal responses...
on a particular tooth are significant, even if they do not resemble the symptoms reported by the patient.

Applicable and Pertinent Testing Techniques

Cold Test

Cold testing is a more reliable test than heat. The test may be conducted with ice, crystals of ethyl chloride, carbon dioxide spray, or cold water. Ice sticks or ice pencils can conveniently be made by filling and freezing the discarded plastic sheaths from disposable anesthetic needles (Fig. 1-17). The advantage of ice is that it is readily available and easy to use (Fig. 1-18). The chief disadvantage to ice is the possible effect of the melting cold water on adjacent teeth or the gingival tissues. To counter this, the adjacent teeth and gingiva can be protected by cotton rolls or gauze (Fig. 1-19). The ice stick should be blotted to remove any melted water immediately prior to the test. Another minor disadvantage is the need for someone in the office to maintain the supply of ice sticks in the freezer.

An equally viable option for the cold test is ethyl chloride (Fig. 1-20) or carbon dioxide sprayed onto a cotton-tipped applicator (Fig. 1-21) or a cotton pellet and then applied to the tooth. An advantage of this choice is convenience and consistency in temperature without affecting the soft tissues. It is always ready to use, and no special preparation is needed to maintain a supply in the office (other than to reorder spray cans).

Again, testing with any of these materials should begin on a contralateral tooth when possible to establish in the mind of the practitioner what would be considered normal for that patient. Presumably, normal teeth within the quadrant of the suspected tooth should also be used (Fig. 1-22).

FIGURE 1-17 Anesthetic carpules used to make ice sticks for testing.

FIGURE 1-18 Testing with an ice stick.

FIGURE 1-19 Protecting adjacent teeth with gauze while ice testing.

FIGURE 1-20 Endo Ice.
Again, all exposed surfaces may be tested in this way. If no response is obtained on any surface while other comparative teeth respond readily, the pulp may be presumed to be necrotic.

**Heat Test**

Unlike cold testing, historically there was no heat test that applied a stimulation at a known temperature or maintained the stimulation at any constant temperature. Contemporary, there are instruments that can be used to apply heat to the tooth at specific temperatures (BeeFill 2in1, VDW, Munich, Germany; Calamus Dual, Dentsply Tulsa Dental Specialties, Tulsa, OK, USA; Elements System, Sybron Dental, Orange, CA, USA). These are actually root canal obturation devices that use heat applied with a specific tip for contacting tooth structure. If not available, a commonly used applicator for heat is temporary gutta-percha-type stopping material warmed in a flame (Fig. 1-25). Other options for applying heat are the rubber polishing wheel
or the rubber prophylactic cup (Fig. 1-26). It may be necessary to test multiple surfaces with more than one method. Delayed responses to heat are more frequent than to cold on both normal and pathologic teeth. For this reason, it is wise to proceed slowly from one tooth to the next. If tests are performed too rapidly on multiple teeth, a delayed reaction may occur for which it is not possible to identify the source. On occasion, more than one stick of warmed stopping may be applied simultaneously to different surfaces to increase the temperature and duration of the heat stimulus. The most useful application of the heat test is the case where the chief symptom is heat sensitivity or actual pain to heat that must be relieved with cold water or ice.

**Dental (Rubber) Dam Application for Thermal Pulp Testing**

The application of a dental dam is sometimes advantageous for routine pulp testing to allow more complete isolation. All pulp tests can be performed more conveniently because it can serve to retract the cheek and tongue. The retraction effect is especially useful during heat testing to avoid accidental burning of the cheek or tongue (Fig. 1-27). With this method, the dam is placed on each tooth separately with the rubber dam clamp. There is no need to establish a complete seal by working the dam interproximally, so the dam can be quickly moved from tooth to tooth.

The dental dam also can be applied for the use of cold or warm water as a test. The advantage of this test could be the bathing of the tooth in liquid, similar to what occurs in reality. Theoretically, the thermal stimulus would most likely reproduce the symptoms experienced by the patient. The disadvantage is that the dam must be applied separately to each tooth to ensure a complete seal. If sensitivity is due to loss of enamel or cementum covering the dentin at the cervical margins, the dental dam may actually prevent an accurate response to the testing.

**Electric Pulp Test**

The electric pulp tester, as indicated before, has no qualitative aspect to the response (Fig. 1-28). In cases where there is no reaction to hot or cold, the reasonable presumption might be that the pulp is necrotic. This would be a valid conclusion if all the teeth tested provided comparable responses. Occasionally in a given dentition, heat and cold tests elicit little response on any of the teeth. The electric pulp test (EPT) can at least provide the information of response or no response that may help differentiate normal from necrotic pulps. During usage, a medium such as tooth paste or gel is used to ensure the electrical contact between the tooth and the tip of the tester. Ideally the tip of the tester is placed at the incisal edge for the anterior teeth (Fig. 1-29). On posterior teeth, the favored location for placement of the tester is on the buccal cusp tip (Fig. 1-30). Many clinicians tend to favor the midfacial or buccal surfaces, but false readings may occur.

The relative number or reading on the tester is not an indication of the relative health or pathosis of the pulp. Because EPTs apply an increasing power on a logarithmic (not linear) scale, responses at the very highest power levels cannot be reasonably accepted as normal. EPTs can provide false positives and false negatives up to 20% of the time. A further limitation of the EPT is lack of response on teeth with immature root development; this can be particularly confusing. Such teeth commonly have open apices and periapical-type radiolucencies associated with the development of the dental papilla. In these cases, a widened apical periodontal ligament space is also typical and completely normal (Fig. 1-31). If any diagnostic questions arise regarding pulpal pathosis in teeth with immature apical development, pulp testing will be unhelpful. It is appropriate to monitor such teeth over time for the emergence of periapical symptoms or lack of continued root development before making the diagnosis of pulpal pathosis.

Traumatically injured teeth may also fail to respond reliably and predictably immediately following the traumatic event, but many teeth will regain sensibility within 3 to 6 months. Once again, long-term monitoring is in order. Development of periapical pathosis either clinically or radiographically would support endodontic intervention. The same is true for sensibility testing of teeth during orthodontic tooth movement, where responses may be highly unreliable (see Chapter 20).

**Anesthetic Test**

When patients are experiencing pain at the time of examination, or pain is elicited by thermal testing, the use of an anesthetic test may sometimes be valuable to confirm the diagnosis. In the maxilla, teeth can often be anesthetized selectively by infiltration. A small amount of anesthetic is
deposited in the periapical region of the suspect tooth (Fig. 1-32). After a minute or two, the pain should resolve if the diagnosis is correct. This test should only be done after all other examination techniques have been used, and the diagnosis is reasonably firm. It is also possible to achieve this effect by using periodontal ligament injection on some mandibular molars, but since the method is not effective for all, the lack of pain resolution could be due to anesthetic failure.

A second circumstance in which the anesthetic test can be useful is a case where the patient is in pain, and the clinician is unable to elicit responses from one or more teeth. The usual diagnostic procedures have been done, and most of the teeth have been ruled out. It is still unclear that the pain is of tooth origin. Of the teeth remaining after testing, the most likely candidate that may be etiologic for the pain is selected. If the pain resolves after the deposition of a small amount of anesthetic solution over the apex, that tooth is likely to be the problem. The anesthetic can be placed via infiltration or periodontal ligament injection. If the pain does not resolve after administering the solution, it is possible that the pain is not of pulpal or periapical origin.
Rubber dam retraction allows multiple heat applications without burning soft tissues.

FIGURE 1-27 Rubber dam retraction allows multiple heat applications without burning soft tissues.

The Sybron Endo Vitality Scanner.

FIGURE 1-28 The Sybron Endo Vitality Scanner.

Electric pulp test on the incisal edge.

FIGURE 1-29 Electric pulp test on the incisal edge.

Electric pulp test on cusp of molar.

FIGURE 1-30 Electric pulp test on cusp of molar.


areas. If there is gingival recession, the exposed gingival areas of the crown are somewhat hypersensitive, as are large metallic restorations. Often these areas will be found around gingivally placed metallic restorations, in which case any thermal testing that touches the metallic restoration may cause an accentuated response.

If the electric pulp tester has been used, data support testing on incisal edges of anterior teeth and buccal cusps of posterior teeth.

Reversible Pulpitis

This clinical diagnosis is characterized by accentuated response to cold and/or hot, compared to neighboring and contralateral teeth. Once again, the response will cease immediately or very soon upon withdrawal of the stimulus. There is no spontaneous pain. The patient reports an undesirable need to avoid foods or beverages of either temperature extreme.

This type of pulpal sensitivity is best exemplified by a tooth with a new restoration. Other common causes are root exposure from periodontal inflammation, periodontal treatment, or recent extraction of an adjacent tooth. There is an occasional onset after minor trauma. Some teeth will develop symptoms without an apparent cause. If an etiology such as caries, exposed cervical margins of dentin, or fractured cusp is discovered, the majority of cases will resolve after appropriate restorative treatment (see Chapter 7).

Test Cavity

Another sensibility test that has limited application is the test cavity. If all other methods of testing are ineffective or inappropriate, as in the case of the electric test on a full crown, a test cavity may reveal dentinal sensitivity as an indication of vitality. The test cavity is generally made in the same position as an endodontic access cavity. The value of this test would be similar to the result of an EPT. The test consists of making a small access cavity without the use of anesthetic. Clearly this is an invasive and irreversible procedure from a restorative standpoint, so it should only be used when it is essential to the diagnosis, all other methods of testing have proven unsuccessful, and the patient is well informed. As soon as the patient feels sensation from penetration into the dentin, the cavity is closed with a bonded restoration. In teeth with calcified pulpal spaces, the patient may not feel any sensation until the pulp has been exposed, which would commit the tooth to completion of root canal treatment, regardless of diagnosis.

FIGURE 1-32 Anesthetic test. A small amount of anesthetic solution is deposited adjacent to the apex of the suspect tooth.

CLINICAL PROBLEM

Problem: A 23-year-old female complained of increasing thermal sensitivity in the maxillary left second molar. Clinical examination revealed a fractured and leaking restoration (Fig. 1-33, A). Pulp tests indicated a pulpal state of reversible pulpitis.

Solution: In the absence of evidence of irreversible pulpal pathosis, the decision was made to replace the restoration. The existing restoration was removed. Only slight incipient caries was observed below fracture lines in the previous restoration. There was no evidence of a coronal fracture in tooth structure. The restoration was replaced using cavity varnish (see Fig. 1-33, B). The symptoms resolved completely within 72 hours.

Clinical Diagnostic Scheme Based on Test Responses

Normal

The clinical definition of normal is a response to cold at a low level of magnitude and immediate cessation of the response on withdrawal of the stimulus. A normal tooth will respond the same way to heat, though in practice somewhat fewer normal teeth seem to react to heat at all. There is no injury imparted to the tooth by this testing. The same tooth may be confidently retested any number of times. Generally, thermal testing that is done using the gingival areas will respond more consistently than the midbuccal or cusp-tip

In no case does the inflammation spread into the periodontal tissues, so no periapical changes are seen in these types of cases (Fig. 1-34). On occasion, the patient might experience continued mild pulpal pain from a minimal restorative procedure (class I amalgam or class III composite restoration). Remember that restorative procedures will have an inflammatory effect on the pulp in addition to any preexisting inflammation caused by other etiologies.
In these situations, if the sensitivity is not improving after 2 weeks or so, removal of the new restoration and placement of the base or sedative dressing may alleviate the symptoms. The problem with this approach, however, is that any additional restorative procedure has the potential to cause additional pulpal inflammation. Consequently, replacement of a new restoration with a sedative temporary restoration may have the opposite effect.

Reversible pulpitis generally will resolve spontaneously and gradually in 4 to 6 weeks upon removal of the etiologic factors. Root canal procedures are generally not indicated for reversible pulpitis; monitoring the patient is indicated. Occasionally when pulp testing reveals that symptoms are due to root exposure, desensitizing solutions or tooth pastes may be recommended to decrease sensitivity. In some cases, this type of hypersensitivity may not resolve after many months of monitoring, which may indicate that the pulp is inflamed beyond its ability to heal (irreversible pulpitis; see later). Chapter 7 discusses identification and management of a hypersensitive tooth in greater detail.

**Irreversible Pulpitis**

Irreversible pulpitis is defined by the symptom of prolonged, painful responses to thermal stimulation or the presence of spontaneous tooth pain with no obvious stimulus. Unlike reversible pulpitis, painful reactions to temperature may last from minutes to hours. This symptom is the typical reason patients seek dental treatment. If present, the spontaneous pain can also last for hours and awaken patients from sound sleep. Often teeth with irreversible pulpitis become painful to biting pressure as well. The diagnosis of irreversible pulpitis with localized pain can usually be made within a few minutes of taking the patient history and performing sensibility tests.

During clinical testing, any tooth that exhibits a reaction longer than about 10 seconds is considered to have irreversible pulpitis and is indicated for root canal treatment. This response occurs with either temperature extreme and occasionally both extremes simultaneously. It is not unusual to observe dramatic painful responses from relatively mild...
temperature stimulation, and the resultant pain can last until anesthesia is obtained. Teeth that react with pain to cold can either be unaffected by heat, or pain is intensified by the application of heat. Cold, on the other hand, will frequently temper or completely relieve pain in teeth due to heat stimulation. Patients with acute heat sensitivity and experiencing prolonged or spontaneous pain will sometimes arrive for examination sipping ice water to control the pain. Upon access opening in these teeth, a small amount of purulence is often seen, followed by excessive hemorrhage due to the presence of an intrapulpal abscess.

**Irreversible Pulpitis Not Localized**

Patients with irreversible pulpitis often present with a history of severe pain, either spontaneous in nature or stimulated by cold foods or liquids. Although the patient identifies a particular tooth or area in which the pain is felt, the clinician is unable to reproduce the symptoms. Likewise, the radiographic presentation is completely normal. Typically several teeth may have large restorations or crowns. The patient may be convinced that a particular tooth is causing their discomfort, but the clinician cannot elicit any thermal or percussion sensitivity from the indicated tooth or any other. In these not-so-rare instances, the clinician should resist the inclination to begin treatment based upon the patient's diagnosis or insistence. Clinical data and diagnostic findings are often confusing and do not lend themselves to a rapid or logical diagnosis. It is best to wait until valid, integrated data can be obtained that will facilitate an accurate diagnosis.

Initially, it is common for the radiographic presentation to be normal or show subtle or suggestive but not definitive changes. This is especially true of mandibular posterior teeth in which the cortical plate is extremely dense. Changes in the periapical bone will not become obvious until significant destruction has taken place.

**Necrotic Pulp**

The physiologic health or pathosis of the dental pulp might be thought of as a continuum that begins on one end with the normal pulp and progresses through stages of increasing pulpal inflammation and degeneration. Ultimately, the pulp becomes necrotic. Though pulpal necrosis is the endpoint of a pulp with irreversible pulpitis, symptoms for the two diagnostic states have a completely different manifestation. Whereas thermal sensitivity is the hallmark of inflammatory conditions, there is no thermal sensitivity with a necrotic pulp. The patient experiences symptoms of pain from thermal stimulation, and the clinician elicits no responses on testing.

Patient symptoms in the presence of pulpal necrosis arise in the periapical tissues as an inflammatory or infectious reaction to necrotic materials and to bacteria that diffuse out of the apical foramen and associated accessory communications. The location of this pathologic process makes possible the clinical signs of percussion sensitivity or pain, palpation sensitivity, swelling, and draining sinus tract. Gradually the apical bone resorbs, and as a result, apical and sometimes lateral rarefaction (loss of bony integrity) appears on the radiograph (Fig. 1-35). Radiographic interpretation of these findings is discussed in great detail in Chapter 3.

**Aerodontalgia/Barodontalgia**

A small subset of cases with significant pulpal degeneration or pulp necrosis exhibit the unusual symptom of spontaneous pain that occurs when there is a significant change in atmospheric pressure. Patients most often experience this during commercial aviation flights in which the cabin is pressurized (aerodontalgia). The pain may subside or be eliminated by reducing altitude or on landing; however, in some cases the pain may continue for several hours. This phenomenon has also occurred from changes as slight as driving over mountain passes where the altitude change may only be on the magnitude of 5000 to 7000 feet. People in deep underwater diving conditions have also experienced these symptoms (barodontalgia).

When patients present for dental treatment, they are often symptom free. It is clinically impossible to reproduce changes in atmospheric pressure, so it may be impossible to reproduce the symptoms by means of routine thermal tests. Nevertheless, thermal testing is usually the most effective means to localize the offending tooth. Testing will at least rule out the normal teeth that could not be the problem. Once the number of possible etiologic teeth has been reduced, continued testing, often with heat, will help confirm a diagnosis.
Putting It All Together: The Final Pulpal Diagnosis

The final pulpal diagnosis is derived from a synthesis and analysis of data obtained relative to the patient's complaint, the clinical examination, evaluation of radiographs, and the objective signs elicited from various tests. As a rule of good clinical judgment, no tooth should ever be relegated to root canal treatment unless the clinician is 90% or better assured that the correct diagnosis has been made and the correct tooth identified. From the history and description of symptoms, the clinician will sometimes know that a root canal procedure is indicated but be unable to identify the specific tooth upon clinical examination. Although contrary to the desire to provide pain relief for the patient, it may often be better to send the patient home with palliative support rather than risk treatment of the wrong tooth. It is especially difficult to send the patient away without treatment when the diagnosis cannot be made in the case of moderate to severe pain. The clinician fears that the patient will lose confidence in his or her diagnostic ability. In reality, however, if the clinician has conducted a thorough examination and has presented the diagnostic dilemma in a compassionate manner, the patient will understand that the symptoms will localize in time to a specific tooth. It will then be possible to diagnose the problem accurately and provide definitive treatment. The best solution to difficult diagnostic problems in endodontics is: Don't initiate a root canal procedure with the attitude of "let's try this and see if it works."

This chapter focused primarily on problem-solving concepts in the diagnosis of odontogenic pain, but the authors fully realize that accurate radiographs are essential in the overall diagnosis of the patient's problem. Many problems with achieving an accurate or most probable diagnosis stem from not having quality radiographs and interpretation of the data they contain. Chapter 2 will address proper radiographic techniques necessary in the endodontic diagnostic scheme, and Chapter 3 will address interpretation of (1) radiographic findings relative to information that may or may not assist tracking pulpal pathosis etiology and (2) findings that will enable a more focused periapical diagnosis. Information gleaned from Chapter 3 will enable the clinician, through problem solving, to create a more accurate patient diagnosis for both pulpal and periapical pathoses.

REFERENCES


RECOMMENDED ADDITIONAL READING

Chapter 2

Problem-Solving Techniques in Making Radiographic Images

Problem-Solving List

- Problem-solving challenges and dilemmas relative to making diagnostic radiographic images addressed in this chapter are:
  - The Ideal Dental Radiographic Image
  - Handling of Film and Digital Sensors
  - Controlling Variables
    - Exposure
    - Film/sensor position
    - Radiation beam angulation
  - Problem Solving in Evaluation of Image Quality
    - Correct and accurate images
  - Effects of Incorrect Angulation on Images of the Teeth
    - Foreshortening
    - Elongation
    - Anterior-posterior angulation
  - A Quality Dental Image Revealing Normal Structures
  - Advances in Radiology: Digital and Cone-Beam Computed Tomography
  - Clinical Directives

The most commonly used clinical tool to assist in making a diagnosis is without doubt the x-ray. It has been an invaluable boon to mankind, giving him a sixth sense to penetrate into the otherwise unknown. It leads us out of the dark as no other diagnostic can. Without x-rays one can hardly practice dentistry in an adequate manner or render the patient a satisfactory oral health service.7

L.I. Grossman, 1946

Before a meaningful discussion of the diagnostic interpretation of radiographs can begin, the technical quality of the image must first be assessed. A poorly made radiographic image will not contribute as much to the process of diagnosis as a well made one, but this self-evident concept is missed by many clinicians. The process of diagnosis may be entirely subverted by erroneous conclusions drawn from inadequate radiographs and could lead to inappropriate treatment. Tension arises when the clinician has made an inadequate image and a decision must be made. Is the information to be gained by remaking the image worth the added exposure of the patient to radiation? This ethical dilemma is usually resolved by remaking the image if the first fails to provide necessary information. Fortunately, modern dentistry has both low-exposure radiographic film and low-exposure digital radiography, so additional exposures have far less long-term risk than in the past. Nevertheless, it is incumbent on the clinician to review the cause of the radiographic error and correct it prior to additional exposures. It is the purpose of this chapter to review principles and practical techniques for obtaining diagnostically useful dental radiographic images, primarily for diagnosis in endodontics.

The Ideal Dental Radiographic Image

What is an ideal radiographic image? There are several aspects to be considered in answer to this question. First, the image should be neither too light nor so dark that it fails to show desired detail. It should have clarity of detail and be free of marks and blemishes. The image should represent the teeth without overlapping of proximal surfaces or roots. It should also represent the teeth as dimensionally accurate as possible, which occurs when the film is able to be placed in a position that is exactly parallel to the long axis of the tooth and the x-ray beam exposes the film at right angles. Clinically, this ideal is difficult to achieve in some areas because of the anatomy of the location into which the intraoral film or digital sensor is to be placed.
Handling of Film and Digital Sensors

Improper handling of film and poor darkroom technique can ruin otherwise excellent images. Dark spots, general foggy darkening, or a completely black film can indicate exposure to radiation or light, either by leaving unexposed film unprotected in the area where films are exposed or by natural light leaking into the darkroom during processing. It can also result from storage in areas where the temperature may exceed 80°F. Blemishes can be due to chemicals on the hands while handling undeveloped film and scratching of the emulsion before complete drying. Problems such as too much or too little contrast may indicate that the kVp is too high or too low. Discoloration such as brown staining of finished radiographs may indicate a problem with the fixer, either insufficient time for fixing or an exhausted fixer solution. If any of these problems arise with persistence, it is wise to review the recommendations of the manufacturer for both the x-ray machine and film to be sure the exposures and film are well matched. Secondly, it is worthwhile to review film handling and darkroom technique with all auxiliary personnel.

Digital sensors are less affected than film by environmental factors. There are no problems with exposure to light or radiation of the sensors not in use. The most frequent problems arise from infection control, frequent use and wear of connections, mechanical degradation, mishandling, the sensor itself wearing out, and patient concerns.

Controlling Variables

Good image making with appropriate equipment consists in the control of three variables: exposure, film or digital sensor position, and beam angulation. A good radiographic image for endodontic diagnostic and treatment purposes is obtained when the center of the x-ray beam passes through the apex and projects the tooth on the receptor film or sensor at a right angle (Fig. 2-1).

Exposure

Always follow the recommended exposure settings provided by the manufacturer of the radiographic equipment. For conventional film, the film type and speed must also be considered. Underexposure results in the loss of details such as the periodontal ligament space and lamina dura around the apex (Fig. 2-2, A). There is also a loss of contrast which makes it difficult to detect pathosis that lacks clear borders, such as caries. Increasing the exposure to recommended guidelines will result in a clinically useful film (see Fig. 2-2, B).

Overexposure tends to make normal structures appear pathologic. Radiolucency is observed in areas such as the cervical regions of teeth just above crestal bone, often referred to as cervical burnout, which resembles caries. There can also be loss of detail owing to excessive contrast in the film (Fig. 2-3).
Film/Sensor Position

If a film packet or digital sensor is not completely behind the tooth to be studied, the tooth or portion of interest will not be on the image. In endodontics, the area of interest is almost always the apex (Fig. 2-4). Commercially available intraoral film positioners such as the Rinn XCP (Dentsply Rinn, Elgin, IL, USA) are designed to place the film or sensor in the ideal position to capture the entire tooth (Fig. 2-5). When the patient bites on the film holder, the film is positioned to the maximum depth, and the apices will inevitably be present on the image (Fig. 2-6). The use of positioners can eliminate many problems in preoperative and postoperative image making.

The major challenge during root canal treatment is to make accurate images while the dental dam is in place. The hemostat can function similarly to the film positioner. The film packet is clamped along the edge and positioned in the mouth so that the instrument rests on the incisors or premolar. This positions the film to the maximum depth. The patient can maintain the film in position extraorally (Fig. 2-7). Digital sensors come with holders of similar design, and once the film/sensor is in place, the hemostat/holder also provides a measure of safety. A film packet or sensor held by a finger might easily become loose in the mouth.

Maxillary teeth are always a greater challenge in imaging because of the limited depth of the palatal vault and the anatomic lack of parallelism between the long axes of the teeth and the surface of the palate. To counter this, it is not necessary to have the film in contact with the tooth. For maxillary imaging, having the film or sensor in contact with

![FIGURE 2-4](image1) Radiograph that fails to capture the root apices. Use on an increased angulation cannot compensate for this error.

![FIGURE 2-5](image2) The Rinn XCP film positioner.

![FIGURE 2-6](image3) The Rinn XCP in place for exposure of a mandibular molar. Note how the bite block device holds the film at full depth. The upper edge of the film is even with the occlusal plane.

**CLINICAL PROBLEM**

**Problem:** Even with a hemostat/holder, the patient is unable to keep the film deep enough to capture the apices of a mandibular molar on a preoperative image.

**Solution:** The film is placed in position with the hemostat/holder, and the patient is instructed to bite together. This will force the film/sensor downward to the proper depth, and at the same time the musculature of the floor of the mouth will relax (Fig. 2-8). There is also less of a tendency to lose this position if the patient should swallow before the film/sensor is exposed. This approach will be effective even with the rubber dam in place.
**CLINICAL PROBLEM**

**Problem:** The patient has a narrow mandibular arch which makes placement of the film packet/sensor difficult for imaging the anterior teeth.

**Solution:** A conventional film packet can be bent at the edges to allow placement in the narrow space (Fig. 2-9, A and B). Pediatric-sized radiographic films can also serve but are shorter in length and may not capture the apices. The only option with digital radiography is to obtain a sensor of narrow width, which is available with some systems. If the mandibular arch is very narrow, as is sometimes the case with mandibular exostoses (tori), the film packet can be bent in half and clamped in the hemostat. Using a sensor in the presence of an exostosis can be most challenging and requires careful placement of the sensor. It is equally important to position the film/sensor as parallel as possible to the long axis of the tooth. The mandibular molars are the easiest teeth to make images of, since placement of the film/sensor is almost always automatically parallel to the tooth (Fig. 2-10). In the mandibular anterior region, the floor of the mouth and the attachment of the tongue to the genial tubercles are impediments to placement of the film/sensor to the proper depth. Images of the anterior teeth often appear very short. So long as the film/sensor is parallel to the tooth, it can be placed farther back into the mouth to allow the base of the tongue to be depressed (Fig. 2-11). **It is not necessary to have the film/sensor immediately adjacent to or in contact with the tooth.** By placing the film/sensor farther back into the mouth, the base of the tongue may be depressed. Placing a plastic cushion along the lower border of the film/sensor where it contacts the soft tissues is more comfortable for the patient (Fig. 2-12).

**CLINICAL PROBLEM**

**Problem:** The patient has a muscular tongue and has a difficult time maintaining the film in position behind the anterior teeth, even though the tongue can be depressed.

**Solution:** Position the film/sensor using the hemostat/holder. Instruct the patient to maintain the handle of the hemostat/holder in contact with an incisor to the side as the hemostat exits the mouth. This will usually work with or without the dental dam in place but may require anesthesia (Fig. 2-13).

The crowns (Fig. 2-14, A) is actually counterproductive. In this position, the film/sensor is never parallel to the long axis of the tooth and will lead to elongated teeth on the image. In ideal palatal placement, the apical edge of the film/sensor is usually in the midline of the vault, and the incisal edge is far from the crown of the tooth (see Fig. 2-14, B). This is the exact position obtained with a film positioner. When the dental dam is in place, the same positioning can be obtained using the hemostat/holder. The dental dam and clamp actually help to keep the occlusal edge of the film/sensor away from the tooth.

The maxillary anterior teeth, especially the canines, present a challenge in film placement, since all sensors and film packets tend to be rectangular. The corners of these image receptors inhibit the most anterior placement, and parallelism is difficult to maintain. With conventional film, it is possible to bend a small portion of the corner to counter this limitation. No such option exists for rigid digital sensors (Fig. 2-15).

**Radiation Beam Angulation**

The third aspect of image making is simply to expose the film or sensor at a right angle to the beam of radiation. If the film is in the proper position, it would seem that this step would be the easiest, but orientation of the radiation beam is difficult to master. Examination of the Rinn film holder demonstrates that if the cone is placed against the alignment ring, the radiation beam will be perpendicular to the film/sensor (Fig. 2-16). In addition, the center of the beam will focus on the center of the film/sensor. With these controls, the object tooth will always appear properly on the film.

When the dental dam is in place, it is difficult to use a film positioner. If the hemostat is used, it is useful to lift the
FIGURE 2-8  

A, It is difficult for some patients to hold the film sufficiently deep in the floor of the mouth.  
B, The hemostat will aid in maintaining the proper position by resting on the incisors. It also helps to have the patient close the mouth.

FIGURE 2-9  

A, Standard sized film packet can be adapted to variable anatomic situations by bending the sides or corners. This will leave a line on the resultant image. Do not place the bend where it will interfere with the desired image of the tooth.  
B, A standard sized film adapted to a narrow arch.

FIGURE 2-10  The anatomy of the lingual space is usually ideal for placement of the film or sensor parallel to the tooth.

FIGURE 2-11  For mandibular anterior teeth, film placement should be as parallel as possible. Contact or proximity to the teeth is not important.
FIGURE 2-12 Edge-Ease cushions make placement of films in the sublingual spaces more comfortable.

FIGURE 2-13 For muscular tongues, instruct the patient to force the hemostat down to rest on the incisor. Most patients can tolerate this without anesthesia. A film positioner functions in exactly the same way.

FIGURE 2-15 Digital sensors are rigid, which can impair placement.

FIGURE 2-14 A, If the film or sensor is in contact with the crown, the resultant image may be elongated. B, Ideal film placement should be as parallel as possible to the teeth. The superior edge of the film or sensor may be in the midline of the palate.

FIGURE 2-16 A, The ring on the film positioner orients the x-ray beam perpendicular to the film. In addition, the center of the beam is oriented to the center of the film. B, The cone is oriented extraorally without requiring visualization of the film/sensor position.
Problem Solving in Evaluation of Image Quality

There are numerous issues to be considered in the interpretation of pathology on radiographic images. Before any diagnostic problem can be considered, however, the quality of the radiograph itself must be assessed. Only limited information can be obtained from a poor-quality image.

The issues already discussed—namely underexposure, overexposure, and failure to have the target tooth on the image—can be corrected by film position and proper exposure. The problems associated with beam angulation are more pervasive and often so subtle as to escape detection until other images are made of the same area (Fig. 2-19). All three images in Fig. 2-19 appear familiar and acceptable clinically.
but only Fig. 2-19, C approximates the true dimensions of the teeth. This is of significant importance in endodontics if the image is to be used to estimate tooth length.

Images exhibiting obvious distortion due to errors in beam angulation also define the source of the error. The error can usually be remedied by returning to the principles of correct film placement and correct beam angulation.

Correct and Accurate Images

Within the realm of clinically acceptable radiographs, there are still variations the prudent clinician would be wise to minimize as much as possible. There are a few clues or signs that indicate the assurance of high-quality radiographs, assuming the exposure is correct. On the mandibular posterior teeth, as stated previously, placement of the film/sensor in the lingual space almost invariably results in a parallel relationship with the long axes of the teeth. If the teeth are parallel to the film, the occlusal surfaces are perpendicular to the film. A quality image should not have any aspect of the occlusal surfaces visible (Fig. 2-20). Despite the favorable anatomic relationship between the lingual aspect of the mandible and the long axes of the posterior teeth, many clinicians or other authorized personnel engaged in radiography have the tendency to angle the beam upward (Fig. 2-21).

There is an apparent fear that the image will not capture the apices. Although the resultant image may appear clinically satisfactory, important diagnostic information may be missed, especially around large metallic restorations.

In the maxilla, it is seldom possible to make images of the posterior teeth without an indication of the occlusal surfaces. The molar teeth can still provide an important clue to film quality, however. Although the palatal root is usually the longest root, the buccal roots are generally within 2 to 6 mm of the length of the palatal root. A film indicating excessively short buccal roots would be questionable, and as often as possible, the buccal roots should appear to frame the palatal root (Fig. 2-24).

In the maxilla, it is seldom possible to make images of the posterior teeth without an indication of the occlusal surfaces. The molar teeth can still provide an important clue to film quality, however. Although the palatal root is usually the longest root, the buccal roots are generally within 2 to 6 mm of the length of the palatal root. A film indicating excessively short buccal roots would be questionable, and as often as possible, the buccal roots should appear to frame the palatal root (Fig. 2-24).

A third clue is the position of the zygomatic arch. The normal anatomy is widely variable, and many teeth are difficult to radiograph without superimposition of this structure. An image on which the arch obscures most of roots of the molar teeth would be suspect and of little diagnostic value (Fig. 2-25).
FIGURE 2-22  A, Radiograph of the mandibular left posterior teeth provided by referring dentist.  B, Posttreatment radiograph indicating gross caries under mesial margin not evident on referral film.

FIGURE 2-23  Visualization of the inferior border of the mandible is a clue to foreshortening of the mandibular teeth. Superimposition of the mylohyoid ridge over apices of the mandibular posterior teeth is seldom found when angulation is correct.

FIGURE 2-24  Acceptable radiograph of the maxillary posterior teeth made using a skull. The palatal root is depicted between the buccal roots.

FIGURE 2-25  A, Exaggerated inferior angulation of the x-ray head for the exposure of maxillary posterior teeth.  B, Diagnostic radiograph made with the same angulation. Note foreshortened roots. The zygomatic arch obscures much of the detail in the area of the apices.
Unfortunately, images of the anterior teeth have few clues that reveal less-than-optimal angulations within the range of clinical acceptability, as seen in the examples in Fig. 2-19. Some possible clues in the maxillary anterior area might be superimposition of the nasal nares. The angulation of the x-ray cone in Fig. 2-26, A demonstrates how the nasal structures can be captured (see Fig. 2-26, B). The correct angulation is depicted in Fig. 2-26, C. In the anterior mandible, excessive upward angulation (Fig. 2-27) might be indicated by the presence of the inferior border of the mandible (mental protuberance) or the genial tubercles, as depicted in Fig. 2-28, A.

**FIGURE 2-25, cont’d** C, Correct inferior angulation. D, Radiograph of same teeth at correct inferior angle. Roots appear longer, and apical detail is now visible.

**FIGURE 2-26** A, Exaggerated inferior angulation in the anterior maxilla would capture a portion of the nasal cavity. B, Clinical radiograph made at an exaggerated inferior angulation. Note the nares at the top of the film. The teeth are excessively foreshortened. C, Correct angle for maxillary anterior exposures.

**FIGURE 2-27** Exaggerated superior angulation for exposure of mandibular anterior teeth. Note how the inferior border of the mandible would be captured on the radiograph.
Effects of Incorrect Angulation on Images of the Teeth

Foreshortening

Teeth can appear much shorter on a radiographic image than they are in reality (see Fig. 2-28; review Fig. 2-26, B). The image may be clear and possess fine detail, but such films are of poor diagnostic quality. The relationship of bone to tooth, such as assessment of crestal bone levels, is impossible. The appearance of pathosis may be hidden or completely distorted. In the mandible, foreshortening is usually another result of the attempt to capture the apices by angling the beam upward, but it can also occur with normal angulation if the molar teeth have a lingual inclination of the long axis. For these teeth, proper exposure would actually require a slight downward angulation of the radiation beam.

CLINICAL PROBLEM

Problem: A 50-year-old female was referred for root canal treatment of a symptomatic mandibular left first molar. The patient had been advised that the tooth may require extraction because of the apparent severe calcification observed on the image. The digital image was emailed to the endodontist (Fig. 2-29, A) prior to the arrival of the patient. The film was reviewed and found to be inadequate due to foreshortening and lack of diagnostic clarity.

Solution: At the examination appointment by the specialist, a new image was made with the film positioner. In the laboratory, the change in angulation is exemplified by photos of the angulation of the x-ray cone on a skull (see Fig. 2-29, B). It is apparent that the tooth is not calcified (see Fig. 2-29, C). Root canal treatment was completed without difficulty. Foreshortening can drastically affect root canal treatment when radiographic techniques are used to determine length or monitor quality during treatment. Elongation is the opposite of foreshortening; in this case, the teeth appear much longer than they are in reality. Detail may be completely distorted in the elongated area. Elongation is most often a problem in making images of the maxillary posterior teeth. One aspect of the problem is the low angle of the x-ray beam, which approaches parallelism with the occlusal plane (Fig. 2-31, A). The resultant image does not appear abnormal until it is compared with an ideal image of the same teeth (see Fig. 2-31, B and C). Maxillary exposures always require a distinctively downward angle relative to the occlusal plane (see Fig. 2-25, C).

A second contributing factor is film or sensor placement. A film/sensor held against the crown of the tooth (see Fig. 2-14, B) and exposed will accentuate elongation (Fig. 2-32).

A third complication pertains to film only. Radiographic film packets are pliable. If the film is held firmly with finger pressure directly against the palate, the superior edge of the film may curve to conform to the shape of the palate (Fig. 2-33, A). The resultant image will generally have good detail in the coronal half and elongation in the apical half (see Fig. 2-33, B).

The maxillary canine is a particularly difficult tooth to capture without elongation. This problem is made more acute in view of the wide variation in the anatomic shape of the anterior palate and the variable length of canine teeth. As mentioned earlier, placement of the film/sensor is limited by the anterior palate. If film is used, it is possible to bend the corner slightly to improve adaptation, but every effort should...
FIGURE 2-29  A, Referral film showing foreshortened and possibly calcified mandibular left first molar. B, Laboratory view of x-ray cone placed at an exaggerated superior angulation. C, Radiograph made at optimal angle. There is no apparent calcification.

FIGURE 2-30  Mid-treatment film to assess quality of obturation. Exaggerated superior angulation resulted in extreme foreshortening. This image could not be used.

be made to avoid curvature of the entire film packet, which would result in elongation of the apical half of the root. The best way to compensate for these complications is to place the film as far back into the mouth as possible and maintain parallelism.

Anterior-Posterior Angulation

An analysis of the film positioner reveals that the ideal anterior-posterior angulation of the x-ray beam is exactly perpendicular to the segment of dental arch in which the target tooth is located. For posterior teeth, this equates to perpendicular to the posterior sextant (Fig. 2-34).

Often, multiple radiographically angled views must be taken to reveal anatomic features not evident on the optimal clinical view. Documentation for this approach has existed for almost 90 years, with recommendations for taking radiographs from three distinct angles.8 The technique is to bring the x-ray head anteriorly so the cone will be angled in a more posterior direction (mesial angulation) while maintaining the correct upward or downward cone angle (Fig. 2-35). If possible, it is advisable to attempt to angle the film/sensor across the arch to approximate a perpendicular relationship with the beam (Fig. 2-36).20 Fig. 2-37 illustrates a clinical example of the view of the tooth and roots from this angulation. The same altered-angle view can be taken from the posterior but this configuration is difficult to use clinically, especially in the maxilla as the zygomatic arch is projected forward over the apices of the teeth. Secondly, the curve of the palate positions the film unfavorably for a beam angle approaching from the posterior.
**FIGURE 2-31**  
A, Low beam angle. Angle of x-ray cone is approximately parallel to the occlusal plane. This is ideal for mandibular teeth, but the contour of the palate will cause elongation in exposures of maxillary teeth.  
B, Image of maxillary posterior teeth exhibiting elongation due to the beam angulation depicted in A.  
C, Ideal image for comparison made at the angle depicted in Fig. 2-25, C.

**FIGURE 2-32**  
Excessive elongation results if film/sensor is held against the crown of the tooth, as in Fig. 2-14, A.
**FIGURE 2-33** A, Maintaining film in position with finger. Finger pressure causes deformation and undesired curvature of the film. B, Film exposed with the combination of low beam angulation and curvature of the film packet as it is formed to the palate with pressure.

**FIGURE 2-34** Ideal anterior-posterior angulation provided by film positioner. Ideal anterior-posterior angulation is perpendicular to the dental arch, here depicted in the posterior sextant of either the mandibular or maxillary teeth.

**FIGURE 2-35** Anterior angle variant position of the x-ray cone for additional views.

**FIGURE 2-36** Demonstration of variable angle techniques with a film packet in a skull. A, Normal position perpendicular to the segment. B, Beam position altered anteriorly. It is very difficult to obtain a film in which the angulation of the beam is altered posteriorly. Buccal roots of maxillary molars can be projected anteriorly if the tooth is in a rotated position.
Excessive angulations from the mesial will displace buccal roots of the molars severely to the distal, overlapping roots and proximal surfaces of the crowns (Fig. 2-38). An image made in this manner will be of little clinical use (see Fig. 2-38). The same is true with excessive angulations from the distal. Another sign of excessive anterior angulation is the appearance of the canine or even the lateral incisor on a molar image.

**A Quality Dental Image Revealing Normal Structures**

What is the definition of radiographic normality of the periapical tissues? The two anatomic features of normality with respect to endodontic diagnosis and root canal treatment are a periodontal ligament space of uniform width and an intact lamina dura around the entire root (Fig. 2-39). The lamina dura in general tends to vary in appearance even on the same root. The periodontal ligament is highly consistent and reliable in almost all anatomic areas (Fig. 2-40).

**FIGURE 2-37** A, Application of variation in angle technique. By shifting the beam anteriorly, buccal objects such as buccal roots or canals will “move” distally. B, Completed treatment. Distal buccal canal is on far left.

**FIGURE 2-38** Length determination film made with excessive anterior angulation. Distortion makes interpretation impossible.

**FIGURE 2-39** Normal periodontal ligament space is of uniform width around entire root. The lamina dura on this tooth is normal and continuous.

**FIGURE 2-40** The normal lamina dura is routinely variable in visibility and width around many teeth.
Advances in Radiology: Digital and Cone-Beam Computed Tomography

Digital radiography has revolutionized and streamlined endodontic diagnosis and treatment. There are several advantages of digital x-ray imaging over analog film imaging that can benefit the clinician: reduced time, reduced radiation, ability to take multiple exposures without repositioning the sensor, storage and maintenance of the images, and electronic transmission of images. Clinical challenges are inability to sterilize the sensors and the thickness of sensors, which can create discomfort for some patients and difficulty in the detection of small endodontic files when radiographically determining working length (Fig. 2-41). When appropriately sized working length files are used, digital radiology has superior accuracy to traditional radiographic exposures. Within this perspective, and when the various capabilities of digital radiology (clear views, inverted pictures, etc.) are used to view the films (Fig. 2-42), both normal and pathologic details can be seen more clearly than on standard radiographic film (Fig. 2-43). An exhaustive look at digital radiography is beyond the scope of this text, but its diagnostic and treatment advantages are worth noting (Fig. 2-44). Although there are some potential technical issues with these devices, they are irrelevant to the problem-solving focus of this chapter. Scientific validation of the best exposure strategies for optimizing specific diagnostic imaging tasks in endodontics is warranted.

There has been a major movement of cone-beam computed tomography (CBCT) into endodontics. This technology can be quite accurate, and its impact on

FIGURE 2-41 A, Digital radiograph of a mandibular first molar with somewhat indistinct root canals. B, When a digital clear view enhancement is used, even No. 10 K-files are easily distinguishable on the digital film.

FIGURE 2-42 A, Radiograph of maxillary molars using a digital radiograph. Note superimposition of zygomatic process that obscures root apices. B, Same film inverted using digital radiographic techniques. Details are somewhat enhanced over A.
Problem-Solving Techniques in Making Radiographic Images

FIGURE 2-43  A-C, These three digital radiographs are the same, except that A is a normal view, B is the enhanced clear view, and C is the inverted view. Different details of the roots, lamina dura, periodontal ligament space, sinus outline, poorly filled root canal, and crown margins can be gleaned from each different view, demonstrating the value of digital radiography for anatomic assessments.

FIGURE 2-42, cont’d  C, Digital radiograph of mandibular molars enhanced with a clear view option. D, Same film inverted in appearance. Both of these enhancing options assist in radiographic assessment. Note clarity of the pulp stone (PS) in the chamber in both pictures and the linear calcification positioned in both mesial and distal canals (arrows).
diagnosis of periapical lesions and possibly their etiologies is significant4,10,14,17-19 (Fig. 2-45). Presently, cost factors for both the clinician and the patient may limit integration of this technology into private-practice settings; larger radiology centers can provide this expertise. Within 5 to 10 years, however, owing to the potential of technology to vastly improve patient care,11 CBCT may very well be considered the standard of care in providing accurate endodontic diagnoses and treatment, in particular surgical intervention and case revision.19
FIGURE 2-45  A, Cone-beam computed axial tomography (CBCT) of the entire mouth. The tooth in question is the maxillary right central incisor that exhibits invasive external resorption. B, Sections 95 to 98 (red outline) demonstrate the nature and location of the resorptive defect, enhancing both diagnosis and treatment planning. C, Pretreatment periapical digital film. D, Following root canal treatment and location of the defect. E, Defect filled with mineral trioxide aggregate. CBCT enabled identification of the defect and its management. (Courtesy Dr. Paul Buxt.)
Clinical Directives

Radiography is an essential and indispensable part of endodontic diagnosis and root canal treatment. Excellence in diagnosis requires excellence in the quality of dental images. A poor-quality radiograph can only invite error in diagnosis and possibly result in harm to the patient. Concepts and techniques for producing good-quality images have been discussed to aid in trouble-shooting current techniques and unsatisfying results. Good diagnosis also requires a grounding in the definition of radiographic normality so that changes that represent abnormal anatomic structures or pathosis can be easily recognized and considered in the overall treatment plan of the case.12

REFERENCES


RECOMMENDED ADDITIONAL READING

Chapter 3

Problem Solving in Interpretation of Dental Radiographic Images

Problem-Solving List

Problem-solving challenges and dilemmas relative to the interpretation of dental radiographic images addressed in this chapter are:

Evaluation of Tooth Anatomy: Problem Prevention

Radiographic Changes Associated With Dental Caries

Radiographic Changes Associated With Tooth Fractures
  - Coronal fractures
  - Midroot fractures
  - Vertical root fractures

Radiographic Tooth Changes Associated With Resorption

Influence of Radiolucent Anatomic Structures on Radiographic Interpretation

Influence of Radiopaque Structures on Radiographic Interpretation

Radiographic Changes Associated With Pulpal Necrosis in Periapical Tissues

Lateral Radiographic Changes Associated With Pulpal Necrosis

Radiographic Changes Associated With Cases of Endodontic Failure

Radiographic Changes Associated With Nonendodontic Pathoses Mimicking Potential Endodontic Problems
  - Cementoma
  - Developmental cysts
  - Healed endodontic lesions
  - Periodontal lesions

The radiographic picture is only one means of diagnosis. It seems absurd for a dentist to bring to a diagnostician a radiographic picture and ask his opinion... the picture may show a tremendous area of rarefaction, but to use it as the sole means of diagnosis is unwise.17

T.P. Hinman, 1921

Within the scope of endodontics, radiographic images serve a double purpose: the confirmation of normality and the indication or details of pathosis. Radiographic images are produced by the differential absorption of radiation by mineralized tissues through which the x-ray beam passes before exposing the receptor film or digital sensor. There are only three types of tissues that can be identified routinely on dental radiographs: bone, enamel, and dentin. Cementum or a cementum-type material can be identified when it is reparative or regenerative. Normal radiographic details and appearance are learned by correlating the knowledge of the physical anatomy of structures discussed in Chapter 1 with their radiographic representations. The model of normality includes a range of variations and implies concepts such as average, commonality, typicality, and rarity.

Deviations from normality include radiographic changes in the anatomy of the teeth and bony structures. Most often, changes are represented as radiolucency or loss of mineralized structure, as in the case of caries, resorption, or infrabony periodontal defects. Occasionally, change can also be represented by radiopacities, as in the case of iatrogenically introduced materials or odontogenic tumors. In this chapter, the aspects of radiographic normality and abnormality relevant to endodontic diagnosis and case assessment will be discussed.
Evaluation of Tooth Anatomy: Problem Prevention

The process of radiographic interpretation should begin with examination of the teeth. Assessment is limited in all areas of dentistry by the fact that the intraoral radiograph is a twodimensional representation of three-dimensional objects. For example, even with well-made digital or film images, it is rarely possible to confirm or rule out the presence of a second canal in the mesial buccal root of a maxillary molar. Three-dimensional radiography is available in dentistry in the form of cone-beam computed tomography (CBCT), which is developing but not yet sufficiently refined to routinely produce the detailed images required for endodontic diagnosis and treatment. When combined with digital radiography, however, CBCT can significantly enhance endodontic care.

Once a quality radiographic film is obtained, knowledge of dental anatomy is crucial for extrapolating twodimensional representations into three-dimensional mental images. For example, anatomic examination of mandibular molar roots teaches that these roots are narrow in the mesial-distal dimension and very wide in the buccal-lingual dimension. A very wide root buccal-lingually will appear narrow on an optimal clinical radiograph. If the radiograph is made using variable angulations of the radiation beam (from the mesial or distal), the root will appear wider. More than one periodontal ligament space may be observed, and the image may be more difficult to interpret if roots of adjacent teeth are overlapped.

One objective of tooth evaluation will be to confirm anatomic form and any variations; it is sometimes possible to see two roots on a mandibular canine (Fig. 3-1, A), but it is equally important to know that a mandibular canine can have two roots, and many such cases will not be discoverable on radiographs. Additional roots and canals must be found by internal exploration during treatment, and CBCT images can assist in this anatomic assessment (see Fig. 3-1, B and C).

Teeth that may be indicated for root canal treatment should be examined for relative length, the number of roots, calcification of canals, and general morphology. Once assessment has been completed, anatomy confirmed, and treatment initiated, canal morphology should be clearly visualized in the mind of the clinician and retained throughout treatment. Variations in the anatomy of posterior teeth such as the mandibular first molar are seen routinely (Fig. 3-2). Fig. 3-2, A shows a molar with two divergent mesial roots; Fig. 3-2, B shows a molar tooth with two divergent distal roots. Even more variations may exist in various ethnic populations.

The number of roots treated should be noted in each case of a previously treated tooth, as well as the quality of treatment (length of fill, density of fill, shape of canal, etc.). Although no abnormal changes may be found radiographically, the tissue remaining in uncleaned canals can give rise to symptoms of thermal sensitivity, percussion sensitivity, and spontaneous pain. Any teeth found to have poor or questionable root canal treatment could be possible sources of symptoms and potential candidates for treatment revision. Further clinical examination of these teeth would be indicated.
FIGURE 3-1  A, Mandibular canine with a bifurcated root.  B, Another case of a mandibular canine investigated using cone-beam computed tomography (CBCT); occlusal view (arrow indicates tooth being evaluated).  C, Proximal view of the two-rooted canine tooth using CBCT. Note sections 94 to 97; not only do they provide a good view of the two roots and two canals, but they also provide valuable information as to the location of the lingual canal and the challenges faced in access opening and orifice location.

FIGURE 3-2  A, Mandibular molar with two mesial roots.  B, Mandibular molar with two distal roots.
FIGURE 3-3  A, Maxillary second molar with confirmed heat sensitivity. B, Posttreatment image indicating previously untreated distal canal.

FIGURE 3-4  A, Initial radiograph of the maxillary left first premolar with heat sensitivity. B, Second view angulated slightly from the distal. Note the small bulge in the gutta percha extending mesially in the coronal third. C, Posttreatment image indicating a previously untreated canal. (Courtesy Dr. Ryan Wynne.)
Radiographic Changes Associated With Dental Caries

The radiographic appearance of dental caries is basic to all dental education, and ample resources exist in the dental literature for further reading on detecting dental caries on routine radiographic surveys. For endodontic diagnostic purposes, the depth of caries past or present is an important radiographic indicator of teeth with pulpal pathosis. While carious exposures of the pulp cannot be seen radiographically, gross caries that approximates the radiographic outline of the pulp chamber is frequently evident even in the absence of symptoms (Fig. 3-5, A). Pulp exposure would be a logical expectation following excavation of such lesions, and root canal treatment of this tooth would be a necessary part of the treatment plan. Bitewing radiographs greatly assist identification of caries and its proximity to the dental pulp; they can be taken with traditional film or as digital images (Fig. 3-5, B).

Caries lesions that appear near pulp horns also are likely to be carious exposures upon excavation. Demineralization of dentin that occurs in the process of caries is progressive and lacks a clear clinical or radiographic border. Most carious lesions extend deeper into the dentin than what can be ascertained radiographically. Fig. 3-6, A represents a symptomatic tooth with a carious lesion in close proximity to the mesial pulp horn. Excavation revealed a gross carious exposure and necrotic pulp. Root canal treatment was indicated (see Fig. 3-6, B).

**FIGURE 3-5** A, Carious exposure of mesiobuccal pulp horn in a maxillary second molar. B, Bitewing digital radiograph showing the location and extent of dental caries.

**FIGURE 3-6** A, Caries near mesiobuccal pulp horn. B, Excavation revealed carious exposure and necrotic pulp. Root canal treatment was indicated.
For many teeth with large carious lesions, there may be no history of symptoms, and sensibility tests may provide normal responses (Fig. 3-7). The most reasonable approach to treatment is to advise the patient that the caries should be excavated, and the decision to treat endodontically or with vital pulp therapy will depend on the remaining dentin thickness (RDT). Although dentistry has no instrument to measure this dimension, there is a good clinical indicator: if the RDT is 0.5 mm or less, the proximity of the pulp will make the dentinal wall appear pink. Studies show that with an RDT of less than 0.5 mm, the prognosis for pulp survival is doubtful. The majority of teeth in this situation will develop symptoms of acute irreversible pulpitis after restoration, and root canal treatment will be necessary. On the other hand, vital pulp therapy has a good chance of success regardless of dentinal thickness, if the patient is young (Fig. 3-8). (Chapter 7 will address vital pulp therapy in detail.)

The decision to treat a tooth endodontically can sometimes be influenced by the economic situation of the patient; successful vital pulp therapy could avoid additional expense.

If it fails, the patient will still be able to receive root canal treatment (Fig. 3-9).

The radiographic appearance of recurrent decay is most often obvious at the margins of existing restorations. Caries beginning at the depth of a previous caries excavation will almost invariably involve the pulp (Fig. 3-10). Caries under existing crowns appears along the margin but may extend extensively under the clinical crown (Fig. 3-11). Bridge abutments are occasionally completely undermined and have no retention.

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**CLINICAL PROBLEM**

**Problem:** A 57-year-old male patient was examined for the chief complaint of recurrent spontaneous pain in the mandibular right teeth (Fig. 3-12, A). Sensibility tests indicated normal responses from the central incisors through the second premolar, but there was no response to testing on the second molar. Radiographs showed no periapical pathosis, but recurrent caries was noted around the margins of the second molar bridge abutment. No other signs of pathosis or abnormalities were noted. The patient had a full maxillary denture.

**Solution:** The diagnosis centered on the mandibular second molar, since all other teeth were ruled out as having normal pulps. A shepherd’s hook explorer (No. 23) was placed under the solder joint immediately anterior to the crown of the second molar. Lifting the bridge with the explorer confirmed that the bridge was loose on this tooth but well retained on the second premolar. Not only was vertical mobility observed, but bubbles appeared in the saliva along the margins of the crown as the bridge was elevated and reseated. The decision was made to cut the bridge distal to the second premolar. Gross caries was found to have undermined the entire clinical crown of the second molar (see Fig. 3-12, B). Following excavation, there was no remaining clinical crown (see Fig. 3-12, C), and the pulp was nonvital. The tooth was eventually retained and restored with a new bridge following a crown-lengthening procedure (see Chapter 17).
Pulpal necrosis and periapical pathosis following vital pulp therapy. Endodontic treatment was then indicated.

Recurrent caries is deeper than original carious lesion. A carious exposure is likely.

A, Recurrent caries under the buccal (or lingual) margin of crown. B, Clinical view of excavated caries shown in A.

A, Radiograph of the abutment teeth of a mandibular right posterior bridge. Note the caries at margins of the crown on second molar. B, Following bridge removal, gross caries was found to involve the entire clinical crown on the molar abutment. C, Gross caries excavated. There is no clinical crown remaining.
Radiographic Changes Associated With Tooth Fractures

Coronal Fractures

Radiographically, the most commonly observed fracture is the posttraumatic image of an anterior tooth with coronal tooth loss (Fig. 3-13, A). Generally, the diagnosis does not depend on radiographic findings, but it is wise to make a radiograph to rule out additional fractures below the level of the crestal bone. Complete coronal fractures often occur in older individuals owing to combined factors of heavy occlusal contacts, full crown preparations and calcification. While these patients are frequently asymptomatic, the teeth are functional and exhibit no periapical pathosis. The diagnostic radiograph is important to assess the degree of canal calcification and the overall root morphology (Fig. 3-13, B). Short roots with severely calcified canals might be treatment planned for extraction.

Coronal fractures in posterior teeth generally occur in a mesial–distal orientation (Fig. 3-14, A), consequently, radiographic evidence of the fracture is seldom visible in the tooth structure (Fig. 3-14, B). The most typical radiographic signs of coronal fracture are changes in the coronal alveolar bone mesially, distally and in the furcation extending apically as far as the midroot level (Fig. 3-14, C) also review Fig. 1-3.

Midroot Fractures

Trauma can also result in midroot fractures. If the fracture occurs just submarginally, the crown will be extremely mobile (Fig. 3-15, A). Radiographically the root is not connected to the crown. If the fracture is more apical, the coronal segment may not be mobile, and the radiograph will be essential in making an assessment and determining the level and extent of the fracture. Midroot fractures will usually not be evident on clinical examination (Fig. 3-15, B). Chapter 19 offers in-depth discussion on treating these teeth.

Vertical Root Fractures

Vertical root fractures are a frequent cause of tooth loss almost unique to root-treated teeth. A second unique feature of this problem is the consistent location of the crack lines on the midfacial/buccal or 180 degrees on the midlingual/palatal regions of most roots. Occasionally a root is found with fractures in both positions. Lack of separation of the fractured segments of the root makes vertical root fractures seldom visible radiographically. The characteristic radiographic change is in the adjacent bone, which is the result of bone resorption along the fracture line. Early changes are typified by lateral widening of the periodontal ligament space. Often there is no apical involvement. As bone resorption continues, a distinct lateral radiolucency develops parallel to the root surface (Fig. 3-16).

When a fracture is visible and significant separation of the fractured segments of the root has occurred, the fracture has probably been present for a long time (Fig. 3-17). A number of causes of root fractures have been suggested by many authors. The etiology is said to involve anatomic, restorative, periodontal, or endodontic factors. No doubt this is probably a multifactorial problem. Endodontically, excessive removal of root structure during cleaning and

FIGURE 3-14  A, Coronal fractures in posterior teeth tend to be mesial-distal in direction. B, Unusual buccolingual fracture in maxillary molar crown is visible on radiograph. C, Mandibular molar with coronal fracture extending to a level below the furcation; note bone loss. The patient did not have evidence of periodontal disease in other areas of the dentition.

shaping can weaken a root. During obturation, using excessive lateral compaction pressure in the presence of an improperly shaped canal and using a spreader that is too large for the shape of the canal can cause a fracture (Fig. 3-18). Curiously lacking in most discussions is the consideration of the forces of occlusion, specifically in the context of bruxism. A common denominator of teeth with vertical root fractures is the presence of heavy wear facets or other signs of excessive occlusal loading. Conversely, it is very rare to see a vertical fracture in a tooth which is out of occlusion. The subject of vertical root fractures is discussed in greater detail in Chapters 5 and 19.

**Figure 3-16** A, A vertical root fracture is not usually visible on a radiograph. B, Lateral bone loss associated with a vertical root fracture.

**Figure 3-17** Wide separation of root segments after vertical root fracture. Clinically, deep narrow periodontal defects are found on both buccal and facial surfaces in cases of complete root fracture.

**Figure 3-18** Vertical root fracture in a second premolar caused by excessive condensation pressure during obturation. Note the widened periodontal ligament space on the distal from crestal bone to the apex. Lateral and longitudinal extrusion of filling materials is a possible sign that fracture occurred during the procedure.
Radiographic Tooth Changes Associated With Resorption

There are four types of resorption of tooth structure that can be identified radiographically. In this section, the radiographic features of these pathologic entities will be described and compared. Further discussion of etiology, histologic characteristics, and treatment options will be found in Chapters 13, 18, and 19.

**Internal resorption** is characterized by a relatively symmetric radiolucency located in the mesial-distal center of the root. Radiographs taken at any angle other than perpendicular to the tooth will confirm the central location of the defect in the root. A key distinguishing radiographic finding is the loss of the canal outline in the resorptive defect. Note the large midroot radiolucency in Fig. 3-19. No canal outline is visible on the large defect, owing to enlargement of the canal space from within. The process is a function of vital yet inflamed pulp. Often at the time of discovery, the pulp may have already become necrotic, so internal resorption may be observed on a tooth with an apical lesion as well as on a tooth without an apical lesion.

**External root resorption**, as the name implies, originates from the periodontium and invades the tooth on the external surface of the root. The defects are usually characterized by an irregular shape and are not centrally located in the root. Many seem to originate at the level of crestal bone in the marginal periodontium and are discovered clinically as a defect in the root surface below the free gingival margin (Fig. 3-20). This type of external resorption is also referred to as cervical resorption.

External resorptive defects can sometimes resemble defects of internal resorption. A key distinguishing factor in most cases is the continued presence of the canal through the resorptive defect (Fig. 3-21). This problem is not of pulpal origin, so the shape of the root canal space is unaltered.

Resorptive defects can have a varied presentation from very early (Fig. 3-22, A) to very severe (Fig. 3-22, B) to the point where a pathologic fracture is possible (Fig. 3-23). There can also be variation in the degree of vertical involvement on the root surface from a localized lesion to one that involves the full root length (Fig. 3-24). Note that in Fig. 3-24, B, root canal treatment was done with the apparent and erroneous assumption that the resorption was of pulpal origin.

**External invasive resorption** is a subset of external resorption. The radiographic feature of this type is a honeycombed appearance in which the root canal appears to avoid invasion. At surgery, the root canal is often found to be surrounded by a thin layer of intact dentin in an area of advanced resorption (Fig. 3-25). This is due mainly to the fact that the surrounding dentin is actually predentin that lacks mineral content.

To confirm a buccal or lingual location of a resorptive defect, radiographs are made using ideal angulations and at angles divergent from ones taken perpendicular to the tooth. The beam is usually angled from the mesial on posterior teeth and from the distal on anterior teeth. Comparison of the films will show that the lesion appears to have “moved” on the angulated film. If the resorptive lesion is on the labial surface of the root, it will appear to move to the distal in comparison with a straight-on view. If the lesion is on the lingual surface of the root, it will appear to have moved mesially. Compare Fig. 3-25, A with the divergent-angle film in Fig. 3-25, B of the same resorptive lesion. In Fig. 3-25, B, which is exposed from the distal, the lesion on the mandibular right central incisor (far right) appears to have moved mesially, indicating it is located on the lingual surface of the root. The radiographic techniques referenced here are detailed in Chapter 2.

**Inflammatory resorption** is a pathologic process exclusively associated with an infected degenerating or necrotic pulp. It is usually seen in the presence of a periapical radiolucency. The affected root may be shortened, and the external surface may appear mottled or irregular in shape (Fig. 3-26).

In most cases, the resorptive process is arrested by nonsurgical root canal treatment.

**Replacement resorption** is often a sequel following replacement of an avulsed tooth or intentional replantation. The onset may be weeks or months after clinical healing. It initially appears as an alteration of root-surface contour far below crestal bone. As the process advances, the root appears to become extremely mottled, and the affected areas are associated with radiolucency in the adjacent bone (Fig. 3-27). Ultimately, the resorbed root may be completely replaced by normal bone.

FIGURE 3-19 A classic example of internal resorption. Signs of pulpal vitality would indicate an active process and warrant immediate endodontic intervention.

FIGURE 3-21 External resorption can resemble internal resorption on radiographs. Note that root canal is unaltered in this case (left arrows indicate margin of lesion, right arrows indicate canal continuity). Within the resorption defect, the appearance of the canal is lost in cases of internal resorption. Compare with Fig. 3-19.
FIGURE 3-22  A, Early external resorption. B, External resorption can be extremely destructive. This tooth required extraction.

FIGURE 3-23  Pathologic fracture of the crown from internal resorption.

FIGURE 3-24  A, A small lesion of external resorption localized to the marginal periodontium. B, Lesions of external resorption which have a distinct vertical component radiographically have a very poor prognosis. Root canal therapy will not alter or arrest the process of external resorption.
Influence of Radiolucent Anatomic Structures on Radiographic Interpretation

The maxillary sinus is a highly variable radiolucency that is commonly superimposed over the apices of the posterior teeth, occasionally extending anteriorly to include the canine. Careful examination of good-quality films will almost invariably reveal that the width of the periodontal ligament remains constant even though root tips may appear radiographically to extend well into the maxillary sinus (Fig. 3-28). This will be an important constant in differentiating normality from pathosis in cases with true pathosis as well (Fig. 3-29), although there are occasional exceptions to this general observation. The normal sinus can resemble a pathologic lesion in which the lamina dura and periodontal ligament space surrounding superimposed root tips will not be evident. Fortunately, these exceptions are quite infrequent (Fig. 3-30). Sensibility testing will be required to differentiate pathosis from normality.

The only other normal radiolucency in the maxilla is the incisive canal. Anatomically, it is in the midline and would rarely if ever be confused with periapical pathosis (Fig. 3-31). Where it appears large enough, the periodontal ligament space on the adjacent root surfaces will still appear of normal width (Fig. 3-32). Pathologic problems in this area will be discussed in a later section.

The mandibular canal, mental canal, and mental foramen most often are located anatomically and radiographically at some distance from the apices of the teeth so that no diagnostic confusion occurs (Fig. 3-33). Within the range of anatomic variation, however, these structures can present diagnostic challenges. The mandibular canal can alter the
normal periodontal ligament space around the apices, similar
to the effect of the sinus on maxillary apices (Fig. 3-34). The
mental canal and mental foramen can also be superimposed
over the apices. If there is no pathosis, the apical periodontal
ligament space and lamina dura will remain intact. The pre-
ence of periapical pathosis, however, can pose a diagnostic
challenge (Fig. 3-35). The position of the mental foramen
has been found to be located between the two premolars 50%
of time, distal from this central location 25% of the time,
and mesial to it 25% of the time.\textsuperscript{13}

\textbf{FIGURE 3-28} Roots of normal healthy teeth which
radiographically extend into the maxillary sinus have an
uninterrupted periodontal ligament space and lamina dura.

\textbf{FIGURE 3-29} Most frequently, an apical lesion will
be radiographically distinct from the sinus cavity.

\textbf{FIGURE 3-30} An unusual case in which the normal sinus
appears as an apical lesion. Pulp testing results were completely
normal for all teeth in the area. This person had been referred for
endodontic treatment. Note the normal periodontal ligament
space and lamina dura on the roots associated with the
radiolucency.

\textbf{FIGURE 3-31} \textbf{A,} The incisive canal is typically located between the roots of the maxillary central incisors. \textbf{B,} With anatomically
short roots, the incisive canal may appear above the apices but still in the midline. It is usually easy to distinguish from an apical lesion.
\textbf{C,} Large apical lesion of pulpal origin on the apex of the maxillary right central incisor. Asymmetry and loss of normal apical
anatomic structures identifies this lesion as pathologic in contrast to the appearance of a normal incisive canal.
**FIGURE 3-32** The periodontal ligament space remains intact in the case of an unusually large incisive canal. Compare this normal incisive canal with the pathologic lateral lesion depicted in Fig. 3-50.

**FIGURE 3-33** A, The typical mandibular canal is located at some distance inferior to the apices of the premolar teeth. B, Frequently, the mandibular canal is not evident on routine periapical radiographs.

**FIGURE 3-34** Superimposition of apices of teeth over the mandibular canal can suggest possible periapical pathosis. In this image, close examination reveals intact periodontal ligament spaces around all apices.

**FIGURE 3-35** A, The mental canal and foramen can resemble lesions of periapical pathosis. Note the intact periodontal ligament space around the apex of the second premolar. B, A mental foramen in close proximity to the apex of the second premolar. C, An apical lesion superimposed over the mental foramen.
Rarely, an anatomic depression on the medial surface of the body of the mandible, known as Stafne’s defect, will appear as a periapical lesion. Sensibility tests will provide normal pulp responses (Fig. 3-36).\(^{20,28}\)

**Influence of Radiopaque Structures on Radiographic Interpretation**

Anatomic or iatrogenic impediments to radiographic interpretation occur when teeth are superimposed over one another or a metallic object obscures the apex. It is not unusual to see impacted maxillary third molars obscuring the apices of maxillary second molars (Fig. 3-37). Impacted teeth in other areas can produce the same effect (Fig. 3-38). Metallic objects that obscure the apex are often permanent ligature wires or plates placed during orthognathic surgery or the reduction of traumatically induced fractures (Fig. 3-39). Implants sometimes have the same effect (see Fig. 3-39). For endodontic purposes, the value of these images is limited by the inability to evaluate the width of the periodontal ligament space or the continuity of the lamina dura at the apex. It is possible, however, to theorize about a possible etiology by evaluating other radiographic aspects of the teeth such as caries, the depth of existing restorations, and the periodontal condition of the supporting bone. Accurate assessment will rely on clinical examination; sensibility testing will usually be the most important component (Fig. 3-40). During root canal procedures in such cases, an electronic apex locator is the only alternative for length determination.

**CLINICAL PROBLEM**

**Problem:** A 38-year-old female presented with a recent onset of mild percussion sensitivity on the mandibular left first premolar. Approximately 8 months earlier, implants had been placed in the positions of the mandibular left first molar and second premolar (Fig. 3-41, A). The periapical image indicated what appears to be superimposition of the implant in the second premolar position over a portion of the apex of the first premolar. Clinical examination confirmed percussion tenderness only on the first premolar. Sensibility tests were non-contributory due to lack of sensitivity on the first premolar and several other presumably normal anterior teeth tested for comparison. The dilemma: How was the diagnosis going to be made?

**Solution:** The spontaneous onset of percussion tenderness was due to one of two possible etiologies. Either the tooth had pulpal pathosis or the tooth was under traumatic occlusal forces, usually associated with bruxism. In this case, the reasonable course was to check the occlusion and eliminate any heavy or premature contact. Occlusion was in fact found to be heavy, and appropriate adjustment was done. The patient was discharged with the advice to monitor the problem. When a diagnosis cannot be confirmed, it is appropriate to wait.

Seventeen months later, the patient returned with more acute percussion tenderness than that observed on the first visit. She related that over the months since the occlusal adjustment, she had experienced occasional episodes of recurrent percussion tenderness lasting 2 to 3 days but not severe enough to seek a consultation. Three days prior to the present visit, the tooth had become acutely tender to percussion. The periapical image did not reveal any deleterious changes, and the occlusion was no longer a factor that could explain the symptoms. A clinical decision was made to initiate root canal treatment. Not only was the pulp necrotic, but during cleaning and shaping of the canal, endodontic files would not extend to the estimated length of the root. The files in fact were in contact with the threaded surface of the implant. Root canal treatment was completed in the usual manner, and the symptoms resolved (see Fig. 3-41, B).
A.

**FIGURE 3-38** A, Impacted canine obscuring the apex of a maxillary central incisor. Apical resorption of the incisor is possible. B, Superimposition of the crown of an impacted maxillary premolar over the mesiobuccal root of the first molar. Close examination reveals that the periodontal ligament surrounding the apex of the mesiobuccal root is intact.

B.

**FIGURE 3-39** Apices of a maxillary molar obscured by fixation device secured with screws. It is not unusual to see apices obscured with ligature wires, arch bars, and implants.

**FIGURE 3-40** A, Radiographic assessment of distal apex of second molar is limited by superimposition of impacted third molar. Apical resorption of distal root of second molar is possible and difficult to confirm. Pulpal assessment must depend on testing, but depth of caries is useful diagnostic information. B, In treatment, the electronic apex locator is necessary for length determination. Radiographic assessment of outcome is difficult.

Occasionally the bone itself may obscure the root apex (Fig. 3-42). The traditional name for this area of increased density is *condensing osteitis*, and it is found more often in the mandibular molar and premolar regions. There is some evidence that these lesions may be related to long-term, chronic pulpal inflammation/degeneration but no evidence to suggest the bone is actually inflamed, so treatment is not required. There is conflicting evidence that these bony lesions may or may not disappear after root canal treatment. It is possible to have an inflamed pulp in an area where condensing osteitis exists, but the two conditions may or may not be related. The decision to treat the tooth associated with such an area must be based on diagnostic assessment of the pulp and not the mere radiographic presence of an opacity.
The only pulpal conditions that cause periapical pathosis are pulpal necrosis and (occasionally) severe irreversible pulpitis (see Chapter 1). At the time of onset of apical inflammation, there may be no changes on a radiograph, yet the tooth will often be acutely tender to percussion, with radiographic changes usually following within a few days. The radiographic lesion which appears is the result of bone resorption caused by the necrotic pulpal tissue and bacteria emanating from the apical foramen. Many lesions develop slowly over a relatively long period of time. Even in cases of acute apical infection without a preexisting lesion, a radiographic lesion may not become evident for as long as 10 days.3,4

The earliest change will be observed as a widening of the periodontal ligament space in the region of the apical foramen. This can sometimes be subtle and difficult to distinguish from the variation seen in the normal apical anatomy. For this reason, the radiograph alone is insufficient to make a final diagnosis. A history of symptoms would be very important, and sensibility testing and the other forms of clinical evaluation would have to be done.

**CLINICAL PROBLEM**

**Problem:** A 48-year-old female with a 1-week history of mild tenderness to percussion on the mandibular left second molar was seen for examination. Sensibility testing was limited by the presence of porcelain veneer crowns on both the first and second molars, and neither tooth responded to hot or cold. Heavy wear facets were observed on the second molar, found to be the symptomatic tooth. A radiograph was made (Fig. 3-43, A), but interpretation was difficult because of the superimposition of the mandibular canal over the apices.

**Solution:** Without a firm diagnosis, it was wise to proceed cautiously. Occlusal adjustment was done, and the patient was advised to monitor the situation. If the symptoms resolved within a few days, the presumptive diagnosis of bruxism would be confirmed. In this case, the woman returned about 10 days later with increasing pain to percussion. A new radiograph now confirmed a widened apical periodontal ligament space consistent with periapical pathosis of pulpal etiology. Root canal treatment was initiated, and a necrotic pulp was confirmed (see Fig. 3-43, B).

**FIGURE 3-41** A, Apex of premolar is obscured by implant. B, During treatment, it became apparent that the apex was cut in preparation for the implant.

**FIGURE 3-42** Radiopaque bone is superimposed over distal apex of second molar.

**Radiographic Changes Associated With Pulpal Necrosis in Periapical Tissues**

The only pulpal conditions that cause periapical pathosis are pulpal necrosis and (occasionally) severe irreversible pulpitis (see Chapter 1). At the time of onset of apical inflammation, there may be no changes on a radiograph, yet the tooth will often be acutely tender to percussion, with radiographic changes usually following within a few days. The radiographic lesion which appears is the result of bone resorption caused by the necrotic pulpal tissue and bacteria emanating from the apical foramen. Many lesions develop slowly over a relatively long period of time. Even in cases of acute apical infection without a preexisting lesion, a radiographic lesion may not become evident for as long as 10 days.3,4

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FIGURE 3-43  

**A**, Mandibular canal makes it difficult to radiographically interpret periodontal ligament surrounding apices of second molar. 

**B**, Ten days following initial examination, radiographic evidence of periapical pathosis is more apparent.

FIGURE 3-44  

**A**, Early signs of periapical pathosis on maxillary central and lateral incisors. Teeth had sustained traumatic injury approximately 2 months previously. 

**B**, Early signs of periapical pathosis in a mandibular molar. This tooth had a coronal fracture to the level of the pulp chamber.

As periapical pathosis progresses, the loss of apical bone will increase, causing a more characteristic periapical lesion. At this point, the pulp will be necrotic. The apical periodontal ligament space will be found to be widened and become continuous with the apical radiolucency; the lamina dura in the apical area is lost. It is still necessary, however, to complete a clinical evaluation to confirm pulpal necrosis (Fig. 3-44). Ultimately a periapical lesion will reach a size that will be virtually diagnostic for a necrotic pulp (Fig. 3-45).

Periapical lesions of pulpal origin always exhibit loss of normal periodontal ligament space and lamina dura in the affected area. As the lesion enlarges to approximate the roots of adjacent teeth, the periodontal ligament space may be lost on these teeth as well, but it cannot be assumed that all

FIGURE 3-45 Periapical lesions such as these are virtually diagnostic for a tooth with complete pulpal necrosis.
involved teeth are necrotic or need root canal treatment. Once again, sensibility tests are indicated. When root canal treatment is completed on the appropriate teeth, healing of the periapical lesion will follow, and the periodontal ligament space will be restored radiographically on both the involved and the uninvolved teeth. Evidence of radiographic healing can occur in as little as 3 months for small lesions and up to 1 year or longer for larger lesions (Fig. 3-46).

Radiolucencies that develop on the apices of maxillary posterior teeth will initially elevate the thin bone of the sinus floor and the Schneiderian membrane lining the sinus (Fig. 3-47). Eventually most larger lesions will form a sinus tract to the buccal or palatal mucosal surface (Fig. 3-48).

**FIGURE 3-46** A, Pretreatment film indicating a large apical lesion encompassing the apices of four mandibular incisors. Pulp tests indicated normal pulpal vitality on the lateral incisors. B, The 11-month reevaluation film indicates excellent healing is in progress.

**FIGURE 3-47** Periapical lesions can elevate the sinus floor and expand the thin bone covering the apices into the sinus cavity.

**FIGURE 3-48** A, Apical lesions frequently develop sinus tracts which drain through the mucosa. B, Opening of a sinus tract on the mucosal surface.
Pathologic perforation through the Schneiderian membrane is fortunately rare but not impossible. It is difficult to make this determination radiographically, because the anatomic relationship between the apices of the teeth and the floor of the sinus is highly variable. Many apices of healthy teeth lie inside the sinus cavity and are covered only by periodontal ligament and the sinus membrane. Loss of these radiolucent structures will be very difficult to discern, even on the best of images. Fig. 3-49, A demonstrates a case of acute apical abscess extending into and occupying the entire sinus cavity. The extent of involvement was only confirmed after surgical intervention during which the entire sinus cavity was enucleated. A 12-year, 3-month reevaluation is seen in Fig. 3-49, B. Note that the healing process resulted in almost complete occlusion of the sinus cavity.

Lateral Radiographic Changes Associated With Pulpal Necrosis

Interruptions in the periodontal ligament or lamina dura laterally can occur at the site of a lateral canal (Fig. 3-50). The process is identical to the development of an apical lesion in which the lateral lesion develops as a reaction to the emergence of necrotic pulpal material and bacteria. Rarely, a tooth with a lateral canal lesion may actually respond to an electric pulp test if the pulp apical to the lateral canal is still vital. These responses are usually much higher on the arbitrary scale of the electric pulp tester compared to those of the presumably normal adjacent or contralateral teeth. Usually there is no response to a cold test.

Periapical lesions of pulpal origin may extend coronally and drain clinically. The radiographic appearance of a sinus tract is similar to a lesion of severe periodontitis (Fig. 3-51). Drainage will usually follow the tract along the root surface.
Problem: A 34-year-old male was referred for routine root canal treatment of the maxillary left central incisor due to fracture of the clinical crown. The existing crown was cemented temporarily (Fig. 3-53, A). The root treatment was uncomplicated, and the patient was returned to the referring dentist with the crown cemented using a temporary post. Twenty years later, the patient was referred again to the endodontist with the tentative diagnosis of treatment failure (see Chapter 5). There was a recent history of local swelling, and a sinus tract stoma was observed near the gingival margin of the same tooth.

Solution: Review of the radiograph indicated that despite the overextension of the intraradicular post, there was no sign of failure (see Fig. 3-53, B). Probing ruled out a vertical root fracture but did indicate that there was a periodontal defect on the mesial that probed 9 mm. The presence of calculus was evident radiographically and was clinically palpable with the explorer. The diagnosis of periodontal abscess was confirmed.

FIGURE 3-52 Molar sinus tracts may involve the furcation.


Radiographic Changes Associated With Cases of Endodontic Failure

Root-treated teeth that fail will develop lesions that are radiographically identical to lesions that result from the extension of pulpal infection to the periapical bone (Fig. 3-54, A). Lesions may occur at the apex or the site of a
FIGURE 3-54  A, Periapical lesions resulting from failed endodontic treatment appear radiographically identical to lesions of primary infection. B, Four year reevaluation after nonsurgical revision indicating complete resolution of the apical lesion.

FIGURE 3-55  A, Lateral lesion associated with a lateral canal communicating with unsealed canal space around intraradicular post. B, Five-year reevaluation of the revised root canal treatment, indicating complete healing of the lateral lesion.

lateral canal (Fig. 3-55, A). Most will respond to nonsurgical revision, after which the periodontal ligament and lamina dura will reappear as a result of healing (Fig. 3-54, B and 3-55, B).

If an asymptomatic periapical lesion is discovered on routine examination, it is wise to ask the patient when the treatment was performed. Lesions typically take 3 to 12 months to resolve following root canal treatment. Sometimes larger lesions require more time. If the treatment in question was completed less than 12 months prior to examination, the appropriate course of action would be radiographic reevaluation of the lesion in 6 months. If the treatment had been completed more than 2 years previously, the tooth may be presumed to have recurrent pathosis and would be indicated for treatment revision in most cases.

Diagnosis of recurrent periapical pathosis is discussed in depth in Chapter 5. The techniques for revision of previous root canal treatment are discussed in Chapter 14.

Radiographic Changes Associated With Nonendodontic Pathoses Mimicking Potential Endodontic Problems

Cementoma

A cementoma, also known as a periapical osifying fibroma or cemento-ossous dysplasia, is a lesion that occurs primarily in the mandibular anterior area. More than one tooth may be involved, and initially there is a developing radiolucency. In time, the lesion will begin to undergo mineralization (Fig. 3-56). Sensibility tests are critical for making this diagnosis. Teeth with cementomas will invariably respond normally to testing and do not require root canal treatment.
central incisors laterally. This is not a lesion of pulpal origin; the teeth will respond normally to tests, and root canal treatment is not indicated (Fig. 3-57).

The term globulomaxillary cyst has been questioned as not describing a distinct histologic entity but rather a group of lesions which occur in the suture line between the maxillary lateral incisor and the canine.\textsuperscript{18,25,32} Although most lesions have been found to be of odontogenic origin, some lesions are distinctly nonapical lesions for which endodontic intervention is not indicated. Sensibility testing is critical to establishing the correct diagnosis.

**Developmental Cysts**

The incisive canal cyst, also known as the nasopalatine duct cyst, is a developmental cyst that occurs in the incisive canal (or nasopalatine duct).\textsuperscript{9} Radiographically, the lesion appears much larger than the incisive canal foramen. It can involve the apices of the central incisor teeth, and the apical periodontal ligament space and lamina dura can be lost. Internal positive pressure can gradually displace the roots of the central incisors.

**CLINICAL PROBLEM**

**Problem:** A 42-year-old male sought dental consultation for acute pain in the maxillary left anterior area. The dentist found a large radiolucent lesion between the apices of the maxillary left lateral incisor and canine (Fig. 3-58, A). On opening, the dentist recorded that there was profuse drainage. The patient was referred to an endodontist for completion of the treatment. Four months later, the patient was seen by the endodontist for the first time. The patient had been symptom free. Note the periapical anatomy on the preoperative film (see Fig. 3-58, A). While the periodontal ligament space appears intact, the lamina dura is interrupted. On opening, there was no drainage, and the root canal treatment was completed. Almost 10 years later, the patient returned to the endodontist for reevaluation of the same tooth. He was experiencing recurrent symptoms of pressure and pain in the area. The periapical film indicated that the lesion had failed to heal, but the apical periodontal ligament space was of uniform width, and the lamina dura was intact (see Fig. 3-58, B).  

**Solution:** Periapical surgery was performed, during which no communication with the apex of the tooth was observed. The curetted soft-tissue lesion was submitted for histologic examination, and a diagnosis of “benign fibro-osseous lesion, possibly representing cemento-osseous dysplasia” was reported by the pathologist. The symptom-free patient returned for reexamination 3 months later, and a posttreatment radiograph indicated excellent healing (see Fig. 3-58, C).

**Healed Endodontic Lesions**

Large lesions in the anterior maxilla are often treated surgically. On surgical exposure of the defect, the entire buccal plate of bone may be missing due to destruction from infection and enlargement of the lesion. Following complete periapical curettage, it is sometimes found that the palatal plate is missing as well. After such through-and-through lesions heal, sometimes the radiolucency will remain above and radiographically separate from the apices of the teeth. This condition is a form of scarring.\textsuperscript{19,26} The lesion is caused by the infilling of fibrous connective tissue instead of bone, yet is perfectly healthy. There is no indication for treatment (Fig. 3-59).
FIGURE 3-58  A, Referral film of a suspected periapical lesion of pulpal origin supplied by the referring dentist. Subsequent to making this film, the tooth was opened for root canal treatment due to acute symptoms of pain. Referral report stated that copious amounts of straw-colored fluid had drained from the canal on opening, no drainage was observed by the endodontist, and root canal treatment was completed on the initial visit. B, Recurrent symptoms in the area 9 ½ years later warranted reevaluation of the lesion. Periapical surgery was performed, and the apical tissue was submitted for histologic examination. C, Three-month reevaluation image indicating healing of lesion.

FIGURE 3-59  Reevaluation 15 years after apical surgery. At surgery, the lesion was observed to fenestrate both the labial and palatal plates of bone (through and through). The apparent “apical lesion” represents normal healing of these lesions.

FIGURE 3-60  Lateral periodontal cyst presented similarly to a lateral lesion. Both teeth responded normally to vitality tests.

Periodontal Lesions

Lesions of periodontal disease do not normally involve areas of the root which would resemble lesions of endodontic origin. Periodontal disease is a process that causes destruction of bone in a coronal-to-apical direction, whereas endodontic lesions generally progress from the apex coronally. Nevertheless, there are some clinical problems which can cause diagnostic confusion.

A lateral periodontal cyst is a lesion of unknown origin that arises predominantly in the mandibular premolar areas.
It is not of pulpal origin but appears similar to a lateral lesion in the presence of a necrotic pulp and lateral canal. Even though there is a draining sinus tract present clinically, both adjacent teeth respond normally to pulp tests in Fig. 3-60, A. This would be considered a lateral periodontal cyst.

Occasionally, lesions of advanced periodontitis will cause severe bone loss in a local area, resembling apical lesions. In Fig. 3-61, the periapical lesion appears to be a classic lesion of pulpal origin until the clinical examination reveals complete dehiscence of the lingual surface of the root to the apex. Root canal treatment would be of no benefit to this person. Chapter 4 will explore this area of diagnosis more completely.

This chapter has presented a selective overview of radiographic diagnosis limited to endodontic pathology. Definitions of normality have been discussed that provide a basis for distinguishing abnormal findings associated with pathology. Some commonly encountered lesions in the bone that mimic disease of pulpal origin have also been presented.

REFERENCES


RECOMMENDED ADDITIONAL READING

Chapter 4

Problem Solving in the Differential Diagnosis of Bony Defects Resulting from Pulpal and Periodontal Pathosis

Problem-Solving List
Problem-solving challenges and dilemmas that deal with the differential diagnosis of bone defects resulting from pulpal and periodontal pathosis addressed in this chapter:

Controversies and Highlights of Disease Interactions
An Endodontic Perspective on Chronic Periodontitis
Periodontal Lesions of Bone that Can Be Confused With Pulpally Induced Bony Lesions
  - Acute periodontal abscess
  - Lesions of chronic periodontitis
  - Periodontal lesions involving the furcation
  - Lesions associated with aggressive forms of periodontitis
  - External root resorption
  - Cemental tears
Pulpally Induced Lesions that Can Be Confused With Periodontal Lesions
  - Furcation or lateral lesions without loss of attachment
  - Acute periapical abscess
  - Chronic sinus tracts of pulpal origin with drainage through the gingival sulcus
  - Chronic sinus tracts of pulpal origin with permanent periodontal attachment loss
  - Response of the periodontium to mechanical root perforations
Bony Lesions of the Periodontium that Do Not Originate from Either Periodontal or Pulpal Pathosis
  - Deep coronal fractures
  - Vertical root fractures
  - Developmental lingual groove on maxillary lateral incisors and similar lesions
  - Other possible rare lesions

I have never found a pulp removed from a pyorrhetic tooth to be normal . . . where a pathologic pulp is present, a pyorrhetic condition cannot be cured by treatment applied exclusively to the external surface of the root, with no treatment of the pulp itself.12

L.R. Cahn, 1927

Interradicular periodontal lesions can be initiated and perpetuated by inflamed or necrotic pulps. Extension of the inflammatory lesions from the dental pulp apparently occurs through accessory or lateral canals situated in the furcation regions of premolars and molars.45

S. Seltzer, I.B. Bender, H. Nazimov, 1967

The relationship of disease processes coming from the pulp of the tooth to the supporting periodontium is a subject that has received much attention in endodontic literature for almost 90 years.10,12,18 The reverse situation has also been controversial: the impact of periodontal pathosis on the dental pulp.* Clinically, two important issues must be kept in focus. Pulpal pathosis and its extension into the periodontium causes a localized periodontitis with the potential for further extension into the oral cavity.26 Periodontal pathosis and its extension have little short-term effect on the dental pulp.26 However, the long-term effect of periodontal

*References 15, 21, 28, 37, 46, 60, and 63.
pathosis, especially in conjunction with concomitant restorative procedures, must be considered in all diagnostic and treatment planning considerations.

### Controversies and Highlights of Disease Interactions

Pulp tissue degenerates after a multitude of insults—caries, restorative procedures, chemical and thermal insults, trauma, and some periodontal treatment. When products from pulp degeneration, in particular inflammatory exudates and bacteria, reach the supporting periodontium, many changes may occur, including a rapid onset of inflammation, lateral or furcation bone loss, tooth mobility, and sinus tract formation through the buccal mucosa or gingival sulcus. If this occurs in the apical region, a periapical lesion forms (see Chapter 3). If this occurs with crestal extension of the inflammation, a periodontitis of pulpal origin is formed. However, the lesion formed has little anatomic similarity to a defect of periodontal pathosis.

Periodontal disease is generally a slow-developing process that may have a gradual atrophic effect on the dental pulp. Complete pulp necrosis caused by periodontal pathosis, however, is uncommon. Changes in the pulp include chronic inflammation, localized tissue death (infarction), fibrosis, decrease in cellular populations, resorptions, local coagulation necrosis, or dystrophic calcification. Periodontal procedures such as deep scaling and curettage (with the use of localized medicaments) and gingival injury or wounding may enhance further pulp inflammation and perpetuate the interrelated disease process in a small number of cases.

The most intimate and demonstrable relationship of the communication of inflammation between the two tissues is via the vascular system, as demonstrated anatomically at the apical foramen and adjacent to aberrant accessory communications. These channels, when patent, may serve as potential routes of inflammatory interchange. Still other channels, covered by cementum, may be exposed during scaling or other periodontal therapeutic procedures. To what extent these vascular communications must be disrupted to cause a resultant overwhelming inflammatory process is unknown and a major concern.

The main anatomic pathways must be considered as potential pathways in the exchange of inflammatory products and bacteria between the pulp and the periodontium (and vice versa) and include lateral/accessory canals that branch off the main root canal, open dentinal tubules (sometimes due to cemental agenesis), the presence of lingual grooves, removal of cementum during periodontal or restorative procedures or loss due to resorptive defects, and root or tooth fractures.

For intact teeth, the principle avenues of communication would be the main foramen, lateral/accessory canals, and dentinal tubules. In the clinical setting, however, there are few means to determine that these particular avenues of communication are actively involved in the exchange of inflammatory substances and/or bacteria. For our purposes, the pathophysiologic relationships that exist between the pulp and periodontium are less important than an accurate diagnosis or one based on the best clinical evidence available on clinical problems and lesions that present on a daily basis. In general, inflammation or bone loss in the periodontium caused by lesions of pulpal origin will heal following a wide range of endodontic treatments. These types of cases are seen as a radiolucent lesion around the root apex, in an isolated furcation that has no other etiology, or on the lateral surface of a root. Specific periodontal treatment in these cases is rarely if ever warranted. The vast majority of lesions of the periodontium do not affect the dental pulp. The incidence of cases in which a connection between a lesion of pulpal origin and one of periodontal pathosis is even suspected is small.

This chapter has three objectives: (1) to clarify the most important diagnostic characteristics of lesions of the periodontium, with emphasis on those that resemble the extension of pulp pathosis to the supporting root tissues; (2) to clarify the distinguishing diagnostic characteristics of periapical lesions of pulpal origin that resemble or are mistaken for periodontal defects; and (3) to discuss the characteristics of lesions that are the result of neither inflammation/infection of the pulp or periodontium, yet may share characteristics of both. Treatment suggestions will accompany the lesions described.

### An Endodontic Perspective on Chronic Periodontitis

The etiology and pathophysiology of chronic periodontitis is extremely complex. Briefly summarized, lesions of the disease are the result of microbiologic and immunologic effects of a biofilm that forms on the surfaces of roots. Fortunately, an accurate clinical diagnosis of periodontitis can usually be made on the basis of physical examination and radiographic findings of bone destruction. The clinical characteristic of this disease may be summarized as a “top-down” process, meaning simply that it begins with inflammation of the marginal periodontium and progresses apically with the gradual destruction of the crestal supporting bone (Fig. 4-1, A and B).

For the dentist/endodontist, the periodontal probe is absolutely indispensable to clinical diagnosis. During assessment of the periodontium, measurement of attachment loss is the standard by which progression or remission of the disease is assessed. Within the discipline of endodontics, the discrimination between periodontal lesions and those originating from the dental pulp can usually be made by identifying the physical characteristics of the lesion itself. The technique of diagnostic periodontal probing should be done using a relatively small-diameter instrument (0.05 mm at the tip) with standard markings (Fig. 4-2). Probing should be done with as uniform a pressure as possible, slightly angling the tip of the probe toward the surface of the root.
differentiation of lesions of pulpal origin from periodontal lesions, probings in the area of principle concern should be performed circumferentially on each tooth in small (1-mm) increments. The intent is to explore the physical morphology or bony architecture of a lesion. There is a distinction between “probing” the attachment levels and “sounding” the location of the crestal bone. In the technique of sounding, the probe is inserted past the level of attachment directly to bone. This is a more accurate method of assessment but will usually require some level of local anesthesia. Generally, probing will yield adequate diagnostic information, especially in combination with radiographs.

Osseous defects resulting from chronic periodontitis are routinely found to be of varying depth but similar in form. Traditionally in routine periodontal examinations, probing depths have been recorded in six locations for each tooth: the mesial, midsurface, and distal of both the buccal and lingual surfaces. For the purposes of endodontic diagnoses and the differentiation of lesions of pulpal origin from periodontal lesions, probings in the area of principle concern should be performed circumferentially on each tooth in small (1-mm) increments. The intent is to explore the physical morphology or bony architecture of a lesion. There is a distinction between “probing” the attachment levels and “sounding” the location of the crestal bone. In the technique of sounding, the probe is inserted past the level of attachment directly to bone. This is a more accurate method of assessment but will usually require some level of local anesthesia. Generally, probing will yield adequate diagnostic information, especially in combination with radiographs.

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Periodontal Lesions of Bone that Can Be Confused With Pulpally Induced Bony Lesions

Bony lesions of periodontal disease are usually not difficult to distinguish from bony lesions of pulpal origin. Periodontal defects begin in the marginal periodontium, and even deep periodontal pockets are usually far removed from the root apex (Fig. 4-4). Confusion in diagnosis usually arises in cases of acute periodontal abscess, periodontal infection causing chronic sinus tracts in the mucosa, or localized periodontal bony lesions extending deep enough to involve the apex of a tooth. The severity of periodontal bone destruction, however, varies in the same dentition. At times it may be quite localized and extend to the root apices. The following discussion of pathologic entities will include diagnostic procedures necessary to (1) arrive at the best diagnosis based on the gathered information and (2) determine the appropriate treatment plan.

Acute Periodontal Abscess

An acute periodontal abscess is clinically identical to many acute periapical abscesses of pulpal origin. The patient may experience severe swelling (Fig. 4-5, A) along with the usual symptoms of acute infection such as pain, fever, and malaise. The location of swelling near the gingival margin is common to both types (see Fig. 4-5, B).

Diagnostic procedures usually begin with a good radiograph. In this case (see Fig. 4-5, C), significant information is immediately apparent: there is loss of crestal bone interproximally, indicating a lesion of periodontitis as opposed to one of pulpal origin. There is no radiolucency at the apices. Since it is possible to have an acute periapical abscess without obvious or significant radiographic evidence of a periapical involvement...
or lateral lesion, the next step in diagnosis is sensibility testing. In this case, all of the maxillary right posterior teeth respond normally to thermal and electrical sensibility tests. This finding eliminates the possibility of a pulpal etiology. The diagnosis of acute periodontal abscess is confirmed by signs, symptoms, and periodontal probings. Treatment planning will be based on probing depths. Probings that are found to confirm attachment loss to the level of the apical third would support tooth extraction as the treatment of choice. Probings to the level of the midroot might favor periodontal surgery to reduce or eliminate pocket depth.

Lesions of Chronic Periodontitis

Bony lesions of chronic periodontitis are sometimes confused with lesions of pulpal origin because of a draining sinus tract. In Fig. 4-6, the patient was referred for endodontic evaluation because of the drainage tract in the attached gingiva over the left central incisor (arrow). In a similar case (Fig. 4-7), probings are consistent with a deep periodontal lesion. The radiograph clearly shows no apical rarefaction on either of the central incisors (see Fig. 4-7, D), and sensibility tests elicit normal responses. Surgical exposure illustrates the morphology of the defect (see Fig. 4-7, E). Contrast these cases with the endodontic case presented in Fig. 4-8. Clinically, the sinus tracts appear nearly identical (see Fig. 4-8, A; also see Fig. 4-6), but surgical exposure of the tooth reveals not only the periapical lesion but also intact crestal bone (see Fig. 4-8, B).

Problem: A 52-year-old male was seen for recurrent local swelling and drainage in the area of the maxillary right second premolar. Clinical examination revealed a draining sinus tract in the attached gingiva near the second premolar. A radiograph indicated that there was a widened apical periodontal ligament space consistent with a developing periapical lesion in addition to a deep periodontal defect interproximally on the distal (Fig. 4-9, A). At this point, the origin of the sinus tract was unknown.

Solution: Sensibility testing was performed. No responses were obtained from the second premolar, and the first molar previously had root canal treatment. A sinus tract exploration was done by placing a gutta-percha cone in the tract and exposing an additional radiograph (see Fig. 4-9, B). This examination indicated that the drainage was of periodontal origin. No communication between the two lesions was evident on the film, and none was found during probing. The diagnosis was concomitant periodontal and periapical lesions. Both root canal treatment and periodontal treatment will be required to resolve the infections in this case (see Fig. 4-9, C).

Lesions of Chronic Periodontitis

Although there may be ample evidence of a general chronic periodontitis in the oral cavity, some localized areas may have developed extremely severe bone destruction. If periodontal defects extend to the apex, the radiographic lesion present may be confused with a periapical lesion of pulpal origin. The patient in Fig. 4-10 was sent for completion of root canal treatment on a second premolar. Note the endodontic access cavity in the crown of this tooth. The loss of bone radiographically correlated with the loss of attachment circumferentially by clinical probing. The extreme mobility of this tooth was another consequence of bone loss. A root canal procedure would have no effect on this condition, so the tooth was extracted.

Problem: A 57-year-old male with a history of recurrent swelling on the palatal aspect of the maxillary left first molar was referred for root canal treatment. The referring dentist noted a large periapical lesion encompassing the apex of the palatal root (Fig. 4-11, A). The radiograph also shows evidence of severe bone loss around the buccal roots that was not noted by the dentist. The molar had no restorations, and there was no evidence of a fracture in the crown.

Solution: Sensibility tests should be performed early in the examination. In this case, results were normal—in fact, the tooth was hypersensitive to a cold stimulus. Periodontal probings indicated that there was bone loss to the apex of the palatal root and confirmed severe attachment loss around the other two roots. As in the previous case, root canal treatment would have no effect on this problem, so the tooth was extracted. In these cases, calculus deposits are commonly seen covering the entire root surface (see Fig. 4-11, B).

Occasionally a periodontal bone lesion may resemble a periapical lesion and, at least radiographically, lack other obvious signs of generalized periodontitis. At the close of Chapter 3, an excellent example was depicted in Fig. 3-60. What appears to be a typical periapical lesion of pulpal origin is in reality a lesion of severe periodontitis. Once again, root canal treatment would have been of no benefit in this case.
Problem Solving in the Differential Diagnosis of Bony Defects


**CLINICAL PROBLEM**

**Problem:** A 38-year-old male presented with a history of recurrent acute abscesses in the buccal vestibule adjacent to the maxillary left first molar. The radiograph showed a “classic” periapical lesion on the apex of the mesial buccal root (Fig. 4-12, A). The lesion was noted to extend coronally along both the mesial and distal surfaces of the root.

**Solution:** Sensibility tests indicated normal responses on this tooth, confirming that this is not a pulpal problem. Periodontal probing revealed complete loss of attachment over the entire buccal surface of the root (see Fig. 4-12, B). Large deposits of calculus were seen and felt on the root surface with the probe. The diagnosis of periodontal abscess was made. Since there was minimal periodontal involvement of the other two roots, the optimal treatment plan was to resect (amputate) the mesial buccal root; pulp exposure resulting from the amputation would necessitate root canal treatment on the remaining roots.

**Periodontal Lesions Involving the Furcation**

Loss of bone in the furcation of a molar due to periodontal disease is sometimes difficult to distinguish from bone loss due to a necrotic pulp (communication via furcation canals) or a sinus tract that is traced to the furcation. As cited earlier, the periodontal probe may reveal a sometimes subtle distinguishing difference. Periodontal defects tend to affect the space in the furcation more or less symmetrically, whereas
FIGURE 4-8 A, Sinus tract similar to Fig. 4-6 but of pulpal etiology. B, Surgical exposure of apical lesion. Note normal crestal bone contours.

FIGURE 4-9 A, Maxillary right premolar area with history of recurrent drainage suspected to be of pulpal origin. There is both apical and periodontal pathosis evident on the second premolar. B, Sinus tract exploration with gutta-percha cone, revealing source of drainage is the periodontal lesion. C, Completed root canal treatment will only resolve the periapical lesion. Periodontal surgery is also indicated to eliminate the pocket. This will resolve both associated infection and the drainage tract.
FIGURE 4-10 Localized lesion of advanced chronic periodontitis. Note tooth has been opened for root canal treatment that will have no effect on this lesion.

FIGURE 4-11 A, Radiograph of maxillary left first molar area with apical lesion of chronic periodontitis. Pulp test results are completely normal. B, Following extraction. Note calculus deposits covering entire palatal root.

Sinus tracts tend to align with one root and more directly with a lesion at the apex. Therefore periodontal defects will tend to probe both vertically (parallel to the root) and horizontally (buccal-lingually, parallel to the occlusal plane). Sinus tracts of pulp origin tend to probe in a vertical direction only, but in some cases the tract may take a tortuous path, depending on the nature of the bone around the tooth, so straight probes will be of less value in the differential diagnosis of a lesion of this type. This emphasizes the need to have both straight and curved probes (Nabers or Cattoni probes, Hu-Friedy Co., Chicago, IL, USA). The furcation defect in Fig. 4-13, A was suspected to be the result of inadequate root canal treatment of the mesial buccal root. Periodontal probings indicated there were deep vertical and horizontal components to the defect. Surgical exploration showed the extent of the bone loss (see Fig. 4-13, B). The entire furcation was devoid of bone in addition to loss of the buccal plate covering the buccal roots, which accounted for the preoperative probing patterns. The diagnosis of advanced periodontitis was confirmed, and the tooth was extracted.

Lesions Associated With Aggressive Forms of Periodontitis

Aggressive periodontitis in young people, once known as juvenile periodontitis, affects less than 1% of the population. This disease process is now associated with a specific pathogen, Aggregatibacter actinomycetemcomitans (formerly Actinobacillus). This pathogen has also been found to be dominant in some global environments, and therefore may be used as a specific diagnostic marker for the disease. However, studies have also indicated that other global populations may have different markers, such as Treponema lecitinioliticum or inflammatory cells and serum globulins that may be associated with the degree of periodontal destruction.
Owing to the diagnostic confusion with an acute periapical abscess and the rarity of periodontal pathosis in children, a necrotic pulp with a periapical lesion is sometimes suspected as the cause of this disease. The case depicted in Fig. 4-14 illustrates a bony lesion in a 12-year-old female who was referred for root canal treatment of the maxillary right first molar. After confirming the presence of a normal pulp with sensibility tests, the patient was referred for a periodontal consultation.

**External Root Resorption**

External root resorption that occurs in the marginal periodontium is often confused with internal resorption of the root. Internal resorption is a pathologic process of pulpal origin. External resorption infrequently involves pulp. Root canal treatment may or may not affect this problem but is often necessary because of pulp exposure or near exposure during repair of the defect (Fig. 4-15). A more detailed discussion of resorption is found in Chapters 3, 13, 18, and 19.

**Cemental Tears**

A cemental tear is a rare periodontal condition often associated with a root-treated tooth. This condition appears...
FIGURE 4-15  A, Lesion of external resorption in marginal periodontium, resembling internal resorption.  B, Problings suggest a periodontal defect.  C, Surgical exposure confirms diagnosis of external resorption that arises in the periodontium.

FIGURE 4-16  A, Maxillary left central incisor with recurrent periapical pathosis and a palatal draining tract.  B, Following extraction, external resorption lesion is seen on the palatal surface.
clinically as a periodontal infection with rapid loss of attachment. Although the etiology is unknown, there is a higher incidence in the elderly. At time of surgery, small segments of the cementum are often observed to have fractured away from the surface of the root. The literature has a number of case reports with some success in treatment outcomes, but the level of evidence for the best way to manage these cases is less than ideal.

**CLINICAL PROBLEM**

**Problem:** Root canal treatment was completed on a mandibular right lateral incisor for an 85-year-old male. There was no indication of periodontal pathosis at the time of treatment. The patient was seen 18 months later for evaluation of a local swelling associated with the same tooth. Periodontal probing revealed a 7-mm localized periodontal defect on the distal aspect of the tooth; all other probing depths were within normal limits. The presumptive diagnosis was a recurrent periapical lesion due to inadequate root canal treatment or a vertical root fracture. A periapical radiograph showed a radiolucency on the distal aspect of the root, extending from the apex to crestal bone level (Fig. 4-17, A).

**Solution:** Exploratory surgery revealed a cemental tear on the labial surface of the root (see Fig. 4-17, B). Fragments of separated cementum were found attached to the elevated tissue and removed. The area of cemental separation was lightly recontoured with a composite finishing bur to remove the irregular margins of the tear, and the root surface was treated with citric acid for 30 seconds to enhance reattachment of the periodontal ligament fibers. After rinsing, the tissue was repositioned and sutured. Reevaluation at 6 months (see Fig. 4-17, C) indicated that probing depth had returned to normal.

**Pulpally Induced Lesions that Can Be Confused With Periodontal Lesions**

There are also periapical lesions of pulpal origin that share clinical and radiographic features with lesions of periodontal origin. Most periapical lesions arise in the bone adjacent to the apical foramen, and there is usually no radiographic confusion with lesions of periodontitis (Fig. 4-18). Diagnosis on the basis of radiographic findings alone can be misleading, however, if a periapical lesion or evidence of a sinus tract should extend to the alveolar crest (Fig. 4-19; see Chapters 2 and 3).

**Furcation or Lateral Lesions Without Loss of Attachment**

Periapical (periradicular) lesions can become quite large and approach crestal bone. Radiographically, the appearance is similar to periodontal lesions with advanced bone loss, particularly because of the loss of crestal or furcation bone (Fig. 4-20, A). Careful circumferential probing will often indicate that there is no loss of attachment in the sulcus. Clearly, a normal probing pattern rules out a periodontal etiology for the lesion. Root canal treatment alone is usually effective to bring about resolution of the radiolucency (see Fig. 4-20, B).
FIGURE 4-18 Typical periapical lesion of pulpal etiology.

FIGURE 4-19 Typical periapical lesion of pulpal etiology with a draining sinus tract along the distal root surface. There was no periodontal disease.

FIGURE 4-20 A, Mandibular right first molar with large radiolucent lesion. Bone loss appears to extend from distal interproximal crest to apex, but clinically there was no break in the sulcular attachment. B, Reevaluation at 15 months, indicating healing of periapical lesion and restoration of interproximal bony architecture.

FIGURE 4-21 A, Mandibular left first molar with radiographic evidence of furcation and lateral bone loss. There were two draining tracts in the attached gingiva but probings were normal. B, One year reevaluation, indicating complete healing.

Some teeth with periodontal attachment and bone loss will develop large periapical lesions that may appear radiographically to merge with the periodontal bone loss (Fig. 4-21, A). These lesions have been identified by many as perio-endo lesions.6,48,63 Once again, however, periodontal probing is the key to diagnosis. In this case, there is definite loss of bone from periodontitis. Nevertheless, circumferential probings identified a normal sulcus depth in the interproximal space, with no break in the attachment. This cannot be a so-called perio-endo lesion in the absence of the
periodontal disease component communicating with a lesion of pulpal origin. Root canal treatment was completed and a 1-year reexamination demonstrates healing of the interproximal crest of bone as well as the periapical lesion itself (see Fig. 4-21, B).

Acute Periapical Abscess

Some acute periapical abscesses of pulpal origin will cause localized swelling of the marginal gingiva (Fig. 4-22, A). Additionally, probings may reveal a break in the attachment, and it is not unusual to observe purulent drainage around the probe tip during oral examination. Probings will also quickly rule out a periodontal etiology if no other defects are found. Routine endodontic examination should include sensibility tests. In the case of acutely abscessed teeth, the pulp is invariably necrotic, as was explained in Chapter 1. A radiograph most often will indicate the presence of a periapical radiolucency. Once the diagnosis is established, the tooth is customarily opened for root canal treatment (see Chapter 15), although in some cases an incision and drainage may also be indicated. The most important difference between acute periapical and periodontal abscesses is that attachment loss in the endodontic cases will be recovered, often within 1 week (see Fig. 4-22, B). Probings will return to normal in the affected site once the infection heals and the drainage ceases. There are rarely any residual defects.

Chronic Sinus Tracts of Pulpal Origin With Drainage Through the Gingival Sulcus

Seldom are sinus tracts of pulpal origin mistaken for periodontal lesions when they appear on the surface of the mucosa. Confusion arises most often when the tract exits through the gingival sulcus. Fig. 4-23, A illustrates a maxillary left first molar with an acute swelling on the mesial palatal surface. Probings identified a possible periodontal etiology, and the patient was referred to a periodontist for

FIGURE 4-22 A, Local swelling secondary to acute periapical abscess. A narrow defect into the furcation was probed. B, One week following routine endodontic emergency procedures, swelling had subsided, and reattachment in the furcation had occurred.

FIGURE 4-23 A, Local swelling on mesial palatal surface of maxillary left first molar, which was presumed to be periodontal. B, Sectioned periodontal probe in the defect. C, Surgical exposure confirms diagnosis of a sinus tract of pulpal origin.
evaluation. Probings were essentially normal except for a narrow tract in the area of the swelling. The periodontist did a sinus tract exploration using a sectioned periodontal probe (see Fig. 4-23, B). The tissue was reflected in the area, and a sinus tract was observed to be a small defect without a change in the general contour of the bone (see Fig. 4-23, C). This image illustrates the bone contours that characterize a “sinus tract–type probing” pattern.27,28 The probing depths along root surfaces with these defects are usually within normal limits until the defect is encountered. The probing depth at this point will precipitously become very deep as the probe enters the tract. Continuing circumferentially, the probing depth will just as precipitously return to normal. Root canal treatment of the molar was subsequently completed and the sinus tract healed uneventfully.

**CLINICAL PROBLEM**

**Problem:** An 18-year-old female college student presented for evaluation of the maxillary right molar area. She related a history of recurrent soreness, local swelling, and a foul taste in the area between the first and second molars. Her family dentist had placed a large temporary restoration in the second molar just before she left for school (Fig. 4-24, A). Probings in the area identified a narrow sinus tract-type probing interproximally on the palatal side. A periapical film with a periodontal probe in the tract indicated the source of the drainage was a large periradicular lesion encompassing the apices of both the first and second molars (see Fig. 4-24, B). Sensibility testing showed that the pulp in the second molar was necrotic, but the first molar responded normally.

**Solution:** Evaluation of the periodontal status revealed a normal, healthy periodontium throughout the dentition. This was consistent with the crestal bone levels on the periapical film. Furthermore, osseous defects of advanced periodontitis would be extremely rare in an 18-year-old individual, so a periodontal etiology was ruled out. The periapical lesion was large and draining through the gingival sulcus. Root canal treatment of the second molar resulted in closure of the sinus tract in 2 weeks.

**Chronic Sinus Tracts of Pulpal Origin with Permanent Periodontal Attachment Loss**

Some periapical lesions that drain through the sulcus can become periodontal lesions as well. In addition to bacteria, biofilm and calculus can form on the root surfaces,1 within sinus tracts, and even on the apices of roots in chronically draining periapical lesions (Fig. 4-25). Fig. 4-26 illustrates the case of a 24-year-old male with no clinical signs of periodontal pathosis. His chief complaint was a local swelling on the vestibular side of the mandibular right first molar.

**FIGURE 4-24** A, Maxillary right molar area with a history of symptoms. Probing indicates a narrow sinus tract on the distal-palatal surface. The sulcus depth was normal in all other areas. B, Radiograph indicating probe extending to the large periapical lesion through a sulcular drainage tract.

**FIGURE 4-25** Calculus on apex of a root with history of chronic drainage from a periapical lesion of pulpal origin.
that had been present for several months. The periapical radiograph showed no evidence of infrabony defects from periodontitis, but a large periapical radiolucency was present on the first molar and extended into the furcation (see Fig. 4-26, A). Clinically, probings confirmed both vertical and horizontal bone loss in the furcation (see Fig. 4-26, B). The outcome of root canal treatment in these cases is uncertain. Many cases will regain attachment after débridement of the root canal, but some will not. See Chapter 1, Fig. 1-13 for review of a case that healed satisfactorily in less than 1 month.

If reattachment has not occurred approximately 1 month after treatment, it is not likely to occur at all. The prognosis for such a tooth is poor, so complete root canal treatment is not advisable until a prognosis has been established. The treatment of choice would be access to the chamber, canal débridement, and closure with calcium hydroxide. Some authors and investigators would recommend using a combination of 2% chlorhexidine along with the calcium hydroxide for better bacterial control. The completion of root canal procedures would be indicated as soon as reattachment is observed, which can occur in as few as 10 days.

**Response of the Periodontium to Mechanical Root Perforations**

Mechanical perforations into the periodontium that may occur during root canal procedures result in one of two types of periodontal lesions. Those found below the level of the attachment have characteristics similar to radicular abscesses that occur adjacent to a lateral canal in the presence of necrotic pulp abscesses. Those that occur in the marginal periodontium have characteristics of periodontal pockets. The prognosis of treatment for each is comparable; lesions have a much better prognosis for complete healing if the attachment is not involved. As a general rule, if a perforation occurs during root canal procedures, immediate repair is very important to prevent contamination of the periradicular tissues by bacteria or materials/solutions used in root canal treatment. Many materials have been used for sealing a perforation, with mineral trioxide aggregate (MTA) the most contemporary and possibly the most favorable for healing. Zinc oxide eugenol has also been used with some degree of success, but materials will be of no value if the site becomes infected.

The case presented in Fig. 4-28 illustrates that if the periodontal attachment is normal preoperatively, attachment will most likely return following surgical repair. During surgery, the attachment area of the root surface should not be cureted. This case also illustrates the general observation that small perforations have a better outcome than large ones. Location is also important in assessing prognosis. Lateral perforations on broad accessible root surfaces have a better...
CLINICAL PROBLEM

**Problem:** A 40-year-old female requested endodontic consultation for a local swelling in the gingiva over the maxillary right canine (Fig. 4-28, A). She related a history of a recent emergency visit to a dentist while on vacation in a distant city. The tooth felt better after the emergency treatment, but upon returning from the trip, the labial gingiva over the tooth became very sore to touch. In the last 3 days, the swelling appeared. Clinical examination confirmed that an endodontic access was made on the palatal aspect of the crown and was sealed with a temporary restoration. A periapical film showed a very generous access cavity. Periodontal probing depths were normal, so a diagnosis of perforation during access to the root canal was considered the most likely problem.

**Solution:** The mucoperiosteal tissues were elevated, and a small perforation was located. Without enlarging the orifice of the perforation, the defect was cleaned with an ultrasonic endodontic file and sealed with MTA (see Fig. 4-28, B). The elevated tissue was repositioned and stabilized with a sling suture. The root canal treatment was completed (see Fig. 4-28, C), and a photograph was made at an 8-month reexamination appointment, at which time periodontal probings were normal.

Severe defects in both tooth and bone can occur (Fig. 4-32). These types of perforations are very difficult to manage successfully because of inaccessibility and the presence of metal in the perforation defect. If repair is attempted, it is usually best if the post can be removed first to avoid the necessity of trying to cut back the metal during surgery in preparation for the repair material.

Perforations into the periodontal attachment are disastrous events which cause irreversible damage to the crestal bone (Fig. 4-33). Regardless of the repair material, recovery of a more coronal attachment level is highly unlikely. In this sense, the lesion must be treatment planned for pocket elimination or extraction. Aesthetics will also be a major factor in the anterior teeth.

CLINICAL PROBLEM

**Problem:** A 70-year-old male was examined for a complaint of chronic soreness in the facial gingiva of the maxillary left lateral incisor. The periapical image confirmed that a perforation during post space preparation had occurred (Fig. 4-34).

**Solution:** The mucoperiosteal tissues were elevated over the area, revealing a large perforation and severe localized interproximal bone loss. The perforation was repaired, and the tissue was positioned apically to eliminate the pocket as much as possible. The patient was advised that the area is likely to heal with a large space between the incisors due to lack of crestal bone support for the papilla.

Prognosis for healing after repair than those on inaccessible surfaces or in the furcations (Fig. 4-29).

Perforations can occur below the periodontal attachment. Strip-type perforations may occur during intracanal cleaning and shaping and during post space preparation (Figs. 4-30 and 4-31). Especially with misdirected post preparations,
FIGURE 4-28  
A, Localized swelling in attached gingiva over maxillary right canine which had been opened for endodontic treatment one month earlier. B, Surgical exposure of perforation. Note interruption of crestal bone, yet preoperative probings were normal. Surgical repair was completed with mineral trioxide aggregate (MTA without enlargement of perforation defect). C, Root canal treatment completed after surgical repair. D, Eight-month reexamination, indicating complete healing.

FIGURE 4-29  Perforation during access cavity preparation into the furcation with associated periodontal breakdown.

FIGURE 4-30  Strip perforation in the course of canal shaping.
With the clinician not realizing the error, root canal treatment was completed; result was acute periodontal abscess. Remedial root canal and periodontal treatment failed to improve severe periodontal defect, and tooth was extracted.

Bony Lesions of the Peridontium that Do Not Originate from Either Periodontal or Pulpal Pathosis

The following lesions have similarities to pulpal and periodontal lesions described in the two previous sections but have entirely unrelated etiologies.

Deep Coronal Fractures

The subject of coronal fractures is discussed as an etiology of pulpal pathosis in Chapter 1. Most coronal fractures in teeth with pulpal symptoms are found to extend to the level of the pulp chamber and no farther. Root canal treatment followed by full coronal coverage provides an excellent long-term prognosis, the latter treatment depending on the age of the patient.

Unfortunately at present, technology does not exist to measure the depth of a coronal fracture preoperatively. Since most fractures develop in a mesial-distal plane, they are not evident on two-dimensional radiographs. Cone-beam computed tomography (CBCT) may serve as an excellent tool in these situations (see Chapter 3). Clinically, fractures can usually be confirmed by visual examination (Fig. 4-35) and transillumination (Fig. 4-36), but the depth and direction cannot be determined with any reliability. If the fracture is
Problem Solving in the Differential Diagnosis of Bony Defects

Problem Solving in the Differential Diagnosis of Bony Defects

FIGURE 4-35 Clinical examination of fracture line with an explorer.

FIGURE 4-36 Transillumination of fractured tooth. The transmission of light stops at the fracture line.

FIGURE 4-37 A, Oblique coronal fracture of maxillary left canine. B, Fractured crown showing angle and extent of fracture. C, Following crown lengthening, tooth is again restorable.

Relatively new and deep enough to extend into the periodontal attachment, there may be slight to no initial changes in the probing depth. One useful early indication is increased tenderness to probing in the location of the fracture compared to other areas around the tooth.

In some cases, coronal fractures are often deep enough to result in mobility of the coronal segments. Mobility is a good clue to the severity of depth and also the likely direction of the fracture line. If a fractured cusp is highly mobile while the remainder of the tooth is firm, the fracture is likely to be oblique with respect to the long axis of the tooth and not extend very far below the free gingival margin. These fractured segments are held only by gingival attachment. Crown lengthening can often make such teeth restorable (Fig. 4-37; see Chapter 17).

A fractured molar is seen in Fig. 4-38. Separation in the fracture line is possible with an instrument, but neither segment is very mobile. This is a grave sign in terms of prognosis. The fracture most likely extends deep and parallel to the long axis of the tooth. Severe periodontal destruction is inevitable along the fracture lines. Fig. 4-39 illustrates a case of a tooth with a deep cuspal fracture that presents as an acute periodontal abscess. The swelling on the buccal is an extension of the infection that originated in the periodontium along the fracture line.

Periodontal complications can present a serious diagnostic dilemma with recent fractures, because signs and symptoms of periodontal involvement are often lacking. As a consequence, some teeth are restored but later develop the periodontal sequelae, and extraction is the unfortunate outcome.

Deep coronal fractures in maxillary molars may follow a different course and extend into the furcation. Clinical examination will usually identify the fracture, but there are seldom any significant radiographic changes. The effect is to divide
CLINICAL PROBLEM

Problem: A 50-year-old male complained of acute cold sensitivity in the maxillary right premolar area. He could not chew comfortably, and clinical examination revealed a mesial-distal fracture line through the crown of the second premolar. There was no mobility of either half of the crown. Sensibility tests confirmed the presence of an irreversible pulpitis. Root canal treatment was completed, followed by placement of a full crown.

Five months later, the patient returned with the complaint of drainage around the tooth and occasional episodes of swelling in the area. Clinical examination showed draining tracts on both vestibular and palatal surfaces but probings on these surfaces were normal. Interproximal probings, however, identified deep narrow defects on both the mesial and the distal surfaces (Fig. 4-40, A). The periapical radiograph confirmed deep periodontal defects interproximally (see Fig. 4-40, B).

Solution: The diagnosis of deep coronal fracture was made, and the tooth was extracted. Postoperative examination confirmed the presence of fracture lines on both mesial and distal surfaces (see Fig. 4-40, C and D). These locations were consistent with a coronal fracture rather than a vertical root fracture (discussed in the following section). A possible treatment plan for coronal fractures without periodontal signs of deep extension would be placement of circumferential protection (e.g., an orthodontic band), removal of occlusal contact, and observing for 1 to 2 months. If no signs of periodontal destruction appear, the tooth could be assumed to be restorable. When multiple sinus tracts are present on an individual tooth, there is a high likelihood of the tooth being fractured, whether a deep coronal fracture or a vertical root fracture. As this case illustrates, placement of a full crown over a tooth with a deep coronal fracture will not prevent periodontal deterioration and eventual extraction.

Vertical Root Fractures

A vertical fracture of the root is a much different entity than vertical fracture of the crown, though the etiology of both may be the same. Generally, vertical root fractures tend to develop from the apex and extend coronally (Fig. 4-42). The clinical presentation is a sinus tract-type periodontal probing pattern that surfaces in the specific areas where the fractures occur, namely the midbuccal or midlingual/palatal
**FIGURE 4-40** A, Probing on the mesial demonstrates deep, narrow defect, indicating periodontal defect. Distal has similar defect but probing on the buccal and palatal surfaces were normal. B, Radiograph indicating periodontal bone loss on mesial and distal surfaces, extending to midroot level. C, Mesial view of extracted tooth, showing fracture line extending from crown to midroot level. D, Distal view of tooth, showing fracture line to same level.

**FIGURE 4-41** A, Clinical view of maxillary right second molar with obvious mesial-distal fracture. B, Extracted tooth, demonstrating that fracture extended directly into furcation and divided tooth in half.
Problem: A 72-year-old male presented with low-grade discomfort in a mandibular central incisor. The discomfort had been vague for 2 or 3 months but now was more focused on this particular tooth. He reports having seen pus coming from around the tooth when he pushed on the gum tissue. Clinical examination revealed a small sinus tract at the muco-gingival junction overlying the severely worn mandibular right central incisor. The tooth was slightly tender to percussion and definitely tender to palpation. A radiograph revealed a previously root-treated tooth with a large radiolucency (Fig. 4-45, A). Two canals were obturated in the tooth, and the quality of the root canal treatment appeared adequate. The initial impression gave a tentative diagnosis of endodontic failure.

Solution: A tentative diagnosis of subacute suppurative periapical periodontitis was appropriate, since the tooth had an apical lesion following root canal treatment, and purulence was present. Incremental circumferential probing was performed and normal sulcus depths found on the mesial and distal line angles (see Fig. 4-45, B and C). Probing between these points indicated a deep, narrow sinus tract-type defect that was pathognomonic of a vertical fracture (see Fig. 4-45, D), and extraction was the treatment of choice. This case emphasizes the use of probing to assess teeth that appear to have failed root canal treatment.

It is uncommon for vertical root fractures to be visible on radiographs. Many fractured roots have no radiographic signs of pathosis at all (Fig. 4-46). This is not surprising, considering the minimal osseous breakdown of a narrow drainage tract as compared to a typical periodontal defect. Since most fractures occur on the buccal or lingual surfaces, bone loss would also be obscured by the root itself. Infrequently, the fractured segments may separate, and the fracture may become radiographically apparent (Fig. 4-47).
As described in the preceding chapter, the most common diagnostic radiographic finding is a widened periodontal ligament space extending from the apex of the fractured root to crestal bone (Fig. 4-48, A). The dimension or actual radiographic width may vary and it may be observed on one proximal surface or both (see Fig. 4-48, B). Chronic lesions in the periodontium from root fractures can reach significant dimensions and resemble primary periodontal lesions (Fig. 4-49). The diagnostic distinctions will be in the results of probings. Periodontal lesions will tend to probe deeply with a wide base in a circumferential pattern, whereas bone loss associated with vertical fractures will probe deeply on buccal and/or lingual surfaces only. Unfortunately, there is no remedy for a vertical root fracture. On single-rooted teeth, extraction is indicated. On multirooted teeth, root resection (amputation) is a possibility (see Chapter 18).

**Developmental Lingual Groove on Maxillary Lateral Incisors and Similar Lesions**

The maxillary lateral incisor will occasionally develop with a groove on the lingual surface of the root. Although the periodontal status may remain normal for many years, the groove appears susceptible to periodontal breakdown. Patients eventually experience signs and symptoms of either acute or chronic periodontal abscess (Fig. 4-50, A), and the defect probes much like a sinus tract (see Fig. 4-50, B). The periapical film in this case demonstrates the groove (see Fig. 4-50, C and D). There is no treatment; extraction is indicated.

The same phenomenon can occur on molars with fused roots. The most typical presentation is on the buccal surface of mandibular second molars, but the phenomenon...
is possible on any multirooted tooth with this anatomic variation. Fusion of the roots sometimes creates a groove similar to the lingual developmental groove of the lateral incisor. Once again, a deep, narrow periodontal defect will be found on the midbuccal surface. Most teeth with these defects will respond normally to pulp tests. Prognosis is poor and dependent on the success of any possible periodontal treatment. When these fusions occur in mandibular molars or premolars, usually a C-shaped canal is present internally.

**Other Possible Rare Lesions**

After traumatic injury, some maxillary incisors will be found to have a deep probing defect in the palatal sulcus. This is


**FIGURE 4-47** Vertical fracture line at apex of maxillary canine. Visible fractures on radiographs are unusual.

**FIGURE 4-48** A, A widened periodontal ligament space identifying vertical root fracture. In this case the radiographic sign may be slight but extends the full length of the root. B, Widened periodontal ligament space occasionally seen on both sides of root.
**FIGURE 4-49** Mandibular left molar with severe bone loss related to longstanding vertical root fracture.

**FIGURE 4-50**

A, Sinus tract on labial surface of maxillary lateral incisor. B, Circumferential probings are normal except in the location of the lingual developmental groove. C, Groove evident on radiographic image of tooth. D, Lingual groove demonstrated on an extracted tooth (arrows).
the direct result of luxation and will generally close spontaneously without treatment.

Periodontal defects associated with enamel pearls are generally found in the furcation areas of molars. Rarely they will cause periodontal breakdown but could present as an acute abscess. Probing is similar to periodontal pockets. Once again, prognosis for the tooth will depend on the possibility of periodontal treatment.

REFERENCES

Chapter 5

Problem Solving in the Diagnosis of Treatment Failure

In attempting to assign the success or failure of operations upon diseased teeth to their proper causes, factors of the greatest importance are frequently left out of account, and the results ascribed to some agent which may have been entirely indifferent. One of these factors, which forms the very foundation of successful root-treatment, is the manner in which the mechanical cleansing of the canal is carried out.18

R.H. Hofheinz, 1892

The patient's subjective data and objective clinical findings to confirm a pulpal diagnosis are discussed in Chapter 1. In many cases, teeth that may be present in the newly symptomatic area have already had a root canal procedure. The process of establishing an accurate diagnosis in these situations must then also include an evaluation of both the treated and untreated teeth. It is a common misperception—at least among many patients, if not some dentists—that once a root canal procedure has been completed, the tooth no longer has the potential for developing problems (radicular pathosis, spontaneous or functional symptoms). This chapter will explore the subjective and objective findings in these cases and highlight the clinical and radiographic criteria that will enable the clinician to determine the outcomes of previous treatment procedures. The approach to this assessment will assume that other diagnostic considerations, as highlighted in Chapter 1 (odontogenic pain) and Chapter 4 (pulpal-periodontal problems) have already been eliminated in the diagnostic scheme.

Nonsurgical Treatment Success

A simplified definition of favorable outcomes with nonsurgical treatment procedures might be: If there is no radiographic evidence of periradicular pathosis prior to root canal treatment, no radiographic signs of pathosis should ever appear following treatment (Fig. 5-1).11 If there is radiographic evidence of periradicular pathosis at the time of treatment, periodic postoperative reexamination radiographs should indicate that the pathosis is healed or is healing.11 As characterized radiographically, this would mean a return to a normal periodontal ligament space and lamina dura, and a normal bony pattern surrounding the root apex (Fig. 5-2). Subjective and clinical corollaries to these findings would refer to the presence or absence of objective signs or patient symptoms. If there are no preoperative symptoms, none should arise postoperatively. Conversely, any preoperative symptoms should resolve completely with treatment.

With these concepts for success in mind, a clinical diagnostic case involving a mixed dentition of root-treated treated and untreated teeth would require a separate and distinct evaluation of the treated teeth, as opposed to just dismissing them as not being the cause of the patient's symptoms.

Problem-Solving List

- Problem-solving challenges and dilemmas addressed in this chapter:
  - Nonsurgical Treatment Success
  - Incomplete Nonsurgical Treatment
  - Alternative Diagnoses often Confused With Treatment Failure
  - Diagnosis of Treatment Failure
  - Causes of Treatment Failure
    - Uncleaned, contaminated canal space
    - Persistence or occurrence of pathosis due to an inadequate apical seal
    - Persistence or occurrence of pathosis due to an inadequate coronal seal
    - Persistence or occurrence of pathosis on roots with presumably nonnegotiable canals
    - Instrument separation preventing thorough canal cleaning, shaping, disinfection, and obturation

Emerging Clinical Directives
FIGURE 5-1  A, Routine endodontic case without radiographic evidence of periapical pathosis at the time of treatment in February 1978.  B, Reevaluation June 2006. The tooth is asymptomatic with normal function.

FIGURE 5-2  A, Large periapical lesion secondary to necrotic pulp on a mandibular right first molar. Lesion appears to have a periodontal complication, but clinical probings were normal. There was a draining sinus tract on the edentulous ridge distal to the tooth.  B, One-year posttreatment reexamination. The apical and distal bone is completely restored along with a periodontal ligament space of uniform and normal width.

CLINICAL PROBLEM

Problem: A 46-year-old patient complained of a periodic dull pain in the lower right quadrant. There was discomfort on chewing but no history of thermal sensitivity. The radiograph indicated previous root canal treatment of the mandibular second premolar and second molar, which according to the patient was completed 7 to 10 years previously (Fig. 5-3, A). Radiographs from the time of the original treatment were unavailable. The only questionable radiographic finding was a slightly widened apical periodontal ligament space on the apex of the distal root on the second molar. The patient had acute tenderness to percussion on the mandibular first molar, but the second premolar and second molar had no discomfort. Periodontal probings indicated moderate general periodontal bone loss, but there was no evidence of defects potentially related to a vertical root fracture on any tooth.

Solution: The challenge was to arrive at the correct diagnosis. The differential diagnosis included bruxism, possible recurrent periapical pathosis on either of the treated teeth, or pulpal disease in the first molar. Occlusion was evaluated, and no occlusal abnormalities were found that would account for the percussion tenderness on the first molar. Thermal sensibility tests on the first molar failed to elicit a response. The diagnosis of pulpal necrosis of the first molar was made; root canal treatment of the other two teeth was judged to be successful. The completed root canal treatment of the first molar is seen in Fig. 5-3, B. All symptoms subsequently resolved.
Incomplete Nonsurgical Treatment

Occasionally the cause of periapical pathosis on a multicanal pulpless tooth can easily be identified when it is obvious that one of the canals has no root filling. It is a matter of semantics whether or not to label this condition as a treatment failure, since the canal in question was never treated. At the same time, it is clearly a failure on the part of the clinician to locate and treat all canals present in the tooth.

**CLINICAL PROBLEM**

**Problem:** The patient was a 55-year-old female with an acute apical abscess. She gave a history that the maxillary left first molar had root canal treatment approximately 3 years previously (Fig. 5-4, A). Clinically there was acute apical palpation tenderness over the apex of the mesial buccal root. There was a radiolucency around the apex of the mesial buccal root; bone associated with the other two apices appeared to be normal.

**Solution:** What was the differential diagnostic parameter? The root canal filling material in both buccal roots suggested that the canals were adequately but not ideally cleaned and shaped, and therefore a true failure was a possibility. A more likely diagnosis for this root was the presence of a second canal or irregular canal configuration.

Fig. 5-4, B shows a file in a second canal clearly separate from the previously treated canal. Fig. 5-4, C shows the completed treatment of this canal only. Arguably, this canal may be the most frequently overlooked canal, owing to its small diameter, the lack of radiographic signs of its presence, and the fact that it is not present in all cases (Fig. 5-5, A to D). Nevertheless, if a maxillary molar presents with a lesion only around the apex of the mesial buccal root in an otherwise adequately treated tooth, an untreated second mesial buccal canal must be the first diagnostic consideration. An uncleaned, contaminated second canal would be one of several possible etiologies for pathosis in a case of inadequate root canal treatment involving the mesiobuccal root (Fig. 5-6).

One of the more perplexing clinical circumstances with the maxillary first molar (and any other tooth that may have a second canal located in the buccal-lingual dimension) is when there is no radiolucency seen on the radiograph, or when the presence of a radiolucency is questionable no matter what angle the film is exposed. In these cases, there may be a lesion present directly behind the root, which is blocked from view by the widening of the mesial buccal root as it approaches the cervical portion of the tooth. An example would be the mesial buccal root of a maxillary first molar with a small palatally located second canal orifice well below the mesial buccal apex. Clinically, the only finding may be tenderness to percussion that is different on the mesial buccal root than on the other roots. Some cases may exhibit localized tenderness to palpation over the root as well. In these cases, it is reasonable to consider either nonsurgical or surgical revision of this root, the choice depending on the other circumstances surrounding the case.

A second common way in which infected/inflamed pulpal tissue in untreated canals causes a symptomatic clinical problem is the onset of acute thermal sensitivity. Symptoms will be typical of acute or chronic pulpitis, and thermal stimulation will cause lasting pain. Episodes of spontaneous pain are also typical, but there are seldom any radiographic signs. The diagnostic challenge is to determine which tooth is causing the symptoms. It should not be assumed that a multirooted tooth should be eliminated from consideration because it has had root canal treatment. Thermal sensibility tests should be conducted on all teeth in the area, including the root-treated tooth. Since the onset of an abnormal reaction to thermal stimulation may be delayed in cases of untreated canals, it is wise to test one tooth and pause before continuing to the next tooth. If tests are conducted too rapidly, it may be difficult to identify which tooth is the cause of a delayed response.

In the evaluation of recurrent pathosis on root-treated teeth, it is important to consider an untreated canal in any tooth that anatomically could have one. These generally are present in a buccal-lingual dimension, as discussed earlier with the maxillary first molar. Mandibular molars common have two distal canals and occasionally two distal roots.
FIGURE 5-4  
A, Apical lesion at apex of mesiobuccal root of an endodontically treated maxillary left first molar.  
B, Endodontic file in an untreated second mesial buccal canal.  
C, Post treatment. Existing root canal treatment of the other canals was judged adequate.

FIGURE 5-5  
A, Cross-section of typical mesial buccal root, indicating a treated mesial buccal canal and an untreated second mesial buccal canal connected by an isthmus (arrows).  
B, Radiographic view palatal root (left) and lateral view buccal root (right) of same tooth.  
C, Pulp chamber with identification of mesial buccal, distal buccal, and palatal canals.  
D, Identification of the second mesial buccal canal.
Mandibular incisors and all premolars may also have two canals or sometimes even three canals (Figs. 5-9 through 5-11).

A second concept of incomplete root canal treatment may be identified as any treatment falling far below the standard of care with respect to obturation as evaluated on a good periapical radiograph. Cleaning and shaping are undoubtedly included as a cause of failure, but inadequacy of obturation is most obvious upon radiographic examination (Fig. 5-12). Root canal procedures completed with such disregard for traditional and proven concepts of cleaning, shaping, disinfecting, and sealing are doomed to failure.

**FIGURE 5-6** A, Inadequate root canal treatment of a maxillary left first molar in which there is also an untreated second mesial buccal root. Clinically, there was local swelling and palpation tenderness localized to the area over the apex of the mesial buccal root. B, Completed revision. Note treatment of second mesial buccal root.

**FIGURE 5-7** A, Previously treated mandibular right first molar with an apical lesion on the distal apex. An untreated second canal in the distal root was the suspected etiology. B, Postrevision radiograph indicating treatment of two distal canals.

**FIGURE 5-8** A, Mandibular left second molar with a lesion caused by failure to treat a second distal root. The endodontic treatment present in the other three canals was judged to be adequate. B, Post revision radiograph.
**FIGURE 5-9** Mandibular right lateral incisor with two canals.

**FIGURE 5-10** Mandibular first premolar with two canals.

**FIGURE 5-11** A, Root treated maxillary first premolar with an apical lesion. B, Postrevision radiograph indicating treatment of a third canal that was the cause of continuing pathosis. (Courtesy Dr. Ryan Wynne.)

**FIGURE 5-12** A, Maxillary central incisor with inadequate root canal treatment. B, Mandibular first molar with inadequate root canal treatment and continuing periapical pathosis.
Radiographic features that mimic those of root treatment failure but in reality are unrelated. The two categories are lesions associated with root fracture and lesions associated with chronic periodontal pathosis.

Chapter 4 provides a broader and more detailed discussion of root fractures, but it is appropriate to review those aspects of lesions associated with fractures that might be confused with failure of root canal treatment. Vertical fractures of the root are almost always associated with root-treated teeth, although some can be seen in other circumstances. The typical lesion associated with a root fracture is a narrow periodontal defect which develops along the course of the fracture line. In many cases, it will resemble a halo or J and is often referred to as a J-shaped lesion (Fig. 5-14). The periodontal probe will be of great value in the discovery and diagnosis of these lesions. If the fracture line extends through the sulcus, the clinical manifestation will be a narrow, deep periodontal pocket usually found on the midfacial or midlingual/palatal surface of the root (Fig. 5-15, A to C). In some cases, if the fracture extends completely through the root, defects will be found on both the buccal and lingual surfaces.

It is common to find chronic sinus drainage tracts associated with these lesions; oftentimes two tracts will appear. The buccal and lingual locations of these fractures and superimposition of the narrow defect over the root itself seldom offer any radiographic evidence of the fracture itself. Infrequently, in cases of complete fracture through the root, the fractured segments may separate, and the fracture line may become visible (Fig. 5-16). Other than exploratory surgery, periodontal probings are often the only means by which root fracture can be differentiated from a developing periapical lesion of pulpal origin.

Clinical and radiographic changes that typify vertical fractures often take time. Tenderness to percussion or continuous low-grade pain may begin at the time the fracture occurs, but development of a periodontal defect that can be probed may not occur for weeks or months. Radiographic

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**CLINICAL PROBLEM**

**Problem:** A 42-year-old patient had a maxillary second molar with only one large canal (Fig. 5-13). The original root treatment was incomplete and led to failure. In addition, there was significant loss of periodontal attachment on the tooth that resulted in increased mobility. The resultant lesion was large, and the prognosis for revision was doubtful.

**Solution:** Following removal of the original gutta-percha filling material, copious purulent drainage was observed. The canal was cleaned, and a calcium hydroxide intracanal dressing was placed. Fortunately all symptoms resolved quickly. After 1 month, sulcular probing depths had returned to normal, mobility had disappeared, and there was no drainage from the canal upon reentry. The revision was completed and a 31-month reexamination indicated complete regeneration of bone in the previous periapical radiolucency (see Fig. 5-13, B).
Problem: The patient was a 63-year-old female with a recent history of local swelling and tenderness in buccal gingival tissues in the mandibular right molar area. The tooth was an abutment for a fixed bridge in place for many years. The radiograph indicated that the tooth had had root canal treatment. There was also a widening of the periodontal ligament space around the distal root (Fig. 5-19, A).

Solution: Periodontal probings were made in 1-mm increments circumferentially around the tooth. A normal sulcus depth of 3 mm was found circumferentially on the mesial half of the tooth. Deep narrow periodontal defects on both the buccal and lingual aspects of the distal root indicated a through and through vertical fracture (see Fig. 5-19, B and C). A joint decision made between the patient and clinician was to reflect the buccal soft tissue and examine the bone and root. This diagnostic surgical procedure confirmed the presence of a vertical root fracture. The crown was removed, and the distal root was resected, thereby preserving the mesial half of the tooth to be restored as a functional premolar (see Chapter 18).
FIGURE 5-17  
A, Mandibular left first molar referred with provisional diagnosis of “endodontic failure.”  
B, One month later, new radiograph displays bone loss consistent with vertical root fracture.

FIGURE 5-18  
Maxillary central incisor with apparent apical lesion. Note vertical fracture line visible in apical third. Lesion was found to probe as a sinus tract–type probing in both midlabial and midpalatal positions. This probing pattern is consistent with a complete fracture through the root.

FIGURE 5-19  
A, Mandibular second molar with history of recurrent local swelling. Tentative diagnosis was “endodontic failure.” Normal probings were found around mesial half of root.  
B, Probing to the apex on the buccal of the distal root.  
C, Probing to the apex on the lingual of the distal root that completes a probing pattern consistent with a vertical fracture extending completely through the distal root from buccal to lingual.
CLINICAL PROBLEM

Problem: A 61-year-old female was referred to the endodontist for revision of root treatment in the mandibular right first molar. The referring dentist initiated root treatment approximately 2 months previously. The patient states that there was no improvement in the persistent infection that appeared to be draining through the gingival sulcus, and that her dentist was convinced there was some irregularity in the root canal anatomy that he was unable to clean properly. A radiograph showed a periapical radiolucency on the distal root of this tooth that extended coronally along the distal root surface (Fig. 5-20, A). There did not appear to be any bone in the interproximal space between the first and second molars. There was advanced periodontal bone loss associated with the second molar as well. Periodontal probing circumferentially in 1-mm increments indicated loss of attachment from the furcation on the buccal surface completely around the distal surface to the lingual surface of the distal root on the first molar. (Fig. 5-20, B). This probing pattern is typical of an infrabony defect of advanced periodontal disease (see Chapter 4).

Solution: A surgical procedure in which the buccal soft tissues are reflected revealed the extent of bone loss (see Fig. 5-20, C). A root resection (amputation; see Chapter 18) was performed and a 12-month reexamination radiograph (see Fig. 18-50, C) indicated complete healing of the original defect. The tooth and the bridge it supports remained functional, the patient had no symptoms, the periodontal pocket was eliminated, and the crestal bone regenerated to a maintainable level.

CLINICAL PROBLEM

Problem: A 61-year-old female was referred to the endodontist for revision of root treatment in the mandibular right first molar. The referring dentist initiated root treatment approximately 2 months previously. The patient states that there was no improvement in the persistent infection that appeared to be draining through the gingival sulcus, and that her dentist was convinced there was some irregularity in the root canal anatomy that he was unable to clean properly. A radiograph showed a periapical radiolucency on the distal root of this tooth that extended coronally along the distal root surface (Fig. 5-20, A). There did not appear to be any bone in the interproximal space between the first and second molars. There was advanced periodontal bone loss associated with the second molar as well. Periodontal probing circumferentially in 1-mm increments indicated loss of attachment from the furcation on the buccal surface completely around the distal surface to the lingual surface of the distal root on the first molar. (Fig. 5-20, B). This probing pattern is typical of an infrabony defect of advanced periodontal disease (see Chapter 4).

Solution: A surgical procedure in which the buccal soft tissues are reflected revealed the extent of bone loss (see Fig. 5-20, C). A root resection (amputation; see Chapter 18) was performed and a 12-month reexamination radiograph (see Fig. 18-50, C) indicated complete healing of the original defect. The tooth and the bridge it supports remained functional, the patient had no symptoms, the periodontal pocket was eliminated, and the crestal bone regenerated to a maintainable level.
radiographic signs of bone destruction at the apex or a specific lateral site.

With the singular exception of an untreated canal with remaining pulpal tissue (discussed earlier), the symptoms of root treatment failure will arise in periradicular tissues in a manner virtually identical to routine pulpal necrosis. Early onset is often characterized by symptoms of percussion sensitivity and possibly palpation sensitivity that may precede radiographic signs of pathosis. As with many cases of pulpal necrosis, developing apical or lateral lesions may become symptomatic, causing the patient to seek consultation. In other cases, lesions of unknown duration may be discovered on routine radiographic examination. Clinically, lesions associated with teeth that have had root treatment may present as acute abscesses or with chronic sinus tracts. The reader is referred to the sections on diagnosing pulpal necrosis in Chapter 1 and Chapter 15 for management of endodontic emergencies.

The second statement at the beginning of the chapter with regard to outcomes suggests that success following root canal procedures would be defined as the healing of any periradicular lesion that exists at the time of original treatment. A number of studies recognize that healing of existing lesions following root treatment is variable and dependent on many factors. Recent investigations into the area of causes for root treatment failure have contributed to our understanding of why periradicular lesions may not heal.

Causes of Treatment Failure

Uncleaned, Contaminated Canal Space

Because the persistence or occurrence of periapical pathosis following initial root canal treatment may have multiple causes,5 treatment planning for revision (see Chapter 15) must first determine etiology. One should presume that all possible causes are present, although it can almost always be anticipated that there is untreated root canal space that contains necrotic, infected, or inflamed tissue.

Chapter 1 discussed failure to débride the canal system of its irritating contents as a prime cause for failure.2,46 When coupled with other identifiable entities such as ineffective three-dimensional filling of the canal space, incomplete fills using only sealers or medicated pastes, and gross overextension of filling materials, the percentage of treatment failures will increase.25,48 The common threads in these failures are incomplete removal of tissue debris and bacteria from the canal system and lack of a radicular seal, both apically and coronally.17,43,51

Persistence or Occurrence of Pathosis Due to an Inadequate Apical Seal

Some cases of failed root canal treatment have obvious radiographic signs of inadequacy in the canal obturation. Fig. 5-21 illustrates an example of a palatal canal that is clearly prepared to within 2 mm of the radiographic apex but is obturated 2 to 3 mm short of the prepared stop.

A failed case of nonsurgical management of an open-apex tooth is seen in Fig. 5-22. Radiographically, the gutta-percha filling fails to fill the canal properly; by a priori reasoning, an apically sealed canal probably does not exist. At this stage of root development, the canal space appears radiographically to have parallel walls. When considering the anatomy of an immature root, in the labial-lingual plane, the canal is actually divergent and wider apically than in a mesial-distal
Problem Solving in the Diagnosis of Treatment Failure

This case amplifies the main causes for the occurrence of periradicular disease and supports initial nonsurgical revision of inadequacies in root canal treatment in most situations. The existing and original crown appeared well done, with excellent marginal fit. It is still possible, however, that coronal leakage developed around the crown margin or the margin of the restoration. There are other possible causes such as regrowth of latent bacteria in the dentinal tubules or dimension.7 It would never have been possible to obturate this canal adequately with standard techniques. The plan for revision included apexification with calcium hydroxide prior to any attempt to seal the canal.60 The previous gutta-percha filing was removed using Gates-Glidden burs and large Hedström files. Treatment time for apexification on the 35-year-old patient shown was 2 years, 9 months. This is essentially the same time frame for treatment on a young patent when using calcium hydroxide. Presently, however, the use of mineral trioxide aggregate (MTA) may enhance and hasten the process (see Chapter 14).

Unfortunately in most cases of failed root canal treatment, the quality of the obturation at the apical foramen cannot be directly assessed radiographically. A second limitation is the inability to assess the quality of the débridement. It is reasonable to assume that if the canal is not properly débrided, it will be impossible to obtain an adequate seal. This is especially true in the contemporary use of resin-bonded root canal filling materials that claim to develop a monoblock-type of bonding in the root canal.15,54,55 If the canal cannot be débrided properly, bonding will not occur, the filling will leak, and it may suffer further from enzymatic breakdown due to the impact of tissue debris and retained bacteria on the resin-based core material and sealer.54

CLINICAL PROBLEM

Problem: A relatively uncomplicated endodontic case was completed by a general dentist (Fig. 5-23, A). No periradicular lesions were present at the time of treatment. Five years later, the tooth became sensitive to percussion, and an apical lesion on the mesial root was discovered on a radiograph (see Fig. 5-23, B).

Solution: The patient was referred for revision of the root canal treatment, which was completed only on the mesial canals. Reexamination 4 years later demonstrated healing of the periradicular tissues (see Fig. 5-23, C).

This case amplifies the main causes for the occurrence of periradicular disease and supports initial nonsurgical revision of inadequacies in root canal treatment in most situations. The existing and original crown appeared well done, with excellent marginal fit. It is still possible, however, that coronal leakage developed around the crown margin or the margin of the restoration. There are other possible causes such as regrowth of latent bacteria in the dentinal tubules or

FIGURE 5-23  A, Posttreatment radiograph of root canal treatment on mandibular right first molar. B, Film of same tooth 5 years later, indicating an apical lesion on the mesial apex. Nonsurgical revision of mesial root completed at the same time. C, Reevaluation after 4 years, indicating complete healing.
inaccessible areas of the canal system. Obtaining a clean canal in a revision is a much greater technical challenge than to achieve cleanliness in a primary treatment. These issues will be discussed in further detail in the next sections. In some cases, after thorough assessment and explanation to the patient, a surgical revision may be the treatment of choice (see Chapter 16).

**Persistence or Occurrence of Pathosis Due to an Inadequate Coronal Seal**

Research supports that coronal leakage following root canal treatment can cause periradicular pathosis or result in its persistence. This theory has been long held based on empirical observation. The problem of coronal leakage is known to occur in a variety of situations. The most obvious is the case of a root-treated tooth that has lost its coronal restoration, leaving the gutta-percha filling material exposed to the oral environment (Fig. 5-24). Studies indicate that in as little as 20 to 90 days, bacteria may penetrate along and apically beyond a well-placed gutta-percha filling. Other common pathways are recurrent caries in contact with the pulp chamber (Fig. 5-25). Marginal leakage can occur around crowns (Fig. 5-26), faulty access cavity restorations (Fig. 5-27), or inadequate core buildups. This is a particular problem with composite materials placed using a bulk technique as opposed to incremental placement (Fig. 5-28). Also, posts that are exposed to saliva or become loose under failing restorations provide ready access for bacteria into the canal (Fig. 5-29). While these concepts are widely held as true in clinical scenarios, data are based on retrospective evaluations. The same type of retrospective data, only in a more extensive and in-depth histologic evaluation, have strongly suggested
that well-prepared and filled root canals seem to resist bacterial penetration even upon frank and long-standing oral exposure by caries, fracture, or loss of restoration.38,39

A seldom identified etiology for failure, or one that may even be thought of as a source of coronal leakage and contamination of the untreated or treated root canal, is the long-term persistence of bacterial plaque and calculus around the restorative margins. Dentinal tubules may serve as portals of entry for external irritants into the root canal58 (Fig. 5-30, A; also see recommended readings at end of chapter). Anatomic alterations in the tooth structure can also exist in this area. Between 5% and 10% of the cemental-enamel junction presents with open, uncovered dentinal tubules14,22,32 (see Fig. 5-30, B). This presents a perfect avenue for communication between the periodontium/oral cavity and the pulp canal space, whether rapidly through virulent pathogenic invasion or slowly through a chronic invaginating process. This usually does not present a problem in teeth that are meticulously maintained through oral hygiene practices or teeth with well-adapted restorative margins that are properly maintained. However, the potential for this etiology to be the cause of failure in teeth with even the best root canal treatment cannot be overlooked in the following situations:

- If the margin is not well adapted (see Fig. 5-30, C) or if there is a small area of undetectable caries (both clinically or radiographically), this may serve as a long-term source of leakage58 (see Fig. 5-30, A). Bitewing radiographs are recommended during the evaluative phase (see Chapters 2 and 3), but their diagnostic capabilities may be limited. In the non–root-treated tooth, this will create a long-term sensitivity or sometimes a vague pulpal problem, whereas in the root-treated tooth, the patient will be symptom free but may have signs of apical or lateral pathosis.

- If the tooth was prepared for a crown and the impression did not clearly mark the finish line, or if the crown was not adapted to cover the entire area of cut, exposed tubules, there will be exposed dentin that can serve as potential avenues of communication to the pulp space (see Fig. 5-30, D, arrows). In the non–root-treated tooth, this will create a great deal of sensitivity or sometimes outright pain, whereas in the root-treated tooth, the patient will be symptom free but may have signs of apical or lateral pathosis.

- In teeth that undergo periodic root planing and curettage, often the cementum is removed along with the adherent plaque, which opens additional pathways for irritants to gain access to the root canal space.58 Coupled with the degree or severity of root instrumentation, this may cause severe discomfort in the non–root-treated tooth, whereas in the root-treated tooth, the patient may be symptom free but will often manifest signs of periapical or lateral pathosis following multiple episodes of periodontal treatment intervention.

The implications of this phenomenon of coronal leakage and treatment failure are significant (see Fig. 5-30, E) is possible (see Fig. 5-5, A-B). It may be wise to consider revision of any root canal obturation that has been exposed to saliva, caries, or a failing restoration, whether or not it is symptomatic or the root shows any radiographic signs of periapical pathosis.62 This scenario, however, must be discussed at length with the patient before proceeding. During case assessment following root canal treatment, consider the following questions: Are the restorative margins possibly leaking? Is there recurrent decay around the restorative margins? Is there leakage around a core buildup or post? Is the post possibly loose? Are there excessive amounts of plaque and calculus around the restorative margins?
Persistence or Occurrence of Pathosis on Roots With Presumably Nonnegotiable Canals

Often root canals may either not be found or are not negotiable. There is a presumption that these canals are calcified, so treatment may not be necessary. However, if there is a periapical lesion present at the end of the root or on its lateral aspect or if one develops over time, this is prima facie evidence of the presence of a canal space and necrotic, infected tissue, even when a canal does not appear patent on radiographs. Studies have shown that there is a greater risk for these cases to develop periapical periodontitis or have persistence of such following root canal procedures.31
Persistence of pathosis on a mandibular molar filled short of the apical constriction in all the canals is seen in Fig. 5-31, A. Radiographically, no canal space is apparent beyond the present radicular filling material. The patient presented clinically with a long-standing gingival sinus tract. The tooth also contains intraradicular posts, which should not prevent nonsurgical revision, since in some molars surgery is not a viable option (see Chapter 16). Limited anatomic access, short roots, certain tooth angles, or medical contraindications frequently limit the choices to nonsurgical revision or extraction. Fortunately, the distal canal and one of two mesial canals were negotiable to the apex after post removal. Clinical examination confirmed healing of the sinus tract after the canals were débrided. Fig. 5-31, B is the appearance at the 1-year reassessment. The ability to negotiate one of two canals in roots such as this greatly improves the prognosis because of the frequent joining of two such canals into one at the apex.

**Instrument Separation Preventing Thorough Canal Cleaning, Shaping, Disinfection, and Obturation**

A separated root canal instrument is seldom if ever the sole cause of failure. Since instruments are stainless steel or nickel-titanium alloy, it would be extremely rare for these materials to cause periapical inflammation. The real problem is that the separated instrument prevents thorough cleaning, shaping, disinfection, and canal obturation (Fig. 5-32, A). When these instruments can be removed, successful revision of treatment invariably ensues. Although it is occasionally possible to remove these instrument fragments with methods to be described (see Chapter 14), the majority cannot be removed nonsurgically. Factors such as canal curvature, overall root width, and the depth at which fracture occurred may make the attempt to remove such fragments unwise. As with calcified canals, a reasonably successful strategy is to complete revision or treatment of the second canal when the root has multiple canals in a case in which the instrument fragment cannot be removed or bypassed (see Fig. 5-32, B). Many canal systems merge to a single common apical foramen. By treating the alternate canal, the instrument fragment may effectively be bypassed. The unknown factor with this approach is that there is no means by which this canal configuration can be confirmed. Consequently, the patient should be informed of the problem, the strategy to be employed, and a plan for periodic reexamination.

Attempts to remove instrument fragments deep in the root canal space invite a number of serious procedural errors such as stripping perforation, instrument perforation, and excessive thinning of the root canal walls. Although citations appear in the literature documenting successful removal, postoperative radiographs typically indicate extremely generous excavation cavities, which begs the question of restorability or at least the prognosis of restoration. Occasionally it may be possible to bypass a fractured instrument segment. With the use of ultrasonically energized root canal files, it is sometimes possible to remove the fractured segment (Fig. 5-33).

If the fragment cannot be removed, the canal is cleaned, shaped, disinfected, and obturated incorporating the fractured segment into the root canal filling material. However, the instrument may not play a significant role in sealing the canal from bacterial penetration via coronal or apical leakage at a later date. Attempts to bypass any fractured instrument segment must be monitored radiographically. In such cases, the prognosis of a successful obturation would depend chiefly on (1) the degree to which the instrument fragment influenced the direction and final diameter of the canal preparation and (2) the presence of contaminated space beyond the instrument. Total blockage of the canal lumen by the
resection may be considered (see Chapters 16 and 18). While surgical intervention has a high degree of success (see Chapter 16), residual bacteria in the apical dentinal tubules or extremely irregular anatomic spaces that could not be addressed nonsurgically may not be removed totally during the surgical procedure, regardless of the radiographic quality.

fractured segment will almost always make an attempt to bypass unsuccessful, with the potential for a root perforation. Alternative treatment planning generally includes cleaning the canal up to the fractured segment and sealing the canal space; the case should be observed for subsequent signs or symptoms. If unsuccessful, periapical surgery or root

**FIGURE 5-32** A, Mandibular left first molar referred for revision and removal of fractured instrument in the mesial lingual canal. B, Off-angle radiograph indicating revision might be possible in the mesial buccal canal. If the instrument cannot be bypassed or retrieved, revision of one canal is often successful if the canals merge.

**FIGURE 5-33** A, Length determination exhibiting instrument fragment in mesial buccal canal. B, Successful bypass of the instrument (arrows). C, Posttreatment image suggesting that the instrument fragment was removed during the course of canal shaping. With use of ultrasonic instrumentation, fragments are often suctioned without notice.
of the resection and root-end filling. This may be due to the nature of the root-end resection and these contaminated irregularities, and signs and symptoms may persist. These problems create both diagnostic and treatment-planning challenges regarding the etiology and choice of management (e.g., second surgery or extraction). Clinically, the patient is usually given antibiotics “in hopes” that the symptoms will diminish. Only too often, this delays necessary treatment-planning alternatives.

These cases emphasize the importance of preventing instrument separation by (1) considering the canal anatomy, (2) paying attention to the objectives of canal cleaning and shaping, and (3) exercising caution when choosing to provide root canal treatment for posterior teeth with complex root canal systems. New file systems made from highly flexible yet durable metals and single-use endodontic files for each case may minimize instrument-separation incidents in the future. Further details on problem solving the management of anatomic complexities will be found in Chapter 13.

Fractured instruments in the root canals of molars are sometimes impossible to remove. They can be beyond reach around curves in small canals or in surgically inoperable roots. Root or tooth resection may be a feasible alternative to extraction (Fig. 5-35). If periradicular surgery or root or tooth resection cannot or should not be done, intentional replantation or extraction are usually the only options remaining.

**CLINICAL PROBLEM**

**Problem:** A 33-year-old female presented with long-standing pain in the mandibular left posterior quadrant. She was convinced that her problem was coming from the first molar, though she could not be sure. She recalled that she had had root canal treatment on one of the molars and was told that that tooth could not cause her any difficulty. Her pain was beginning to be accentuated by biting. Clinical examination indicated pain to percussion and palpation on the second molar, with a more subdued response on the first molar. Both teeth were unresponsive to thermal stimulation, and periodontal probing was within normal limits. A radiograph showed a large radiolucency on the distal root of the first molar and a small radiolucency on the mesial apex of the second molar. The second molar appeared to be filled with a paste filling. The canals of both roots were filled well short of the radiographic apices and there was a separated instrument fragment at the mid root level of the mesial root.

**Solution:** Because of the patient's symptoms and chief complaint, a decision was made to treat both teeth simultaneously. After significant attempts to remove the fractured instrument segment in the mesial root of the second molar, the metallic object was bypassed with a file (Fig. 5-34, B). Both teeth were obturated with gutta-percha and sealer, and the patient's symptoms ceased (Fig. 5-34, C). The fractured instrument segment was incorporated into the root canal filling. A 4-year reevaluation shows excellent healing for both teeth, and the patient was symptom free (see Fig. 5-34, D).

![A B C D](image_url)

**FIGURE 5-34** A, Mandibular left second molar with fractured instrument in mesial root. B, Successful bypass of the instrument (arrows). C, Completed revision. Note fragment is now located more apically than originally and may compromise the apical seal (arrows). D, Four-year reevaluation. Apical healing appears excellent.
buildups over minimal clinical crowns are not likely to survive extraction in one piece. If these conditions are favorable, replantation can be very successful (Fig. 5-36). In all cases, the patient should be informed of the potential outcome of extraction alone.

Intentional replantation is only an option in selected cases. One criterion for selection is an anatomic root morphology that is conducive to extraction without tooth fracture, such as a fused or cone shape. The restorative condition of the tooth is also important. Teeth with posts and core

**FIGURE 5-35** A, Instrument fragment in distal lingual canal of mandibular molar. Nonsurgical removal has not been possible using conservative techniques. Apical surgery is not possible. B, Distal lingual root amputation was performed to retain the tooth as a terminal abutment for a removable partial denture.

**FIGURE 5-36** A, Maxillary second molar with chronic apical lesion. Presence of posts in two canals and a lesion involving the palatal root made intentional replantation the treatment of choice. B, A conical root morphology is ideal for successful extraction. The orifices were filled with MTA. C, Eight-year reexamination. The tooth was asymptomatic and had normal function.
Emerging Clinical Directives

In the area of microbiology, residual infections primarily caused by *E. faecalis* have become the subject of numerous studies. Statistically, this organism is isolated relatively infrequently from primary infections of the root canal system. In isolates from posttreatment lesions, the percentage rises significantly, although in specific geographic populations, other organisms have been identified to be just as critical. This is important because these microorganisms have proven to be difficult to eliminate from the root canal system by all methods now in clinical use. The resurgence of interest in endodontic irrigants and disinfectants, along with the issue of biofilms, are examples of concerns about this problem (see Chapter 12).

Many authors have described multiple conditions that may cause posttreatment disease. The most obvious are vertical root fractures, true cysts, foreign body reactions, extrusion of materials through the apical foramen, and extra-radicular infections, such as with yeasts or fungi. Of these entities, only vertical root fractures can be diagnosed clinically. The treatment for this problem is always extraction or root removal. Since the etiology of most cases of persistent periapical pathosis cannot be confirmed preoperatively, nonsurgical revision is usually indicated, with a plan for postoperative monitoring. However, a significant percentage of these cases will eventually require apical surgery.

The radiographic and clinical appearance of root canals obturated with a paste filling material that was extruded through the apical foramen during treatment is seen in Fig. 5-37. It is not surprising that subsequently, periapical lesions developed. Although nonsurgical revision was necessary to correct the inadequate root canal treatment, apical surgery was required to remove the excess material.

Of the remaining conditions cited for failure in the literature, inadequate root canal treatment without alteration of the canal morphology is considered to be the only cause of posttreatment disease that has a good chance for success with nonsurgical revision. Two other conditions for failure that are cited are inadequate root canal treatment with alteration of the root canal morphology and infection remaining in inaccessible areas in the apical portion of the root canal system. Nonsurgical revision of root canal treatment is not very likely to result in healing in many of these cases, even with an extensive revision. The recommendation for all of these conditions is periapical surgery. A final condition may be the presence of excessive material extruded beyond the apical foramen. More often than not, surgery will be indicated if the patient is symptomatic.

The diagnosis of treatment failure begins with the elimination of alternative etiologies. Using the criteria for determining treatment success, treated teeth can be assessed for relative success or failure. Although the success rate for nonsurgical root canal treatment is high, there are known conditions that will cause treatment failure. In the presence of symptoms, a diagnostic pathway has been described in a problem-solving format to yield the proper diagnosis and potential courses of treatment. Problem solving the technical aspects of these choices is detailed in Chapters 13, 14, and 18.

REFERENCES


*References 9, 21, 33, 35, 42, and 59.

**FIGURE 5-37** Extrusion of paste filling material into maxillary sinus. Note inadequate root canal treatment that failed.
44. Saunders WP: Considerations in the revision of previous surgical procedures, Endod Topics 11:206-218, 2005.

RECOMMENDED ADDITIONAL READING
Chapter 6
Problem Solving in the Diagnosis of Nonodontogenic Pain

The condition (tic douloureux) frequently results from chronic irritation of the fifth cranial nerve. The pain is very acute, and occurs in distinct paroxysms, gradually increasing in severity, until it reaches a climax, when it quickly subsides. The attack may occur at any time and is provided by speech, laughing, talking, the movement of a muscle, etc., and even slight noise or light touch, as placing the hat on the head, may cause a paroxysm. The patient lives in constant dread of an attack.6

J.P. Buckley, 1910

In the course of clinical practice, it is typical that pain is the reason many patients seek a consultation. Some symptoms are virtually diagnostic for pulpal and periapical pathosis. When a patient reports protracted pain that results from thermal stimulation, for example, there is a high likelihood it is of pulpal etiology; only the dental pulp is capable of such painful responses. The main diagnostic task is to find out which tooth is the problem.

In other cases, the history of symptoms is not so specific for pulpal or periapical pathosis. Through diagnostic procedures and radiographic interpretation described in Chapters 1 and 3, an etiology can usually be identified, or the facts can be narrowed for further assessment. Nevertheless, it is common to encounter patients with pain problems for which the etiology is quite elusive. It is the purpose of this chapter to discuss some of the most common and often perplexing oral-facial pain problems that are not attributable to teeth but are nonodontogenic in origin.

It is not the goal of this chapter to be encyclopedic. Other sources in the endodontic and dental literature have already described an extensive array of medical conditions from which oral and facial pain symptoms have occasionally been observed.12 The majority of these conditions (e.g., temporal arteritis, otitis media, sialolithiasis) have an array of signs and symptoms that usually manifest in the tissues of origin. The reported dental symptoms are not typical, and it is extremely unlikely that these conditions would present with primary oral symptoms that would be confused with pulpal or periapical pathosis. In all cases, if the source is not of odontogenic origin, a careful and thorough examination of the teeth will typically rule out a dental etiology.

If a case of oral-facial pain is encountered for which no dental etiology can be found, the patient should be referred to an oral surgeon or physician for further evaluation. It is not the responsibility of the dentist to make the diagnosis or manage the treatment of such a case. It is the responsibility of the dentist to rule out a dental etiology and assist the patient in resolving the problem through an appropriate referral. To facilitate this problem-solving endeavor, various nonodontogenic pain scenarios will be presented in the...
manner they are most commonly encountered: thorough analysis of clinical cases.

**Occlusal Discrepancies**

Occlusal discrepancies are a common source of patient discomfort. Many are not tooth related, but with data gathering and problem-solving techniques, the source of the patient’s distress can usually be identified and eliminated rapidly.

**PROBLEM SOLVING**

**Problem:** A 31-year-old female was referred for root canal treatment on her mandibular left first molar. She stated that she could not chew comfortably on the tooth. She had no thermal sensitivity and was not experiencing any spontaneous pain. A radiograph gave no evidence of dental caries, periapical pathosis, or periodontal disease (Fig. 6-1). Pulp sensibility tests were performed on all the mandibular left posterior teeth, all of which responded normally to cold. Further inquiry indicated that 3 months earlier, a crown was placed on the first molar. The patient recalled that the symptoms actually began around that time. The occlusion was checked with articulating paper (Fig. 6-2), and a large premature contact was found. The occlusion was reduced and refined in this area, and the patient felt some immediate relief.

**Discussion:** An examination should always begin with an accurate and detailed history of symptoms. Occasionally the patient may not recall all pertinent details, or the clinician may follow a line of inquiry that initially does not reveal important clues. It is appropriate to treat the case as having a potential problem and perform usual tests to confirm or rule out a pulpal diagnosis that requires treatment. In this case, having performed tests, it was clear that the pulp was normal in all three teeth, and the pain was from another source. Since the only symptom has been sensitivity to occlusal pressure, it was logical to assess the occlusion, which proved to be the problem. A simple occlusal adjustment of the prematurity was the only treatment required.

**FIGURE 6-1** Mandibular left first molar with symptoms of percussion tenderness.

**FIGURE 6-2** Almore articulating paper (Almore International Inc., Portland, OR, USA).

**PROBLEM SOLVING**

**Problem:** A 53-year-old male was seen on referral. For several weeks, he had been unable to chew comfortably on the mandibular right first molar. When he awoke, there was usually a particular soreness in the tooth. He had not had recent dental treatment, and there was no history of thermal sensitivity. A radiograph indicated no caries, periapical pathosis, or periodontal disease (Fig. 6-3). Full porcelain veneer crowns had been done approximately 10 years previously on the mandibular right posterior teeth. Pulp sensibility tests were limited to heat and cold, owing to the lack of exposed tooth structure necessary for an electric pulp test. Multiple tooth surfaces were tested, and each tooth was tested at least three times, with no responses to either hot or cold that would indicate a pulpal problem. Analysis of the occlusion with articulating paper indicated heavy wear facets on almost all the posterior teeth including the first molar, yet this tooth was only mildly tender to percussion. Occlusal adjustment was performed on this tooth, and the patient related that there was an immediate improvement.

**Discussion:** This case differs from the first case in the fact that the presence of pulpal pathosis can neither be confirmed nor ruled out. It is inappropriate to proceed with root canal treatment, because there is no confirmation of pathosis. In this case, the occlusal adjustment is both a diagnostic procedure and a potential final treatment.

As for the prematurity found in the first case, occlusal adjustment may be the only treatment required. On the other hand, if sensitivity to percussion is of pulpal origin, (degenerative or irreversible pulpitis), an occlusal adjustment will improve but not eliminate the problem. In time, more definitive signs or symptoms of pulpal pathosis will become apparent, with the potential for radiographic changes at the end of the root (increase in the width of the periodontal ligament space and loss of the lamina dura; see Chapter 3). If the tooth
becomes increasingly sensitive or painful to percussion, the etiology would be primarily pulpal in origin, since occlusal contact has already been eliminated. Greater changes in the apical periodontal ligament space may also be seen radiographically, depending on the position of the root or roots in the bone.\textsuperscript{1,2} Under these circumstances, what also may have to be considered is a root or tooth fracture (see Chapters 4 and 5).

The appropriate course of action at this point is to wait and watch. The patient is now informed of the possible outcomes and should be encouraged to return if the symptoms become worse at any point in the future. It is impossible to predict when a true pulp problem and its sequelae may evolve. It may occur in a relatively short period of time, such as a gradual increase in symptoms over a span of days, or it may not become apparent for months.
CLINICAL PROBLEM

**Problem:** The patient was a 35-year-old female with a 17-month history of continuing pain following root canal treatment of the mandibular left first molar. A postoperative radiograph of treatment was provided by the referring dentist (Fig. 6-4, A). The following history was also provided:

**Case History**

*Referring clinician notes:* Root canal treatment was completed on the mandibular left first molar for “local swelling and the feeling of warmth” over the area of the apices. Following treatment, the symptoms persisted to the present time despite antibiotics, one complete retreatment/revision, and a third reopening to remove the filling material in the distal canal. This is the status of the tooth at present.

*Patient-related information:* Subsequent to the initial treatment, the symptoms resolved for a time then returned. The pain had been continuous in the area of initial treatment and was the same pain felt prior to treatment. At no time were there symptoms specific to the tooth (i.e., cold, hot, or percussion sensitivity). Ten months following treatment, a feeling of external swelling developed on the inferior border of the left mandible, which prompted a return to the dentist.

A radiograph was made on return to the treating dentist 10 months post treatment (see Fig. 6-4, B).

- On this date, antibiotics were prescribed.
- Later in the same month, the dentist decided to do a complete retreatment of the tooth.
- Over the next 2 months or so, two more prescriptions for antibiotics were given.
- Neither the retreatment/revision nor the courses of antibiotics had any lasting effect.
- Six months after her return, 16 months from the original treatment, the patient returned again with the same complaint.

At this point, the dentist chose to remove the gutta-percha root filling from the distal canal, which was done on a subsequent visit 2 weeks later (see Fig. 6-4, C).

- Removal of the gutta-percha filling had no effect on this pain.
- The patient was referred for specialist evaluation.

*Clinical examination on referral appointment:* The patient stated that the swelling had always been felt externally in the area along the inferior border of the mandible (Fig. 6-5). At no time was there any swelling noted intraorally, which was confirmed by the clinical examination (Fig. 6-6). There was no swelling or tenderness to palpation found lateral to the first molar or anywhere in the vestibule. Further clinical examination indicated there were no caries, no fracture lines, and normal periodontal probings. The other teeth in this quadrant responded normally to pulp sensibility tests.

From a problem-solving standpoint, it is worthwhile to consider some important questions in establishing a tentative differential diagnosis: **First, is there a tooth/pulp etiology for the pain in this case?**

*Discussion:* A review of historical data reveals no evidence to support a diagnosis of pulpal pathosis other than the original conditions as stated by the dentist. There was no preoperative record of sensibility tests on the first molar, and the patient relates a history of symptoms uncharacteristic of pulpal or periapical pathosis. In addition, the history does not include any symptoms directly related to a tooth/pulp, such as an abnormal thermal response or sensitivity to percussion. A review of radiographs throughout the period of observation and treatment indicated a consistently normal apical periodontal ligament space around the apices of the first molar. The clinical findings indicated a remote location of discomfort relative to the alveolar arch. There was no evidence of pathosis in the vestibule lateral to the first molar, and the sensibility test responses on all adjacent teeth were normal, as were the periodontal probings. Conclusion: The patient’s problem is not related to the tooth or the treatment rendered.

**Second, what are the diagnostic possibilities for oral and facial pain that might fit this dental history?**

*Discussion:* Diagnostic possibilities are trigeminal neuralgia, atypical facial pain, and temporomandibular disorder.

**FIGURE 6-5** Patient feels the pain along the inferior border of the mandible.

**FIGURE 6-6** No signs of tenderness or swelling around the teeth.
**Trigeminal Neuralgia**

Trigeminal neuralgia affects about 155 per 1 million people and most often occurs after the age of 50. Its devastating effects have been known for over 100 years, and a wide variety of attempts have been made to identify its etiology and determine a successful treatment. It is unilateral and follows the distribution of either the mandibular or the maxillary branch of the trigeminal nerve, occasionally both. There is evidence that trigeminal neuralgia is also found in some people afflicted with disorders such as multiple sclerosis that affect the myelin sheath of the nerves.

Trigeminal neuralgia is characterized by short episodes or bursts of pain described as intense and similar to electric shocks. Onset is usually random and unpredictable, but occasionally the sufferer will describe a “trigger zone,” an area of the face or a locus in the oral cavity that initiates the pain upon physical stimulation. This may occur during face washing, teeth brushing, experiencing a cold breeze, or simply moving the facial muscles. Painful attacks are not initiated by hot or cold stimulation of the teeth. Most often the diagnosis can be recognized from the history, since the symptoms are unique compared to pain of pulpal or dental origin.

Episodes of pain with trigeminal neuralgia do not occur during sleep and usually last from a few seconds to a minute. There are no physical signs of pathosis, and pain is unresponsive to analgesics. Most often, the history and routine pulp tests will easily rule out the teeth as a cause. The importance of taking a complete history cannot be overemphasized. In many cases, the diagnosis of trigeminal neuralgia can be quickly ruled out on that basis alone.

In the case of the 35-year-old female described in the previous problem box, the pain is not spasmodic but lasts for extended periods of time. It is described as a continuous dull ache, and there has never been an episode of acute sharp pain. Physically, there is an area of tenderness externally, along the mandibular border, the palpation of which does not initiate the pain. Conclusion: Trigeminal neuralgia can be ruled out as an etiology for this patient.

**Atypical Facial Pain**

Atypical facial pain, also known as persistent idiopathic facial pain (PIFP), is a diagnosis that was introduced in the mid-1920s. It is basically a diagnosis of exclusion. If all other entities are ruled out, it must be atypical facial pain. Some neurologists believe the term falsely gives the patient a sense that they have a diagnosis, when in fact a better term might be undiagnosed facial pain. It is easy to see that this is not the place to start when attempting to diagnose an oral pain problem. The International Headache Society defines atypical facial pain as pain that is present daily and persists most of the day. At onset, it is confined to a limited part of the face, is deep and poorly localized, is not associated with sensory loss or neural symptoms, and no abnormalities are found with laboratory or imaging studies. Frequently, psychiatric symptoms of depression and anxiety are also experienced by persons suffering this pain, further obscuring its etiology.

Although this entity would be a convenient solution to many diagnostic dilemmas, it is a relatively rare final diagnosis. It would be appropriate to refer the patient for medical evaluation if such a diagnosis were suspected. In the case of the 35-year-old woman under consideration, there were clinical signs of pathosis. There was an area of palpation tenderness and the feeling of swelling in a consistent, well-differentiated area of the mandible. Conclusion: Atypical facial pain, or PIFP, can be confidently ruled out in this case.

**Temporomandibular Disorder**

Temporomandibular disorder (TMD) is a complex entity that can involve chronic inflammation and pain in any or all of the following tissues: temporomandibular joint, teeth, and the muscles of mastication and associated tendons and ligaments. There may also be degeneration of the articular surfaces of the joint. TMD is a problem involving not only the hard and soft tissues but also the personality and is strongly influenced by social and environmental factors. It is not unusual to encounter older individuals with ample evidence of a long history of bruxing, who only recently have developed symptoms. Extraordinary stress is a typical precipitating factor. Because of the complexity of the subject, this descriptive section will focus on the types of signs and symptoms that might be confused with pain of tooth/pulpal origin.

The majority of patients with TMD report symptoms associated with the muscles. The most common causes for muscle symptoms are overuse of the masticatory muscles through parafunctional habits such as bruxism or clenching. In the observations of the authors, the symptoms are almost invariably unilateral. Frequently, patients suffering from this pain are unaware of any tendency to clench or grind, giving credence to the probability that most of this activity occurs during sleep. For this reason, during a diagnostic inquiry, it is worth asking whether the patient is ever awakened from sleep with the pain or has pain on awakening in the morning. Another related symptom is the feeling of muscle fatigue. The masseter muscle is easy to palpate and can be found to be tender at either its origin or insertion, seldom both.

In reviewing the facts in the case of the 35-year-old woman presented in the Clinical Problem box, the examination indicated that the patient experienced swelling and pain over the insertion of the masseter. Anyone who does strenuous physical work or exercises recognizes that a muscle exercised to the point of fatigue will become sore from lactic acid accumulation in addition to becoming hard, enlarged, and warm. This fits perfectly with the history of “local swelling and feeling warm,” and it explains why there are no intraoral signs or symptoms.
The bruxing or clenching habit is characterized by periods of symptoms lasting days or weeks interspersed with periods of relative comfort. When interviewed about their history, many patients will recall that symptoms have come and gone over a long period of time. Clearly these findings are vastly different from what is identified with pulpal pathosis that develops rapidly and localizes to a specific tooth. Even in cases of pulpal degeneration that develop over a longer time frame, there is an ultimate progression to a more acute and localized condition.

Conclusion: The patient described in the Clinical Problem box is most likely suffering from chronic TMD manifesting in the left masticatory muscles. There may or may not have been any indication to perform root canal treatment on the mandibular molar in this case, though at this point, it was necessary to complete what had been initiated. The definitive treatment for her symptoms at this point would be treatment for TMD.

Further Observations on the Diagnosis of TMD: Maxillary Symptoms

There are far more patients with symptoms in the area of the origin of the masseter (the zygomatic process) than the insertion (the external inferior border of the mandible). The typical reason for referral to the endodontist is the presumption of periapical pathosis at the apices of the maxillary first molar. Once again, the chief complaints are soreness “over the apices,” tenderness to palpation, and often “swelling.” On clinical examination, in addition to the lack of evidence of pulpal disease and its extension to the supporting bone, there is no palpation tenderness over the apices on the lateral surface of the maxilla (Fig. 6-7, A). Palpation should be continued laterally under the zygoma, with the area of tenderness typically found laterally on the anterior aspect of the zygoma (see Fig. 6-7, B [arrow]). This can

![Figure 6-7](image-url)

**FIGURE 6-7** A, No palpation tenderness over the apices of the teeth. B, Anatomically, there is an approximate distance of 1 cm between the facial surface of bone over the apices and the prominence of the zygomatic arch. C, Palpation tenderness is frequently found over the anterior zygomatic arch. D, The location of the palpation tenderness intraorally is the attachment of the masseter muscle to the anterior aspect of the zygomatic arch.
be felt both intraorally and externally (see Fig. 6-7, C and D).

**Dental Signs of Temporomandibular Disorder**

The teeth are valuable resources for diagnostic signs of TMD as well as being the objects of its destructive effects. Some patients, usually the young, may present without visual evidence of bruxism or clenching (Fig. 6-8). The typical older sufferer, however, will usually exhibit signs such as wear facets, coronal fracture lines, multiple fractured cusps, and pitting of gold restorations (Fig. 6-9, A to D).

**FIGURE 6-8** Physical signs of bruxism are often lacking in younger people.

**Dental Symptoms of Temporomandibular Disorder**

In addition to the restorative problems like wear and cuspal fractures, TMD often is the cause of deep coronal fractures which affect the pulp. Coronal fractures can lead to acute pulpitis or pulpal necrosis (Fig. 6-10). They can occasionally extend well beyond the pulp chamber level and cause periodontal bone loss (Fig. 6-11). After an evaluation of the oral soft tissues, a clinical examination should always evaluate all aspects of the teeth and not just focus on the presence or absence of caries. The history, pulp tests, and radiographs will confirm or rule out endodontic pathosis. More than likely, a patient with pulpal disease from a coronal fracture of TMD origin will have symptoms of both problems.

The usual dental symptom of TMD is sensitivity to occlusal pressure, which may present as sensitivity only from vertical pressure or only from lateral pressure or both. A single tooth may be affected or several teeth in the posterior sextant. Discomfort from vertical pressure typically only occurs from a heavy or premature contact in centric occlusion. Lateral sensitivity typically occurs from heavy or premature contact in lateral excursion, particularly on balancing-side inclined planes. These nuances can be easily tested. Devices like the Tooth Slooth (Professional Results Inc., Laguna Niguel, CA, USA) are available for testing occlusal sensitivity (Fig. 6-12, A). These tests can also be done with a cotton applicator (see Fig. 6-12, B) and temporary stopping (see Fig. 6-12, C).

Endodontic complications associated with coronal fractures. Transillumination for confirmation of deep fractures.

A, Periodontal abscess associated with a deep coronal fracture. B, Coronal fracture extending past the periodontal attachment, causing infrabony defects similar to lesions of advanced periodontitis. C, Transillumination of the fracture line in the tooth depicted in A and B.

Occlusal pressure testing with the Tooth Slooth. Testing with the wood handle of a cotton applicator. Testing with dental stopping.

Stopping has some advantages in that both vertical and lateral occlusal forces can be analyzed independently.

It usually helps the process of testing to start on the unaffected side as a demonstration. The patient is instructed to bite through the stopping like biting through a nut (Fig. 6-13). First, the fact that the material is somewhat soft gives qualitative information relative to the degree of pain. If, for example, the patient cannot bite on the material at all, the pain problem is severe, possibly an indication of pulpal pathosis. If there is visual evidence of coronal fracture, pain on biting through the stopping may separate the fracture slightly. This will cause acute pain of pulpal origin if the pulp is vital. It will also cause acute pain in the periodontal ligament. The patient will seldom be able to bite with much
pressure on the material. Conversely, most people who have pain on occlusion from TMD will be able to slowly bite through the material. A symptom-free tooth will have no pain biting forcibly through the stopping.

Second, the direction of bite force can be tested. If the patient can bite through the material but cannot tolerate moving in lateral excursion while maintaining the bite on the material, the tooth will probably need adjustment of the balancing-side cusps (Fig. 6-14).

Once the painful teeth are identified and the direction of pain has been determined, articulating paper can be used to identify the contact that needs adjustment (Fig. 6-15). A selection of stones and finishing burs will be needed to relieve the occlusal contacts (Fig. 6-16).
A selection of stones, diamonds, and finishing burs are for occlusal adjustment. It is also appropriate to polish areas which have been ground.

Treatment of Heavy Occlusal Contacts and Prematurities

The general approach to the treatment of occlusion-induced pain is reduction of the occlusal contacts. It is best to begin only in centric occlusion. After marking the occlusion with the articulating paper, have the patient tap only vertically. Once the contacts have been identified, a finishing bur or a diamond bur (for porcelain) should be used to reduce the heaviest centric contacts. In addition, large surface-area contacts should be reduced to small areas. It is not the objective to eliminate all contact completely. After the initial reduction, another check is done with the paper. If necessary, the procedure is repeated until the contacts are relatively uniform on all teeth (Fig. 6-17). Next, the procedure is repeated by having the patient clench and grind in lateral excursion. Balancing-side contacts should be eliminated, and heavy contacts on the functioning cusps should be reduced (Fig. 6-18).

The strategy of occlusal adjustment will generally alleviate the symptoms of occlusal pressure pain, but some patients will need additional support for relief. The night guard or occlusal appliance is relatively easy and inexpensive to fabricate (Fig. 6-19).

FIGURE 6-16 A selection of stones, diamonds, and finishing burs are for occlusal adjustment. It is also appropriate to polish areas which have been ground.

FIGURE 6-17 A, Pretreatment photo showing heavy wear facets on mandibular left first and second molars. B, Occlusal contacts marked in centric occlusion first. Instruct the patient not to grind at this point. C, Centric contacts reduced; large areas of contact reduced to small areas of contact. Note heavy contact on distal marginal ridge of second premolar. This should be reduced from a “doughnut” or circular mark to a contact similar to what has been produced on the molars.
Additional and Effective Pain-Relieving Strategies

- Educate the patient about the relationship between stress and TMD. Knowledge can help reduce the symptoms and the stress caused by them. The patient may be able to reduce stress or at least see an end to their present circumstances.
- Hot, moist compresses over the masseter may increase circulation and relieve the ache, in conjunction with the short-term use of prescription-strength NSAIDs (800 mg ibuprofen every 6 hours). Many patients will experience rapid relief.
- Also for short periods of time, a prescription for muscle relaxants may provide relief, especially at night.

Maxillary Sinusitis

When patients present with symptoms primarily in the maxilla, maxillary sinusitis must be included in the initial differential diagnosis. While an odontogenic etiology accounts for 10% to 12% of the maxillary cases of diagnosed
Other Etiologies of Pain in the Oral Cavity and Head

The remaining list of pain-inducing pathologic entities are known to cause facial pain. Generally these entities will not present with oral or specifically pulpal-type pain, especially as the primary or initial symptom. In fact, dental symptoms are rare for most of these lesions. In any case, routine testing of the dentition should rule out a dental etiology if there is any question.

- **Cluster headache**—severe unilateral pain is located around the eye (photophobia), comes in groups, and is debilitating.

- **Cardiogenic**—affects the left mandible and is an extension of the area commonly affected by angina pectoris. It is caused by ischemia of the coronary arteries.

- **Sialolithiasis**—blockage of a salivary duct. Most often the primary symptom is swelling of the gland, especially at mealtime. Commonly found in Stensen’s duct adjacent to the maxillary posterior teeth.

- **Neoplasia**—pain will depend on location and tissues involved, but other signs and symptoms will make confusion with endodontic pathosis extremely unlikely but not impossible.

- **Otitis media**—pain and signs of pathosis will be localized in the affected ear. Will not be a diagnostic challenge for the physician.

- **Post herpetic**—a significant facial pain problem that follows about 20% of cases of infection with herpes zoster (shingles). Patients with this problem will have already suffered through the disease.

Pulpal pathosis is the most common cause of oral and facial pain. There are several nonpulpal pathologic entities that can also cause symptoms of oral and facial pain; TMD is the most common. In fact, in the experience of the authors, it is the most common nonendodontic reason for referral to a specialist for evaluation. The diagnostic procedures and treatment strategies have been presented.

Should a patient present with a painful problem that does not fall into one of these diagnostic categories, a presumptive diagnosis can be made, but the task of final diagnosis should be left to specialists in the fields of oral maxillofacial surgery or medicine. The appropriate task of the dentist is to rule out a possible dental etiology, if possible make a tentative diagnosis, and refer the patient for evaluation.

REFERENCES


RECOMMENDED ADDITIONAL READING
The task of keeping alive the exposed healthy pulp demands an undamaged pulp, capable of reacting to treatment. Damage to the enamel, be it of a chemical, mechanical, or bacterial nature and to a greater degree similar damage to the dentine of the tooth, may affect the pulp and the adjoining odontoblasts. Apart from caries prophylaxis and the early treatment of carious defects in the human dentition, dental treatment if carried out with the necessary understanding of the basic physiology of the dental tissue, can often keep alive the vital pulp of the tooth, which as an organ for nourishing and registering stimulation has to fulfill an important function.38

W. Hess, 1950

Problem-Solving List
Problem-solving challenges and concerns with dentin hypersensitivity and vital pulp therapy addressed in this chapter are:

Dentin Hypersensitivity: Patient Considerations, Etiologies, and Treatment Issues from an Endodontic Viewpoint

Directives for Considering Vital Pulp Therapy
- Are vital treatment procedures viable options in contemporary dentistry?
- When is treatment of the vital pulp preferable to root canal treatment?
- When is root canal treatment preferable to vital pulp treatment procedures?

Materials for Vital Pulp Therapy

Treatment Modalities to Maintain Pulpal Vitality
- Stepwise excavation and indirect pulp capping
- Indirect pulp cap
- Direct pulp cap
- Pulpotomy procedures

Dentin Hypersensitivity: Patient Considerations, Etiologies, and Treatment Issues from an Endodontic Viewpoint

One of the more challenging problems to deal with in dentistry is to maintain teeth in symptom-free function over the life of the patient. Over time through normal wear, function, and maintenance, some teeth create a “sensitivity” problem for the patient to a point where the patient is alerted to teeth that give them a shooting sensation, a tingling sensation, sometimes a painful sensation, or at times just a different feeling during normal daily activities. The teeth may or may not be painful, depending on the patient’s perception, pain threshold, and emotional and physical factors.52 Yet they grab the patient’s attention when they ingest certain foods or liquids, chew, brush their teeth, and even just take in a cool breath. For the patient, the quality of life, defined in this case as a pain-free oral cavity, has been altered.

In some cases, the patient can identify the problem tooth and go directly to the sensitive part of it; in other situations, the problem is not focused and rather vague but very real. Daily, these patients are referred for an endodontic evaluation or are sent to have root canal treatment. In most circumstances, root canal treatment is unwarranted, but the patient feels that their dentist does not know what to do about the sensitivity that is present and has been for a period
of time. A root canal procedure will certainly solve the problem. This is the quick fix and unfortunately occurs in many private-practice settings. However, the real question is whether this degree of treatment is truly indicated and in the best interest of the patient. In the bigger picture, the patient needs a diagnosis and treatment plan to maintain the vitality of the dental pulp in a particular tooth or teeth and if possible to restore symptom-free function. This approach to the problem is neglected or simply cast aside when even more extensive insults to the tooth in the form of a crown or root canal treatment and crown are offered. This is the antithesis to problem solving and turns dental treatment planning and treatment into nothing more than a technical trade that provides an identified service for a fee. Such “care” is driven by business models that dictate the need to treat with high-end services to be profitable, as opposed to managing patients’ problems in a preventive manner that maintains both tooth integrity and symptom-free function whenever possible. In dental practices that are run as managed profit centers, an investigative, compassionate, and caring approach may not be a priority that ensures the bottom line of fiscal solvency.

Tooth hypersensitivity, or more frequently identified as dentin hypersensitivity, is defined as a short pain arising from exposed dentin in response to stimuli. Typically, thermal, evaporative, tactile, osmotic, or chemical stimuli produce responses which cannot be ascribed to any other form of dental defect or disease (except for incipient, undiagnosed, or unidentified caries). Mostly, the sensations dissipate quickly and completely when the stimulus is removed. While many theories have been proposed for this problem (see Recommended Additional Readings at the end of this chapter), the most likely is a change in fluid flow with the dentinal tubules that excites neural endings at the pulp-dentin interface (classic hydrodynamic theory). The size and patency of the dentinal tubules also have a direct bearing on the degree of sensitivity. Essential to patient management in these situations is (1) an understanding of what causes dentin hypersensitivity, (2) a thorough clinical assessment and identification of the etiologic factors, and (3) a diagnosis and reasonable treatment plan. Common etiologies for this malady have been identified as:

1. A small crack in the tooth that exposes dentinal tubules.
2. An area of dentinal tubule exposure along the cervical line at or slightly below the crest of free gingival. This may be due to wear; to gingival recession with exposed tubules at an incompletely sealed, abnormal cemental-enamel interface* or as a result of cemental agenesis; or due to tissue shrinkage subsequent to periodontal surgery.
3. A leaking margin around a restoration or a cracked restoration exposing dentinal tubules.
4. An occlusal area in which the inner slopes of the enamel have not fused in the region of the central groove of posterior teeth, with exposed dentin beneath the groove; or the presence of giant dentinal tubules on a cusp tip for which there was no enamel covering or enamel has worn away.
5. A small area of initial or recurrent caries that cannot be readily identified.
6. Identifiable abfractions, attritions, abrasions, and erosions.

The two most common etiologies have been identified as gingival recession and attrition, but this should not bias the clinician. Exhaustive evaluation of the patient’s problem is warranted because different patient populations may present with a much wider range of etiologic factors. For example, recession or tooth wear that may be identified as etiologies may in themselves be caused by acid diets and irregular or excessive tooth-brushing habits. Moreover, the overwhelming consumer craze for teeth whitening has contributed greatly to dentin hypersensitivity.

With the first etiology, a simple evaluation using a fiber-optics (transillumination), biting tests, and magnification can determine the extent of the problem and a possible solution (see Chapters 1, 3, and 4). In the second situation, simple desensitization procedures are indicated. With etiologic factors 3 through 6, simple restorative procedures and possible changes in oral home-care practices would be advised. In the last scenario, vital bleaching, desensitization would seem to be the treatment of choice. Without supporting data and a diagnosis to indicate that root canal treatment is warranted, the patient should not be subjected to needless procedures. A final procedure that may in time serve to provide rapid and lasting desensitization for the patient is the use of lasers. There has been limited success thus far, but their use to block the permeability of dentinal tubules on a predictable basis seems both reasonable and attainable (see Recommended Additional Reading).

Desensitization techniques and minimally invasive procedures to eliminate the patient’s hypersensitivity would seem to be the treatments of choice to manage the patient’s chief complaint in these situations. This approach goes hand in hand with the initial phases of vital pulp therapy. Many clinicians may not identify this approach to management as being within the scope of endodontics, because too often endodontics and the everyday use of the term are erroneously equated only with root canal treatment. Treatment modalities for vital pulp therapy do fall within the scope of endodontics and should be considered first before doing a root canal procedure.

### Directives for Considering Vital Pulp Therapy

It is a reasonable goal of endodontic research to seek diagnostic and treatment methods that more predictably determine
the status of the dental pulp and preserve the vitality of the pulp under all conditions, especially when the vital pulp has exposed. Preserving pulpal vitality would have several advantages. The current techniques of vital pulp capping or pulpotomy are much less complicated and time consuming than root canal procedures. From a public health perspective, reduction of the number of teeth requiring root canal treatment would lessen the economic burden of dental care and increase tooth retention. In the lower-income sectors of the economy on a global basis, the choice of a root canal procedure is currently not a viable option.

Are Vital Treatment Procedures Viable Options in Contemporary Dentistry?

Yes, pulp capping can play a major role in pulp and tooth retention. Recent studies have provided a great insight into the pulpal responses to irritants (see Recommended Readings). Early, careful intervention to eliminate the etiologies for pulpal disease and prevent further damage to the pulp generally yields a positive outcome. Research confirms the inherent capability of the dental pulp to heal, but at this point—with the currently available imprecise methods of pulpal assessment, variations in operative techniques, and variety of pulp treatment materials—there are limitations to an ideal response.

When challenged by irritants, the pulp has an amazing capacity to form a hard, reparative tissue, sometimes in the form of its original tissue, tubular dentin (Fig. 7-1), and sometimes in the form of a gnarled, irregular or irritational dentin (Fig. 7-2, A). The nature and intensity of the insult and the host’s response will usually determine the nature of the reparative tissue. The pulp tries to stand its ground, so to speak, by forming a calciotraumatic line to block the ingress of both bacterial toxins and bacteria themselves (see Fig. 7-2, B).

Ideally, the clinician should strive to prevent a pulpal exposure, especially under optimal conditions when there are no signs or symptoms of pulpal pathosis. A step-wise approach to caries excavation known as an indirect pulp cap is one possible treatment option that may prevent an exposure and allow for remineralization of the affected dentin or stimulate the formation of dentinal sclerosis and irritational dentin. Unfortunately, there is no correlation between symptoms and the degree to which the pulp may be affected by the invasion of caries. The extent to which bacteria may have invaded the pulp cannot be determined preoperatively. Nevertheless, the pulp possesses some capability to respond favorably even in the presence of bacteria (Fig. 7-3).

When signs or symptoms are not of consideration and an exposure occurs, the visual appearance of the exposure (Fig. 7-4, A) and the amount of hemorrhage (see Fig. 7-4, B) must be assessed. Small exposures would have a better prognosis than large or multiple exposures. A small amount of hemorrhage is normal and will usually slow with sterile water, saline, or sodium hypochlorite lavage. The use of chlorhexidine has also been shown to be effective in these situations. Care must be taken to not probe into the exposure or otherwise mechanically irritate the pulp. The preparation should be kept moist because desiccation is a strong irritant to the vital pulp. If the hemorrhage is profuse, the prognosis for maintaining pulpal vitality by pulp capping is poor. The use of strong hemostatic agents such as ferric sulfate or racemic epinephrine should not be used; the infusion of strong chemicals into the blood clot that forms may be deleterious to the pulp.

When Is Treatment of the Vital Pulp Preferable to Root Canal Treatment?

Possibly the most important indication for vital treatment procedures is in the case of pulpal exposures on teeth with incomplete root formation. In these cases, preservation of pulpal vitality is an essential objective for all exposures—whether traumatic, mechanical, or carious—to permit normal apexogenesis. Removal of the pulp immediately eliminates the possibility of further root development, leaving the root canal with an open apex and the root itself with thin dentinal walls that cannot undergo thickening, owing to loss of the radicular pulp. Root canal procedures in teeth with open, immature apices are more complicated, more time consuming, and less predictable in terms of outcome. Teeth with large-diameter...
canals and thin-walled roots are more prone to fractures of all types.\textsuperscript{5,27,28,72}

Fortunately, the pulps of teeth with immature root formation have a more generous blood supply than teeth with fully formed roots and apical closure. As a consequence, they are more tolerant of injury and exposure to microorganisms. Vital treatment procedures are far more likely to succeed in teeth with open, immature apical development than in teeth with mature root formation. With these factors in mind, vital techniques should be considered even when symptoms of pulpitis are present.

There is growing evidence that vital pulp treatment is effective for carious exposures on permanent teeth. Clinicians must remember that a carious exposure does not necessarily imply that bacteria actually reached the dental pulp. Often the demineralized front of dentin that contains bacterial byproducts has reached the pulp, but not the bacteria themselves. Studies have found that with techniques to be described, both direct pulp caps and coronal pulpotomies can preserve pulpal vitality with a very high degree of predictability.\textsuperscript{11,17,32,33} Although the majority of patients in these studies were in the 10- to 13-year age range, one study included cases with patients as old as 45.\textsuperscript{17} These findings open up new and exciting avenues of research. With currently available materials and the potential of more new developments, vital therapy in many cases of carious exposure may be a viable and predictable treatment option in the future.\textsuperscript{24}

\section*{When Is Root Canal Treatment Preferable to Vital Pulp Treatment Procedures?}

Preoperative pulp sensibility testing would be appropriate for teeth with large carious lesions, but some teeth may respond positively to tests and still have localized intrapulpal inflammation and tissue degeneration. Factors that have been cited as
**Problem:** A 9-year-old male was brought to the dentist with a fractured maxillary right central incisor. The tooth had symptoms of irreversible pulpitis. There were prolonged pain reactions to cold, and the patient had experienced episodes of moderate spontaneous pain relieved by over-the-counter analgesics. The parent related that the tooth was fractured in a playground accident at school a month earlier. There had been little pain initially, and because of the Christmas holidays, no treatment was sought. Clinical examination indicated a complete midcoronal horizontal fracture with exposure of the coronal pulp. The periapical film indicated that the tooth had an open, immature apex and the apical periodontal ligament space was widened 2 to 3 mm more coronally than what would be typical of a normal physiologic apical formation (Fig. 7-5, *A*).

**Solution:** Although the symptoms and radiographic appearance of the periapical tissues suggested an irreversible pulpitis, the potential problems associated with root canal treatment of the open apex highlighted the need to consider a form of vital therapy. A direct pulp cap (partial pulpotomy, also known as the Cvek technique), was performed with calcium hydroxide, in which a sterile high-speed diamond bur is used under copious water irrigation to surgically excise the inflamed pulp tissue. The excision is considered complete when the pulp stump no longer bleeds profusely. The intent is to remove the contaminated, degenerating tissue and create a new surgical wound that will respond favorably to the placement of calcium hydroxide. The pulp cap was covered and sealed with an amalgam restoration (see Fig. 7-5, *B*). Postoperatively, the symptoms gradually resolved. Sensibility testing in the subsequent months indicated a return to normal pulpal responses. One year later, a reevaluation radiograph indicated normal physiologic completion of apical formation (see Fig. 7-5, *C*). Root canal treatment was then completed in preparation for a post-retained restoration.

**Discussion:** This case was treated more than 30 years ago with materials available at the time, which were limited. Fortunately, the choice of materials has improved, and the prognosis for pulpal healing has improved as well. Nevertheless, the preoperative conditions were no different than many cases today, so this case illustrates the reparative potential of pulp tissue in teeth that exhibit immature root development. Had this treatment approach failed, apexification (techniques for nonvital pulps) would have been indicated (see Chapter 13), which 30 years ago would have consisted of multiple applications of calcium hydroxide over an 18- to 24-month period of time.

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**FIGURE 7-5** A, Traumatic fracture of a maxillary right central incisor in a 9-year-old boy. The tooth was examined approximately 1 month after the accident and was symptomatic of irreversible pulpitis. B, Postoperative radiograph of Cvek pulpotomy with calcium hydroxide. C, One-year reevaluation radiograph. The tooth responded normally to pulp testing, and the apex was closed.
In teeth with mature root formation, caries extending directly into the pulp, resulting in multiple exposures or complete unroofing of the pulp chamber, would be indicated for pulpectomy and root canal treatment (Fig. 7-7, A and B).

**Materials for Vital Pulp Therapy**

Historically, the standard material indicated for both indirect and direct pulp capping has been calcium hydroxide. In the treatment regimen of indirect pulp capping, calcium hydroxide has been shown to cause remineralization of affected (but not infected) dentin while maintaining pulpal vitality. Application of this material to direct pulp exposures usually results in a relatively symptom-free postoperative course, with gradual dentinal bridging of variable type and quality over the exposure site. Unfortunately, calcium hydroxide use is associated with a potential risk of continued calcification of the entire root canal system. Histologically, this is a very irregular process, leaving portions of the canal spaces that may not be visible radiographically. Despite a lack of symptoms or radiographic evidence of apical pathosis, it is unwise to conclude that the canal space is completely calcified to the apex and that root canal treatment will never be required (Fig. 7-8, A). The pulp tissue in these spaces often degenerates and becomes necrotic at highly variable lengths of time postoperatively. Signs and symptoms of apical inflammation or apical lesions may develop from a few years to decades after the pulp capping procedure.

Some teeth that appear to have calcified canals may in fact have canal spaces that can be penetrated and successfully treated (see Fig. 7-8, B). The techniques for treating these difficult cases are discussed in Chapter 13. Unfortunately, calcium hydroxide used in either a direct pulp cap (Fig. 7-9, A) or pulpotomy (see Fig. 7-9, B) may stimulate significant calcification to a point where the tooth may be untreatable with nonsurgical techniques.

Mineral trioxide aggregate (MTA) was introduced in the mid-1990s. Marketed under the name Pro-Root MTA (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), it is essentially a derivative of Portland cement (Fig. 7-10). The original formulation was gray and discolored anterior teeth, so a white formulation was subsequently introduced. This material has withstood the rigor of extensive histologic investigation as a pulp capping and pulpotomy material. One study using human third molars compared dentinal bridging of pulp exposures using MTA and calcium hydroxide. The teeth were extracted after 2 months and examined histologically and histochemically. Dentinal bridging was observed in 100% of MTA cases but only 60% of calcium hydroxide cases. Furthermore, less dystrophic calcification has generally been observed with MTA than with calcium hydroxide. MTA has been shown to have a much better success rate than traditional formocresol for pulpotomies in primary teeth.

**FIGURE 7-6** Exposure of a pulp with an intrapulpal abscess and purulent exudate.

**FIGURE 7-7** A, Clinical photograph of a severely carious mandibular right first molar. B, Radiograph of same tooth. This molar is indicated for root canal treatment.

indications for pulpectomy are uncontrollable hemorrhage from the exposure site, purulent exudates emanating from the exposure site, and complete lack of bleeding. Purulent exudate (Fig. 7-6) would indicate an intrapulpal abscess for which no evidence exists that suggests a positive outcome for either pulp capping or pulpotomy. Similarly, if the exposure site is pale yellow and without hemorrhage or exudates of any type, the pulp may already be partially necrotic.
**FIGURE 7-8** A, Mandibular right second premolar with apparent calcification of the root canal when viewed radiographically. It would appear no pathosis could develop in this tooth. B, The completed root canal treatment following the onset of acute apical periodontitis. The canal was very small but patent to the apex.

**FIGURE 7-9** A, Severe dystrophic calcification of a mandibular left first molar after a calcium hydroxide pulp cap. B, Severe dystrophic calcification of a mandibular left first molar after a calcium hydroxide pulpotomy.

**FIGURE 7-10** Mineral trioxide aggregate (MTA) marketed as ProRoot in the original gray formulation. (Courtesy Dentsply.)

and is now recommended as the material of choice for pulpotomies in primary teeth.\(^{34,68}\)

The use of MTA in pulpotomies on permanent teeth has also been studied clinically.\(^{11,30,78,79}\) The findings compare favorably with the results of MTA pulpotomies in primary teeth and are more favorable when calcium hydroxide is used.\(^{30}\) MTA has also been studied clinically as a direct pulp capping agent,\(^{17,79}\) and excellent clinical responses\(^{17}\) have been noted, with the majority of teeth responding normally to sensibility testing.

The clinical preference for either gray or white MTA has been controversial, but data that support significant differences in the outcomes are limited.\(^{17}\) Only white MTA is presently available in the United States. Other countries have begun to produce various versions of the gray material. However, the physical make-up of the powder may not be micronized or have its impurities removed, in addition to being a little more challenging to mix and place. There has
been a major global research and development impetus for a more user-friendly MTA with better mixing, manipulating, placing, compacting, and setting-speed properties.

The MTA powder is mixed with water into a thick paste (Fig. 7-11, A and B). Setting time is lengthy, so the material can be carried to the prepared tooth with any spoonlike instrument. For pulp capping procedures (e.g., open excavation), a rather wet mix will flow easily over the exposed pulp. Bleeding should be controlled by rinsing with sterile water, saline, or sodium hypochlorite. If the mix contains too much water, the excess may be removed by blotting with a cotton roll on the mixing pad (see Fig. 7-11, C) or with dry cotton pellets in the tooth. A drier mix is preferred for placement into smaller preparations (described later in the partial pulpotomy technique, Cvek pulpotomy). Special tools are available for carrying and placement of this material (see Chapter 16).

Treatment Modalities to Maintain Pulpal Vitality

Stepwise Excavation and Indirect Pulp Capping

Substantial research evidence supports indirect pulp capping as a viable and successful approach to deep carious lesions. Criteria for case selection include minimal preoperative symptoms, a carious lesion radiographically deep enough to involve the pulp, no apical pathosis, and a positive response to pulp testing. The technique requires thorough excavation of caries peripheral to the pulp. Only the softest caries is removed from the central area over the pulp chamber. Pulp exposure is avoided if possible. Calcium hydroxide is then applied to the carious dentin, and a temporary restoration is placed. The choice of temporary restorative material is based on the desired length of recall, usually 6 to 12 months. However, what is most important in this regard is that the restoration seal the cavity margins to prevent any bacterial leakage.

On the subsequent reevaluation, if the patient is symptom free and the tooth appears normal radiographically, the carious lesion is reentered, the caries is removed to the dentinal bridge, and a permanent restoration is placed. The more recent evidence of the success rate of MTA pulp cappings and pulpotomies raises the question of whether or not there is any advantage to a two-step treatment regimen in indirect pulp capping. In fact, there may be two important disadvantages. The first is the requirement of patient compliance. In many practices, the assurance of a return visit in 6 to 12 months for additional excavation and restoration is of concern. Secondly, the two-step treatment is more expensive, requiring twice as much operator and office time. Thirdly, as already noted, a bacteria-tight seal is essential between visits. Current evidence regarding vital treatment with MTA in both primary and permanent teeth leads to the conclusion that indirect pulp treatment may not be worth the additional time or expense.
Direct Pulp Cap

Techniques for vital pulp capping are useful in two types of pulp exposures: carious and some mechanical (iatrogenic) exposures. The conditions of the pulp and the physical presentation of the exposure sites requires a separate consideration of the treatment of each type.

Carious Exposure

Case selection is important to successful outcome. The importance of maintaining pulp vitality in open apex cases cannot be overemphasized (Fig. 7-12, A and B). All studies consider preoperative symptoms important in the selection of teeth for vital treatment. Preferably, teeth should be free of symptoms, but teeth with symptoms of reversible pulpsitis such as increased thermal sensitivity and episodic mild spontaneous pain may be considered. Preoperatively, the routine sensibility testing of teeth is indicated; some carious exposures may have already caused partial to complete pulpal necrosis. Teeth with symptoms of irreversible pulpsitis or developing apical pathosis are not suitable for vital treatment (see Chapter 1).

Unlike indirect pulp capping procedures, the caries are excavated thoroughly and a final restoration is placed to create a “bacteria-proof” seal.14,42,71 Most clinicians favor a large, low-speed round bur for caries removal, but some suggest completing the excavation in the area of potential exposure with a coarse, high-speed diamond bur.9,71 Bleeding will often occur with small exposures. The operative field can be rinsed with water until bleeding ceases (see Fig. 7-12, C). If there is significant bleeding, 3% sodium hypochlorite or 2% chlorhexidine can be placed in the cavity preparation and left for up to 10 minutes for hemostasis. The operative field should be left moist at all times. MTA is then placed over the floor of the cavity preparation (see Fig. 7-12, D). Some clinicians favor a flowable compomer to cover the MTA, others use a layer of glass ionomer cement because it is hydrophilic and compatible with the moisture in the MTA and the cavity preparation. After setting, the entire cavity preparation and the glass ionomer cement base can be etched for the placement of a permanent, bonded composite restoration (see Fig. 7-12, E and F).

Even in some cases of a large carious exposure with minimal symptoms, a pulp cap may be successful in an adult patient. The patient in Fig. 7-15, A was a 30-year-old man with no complaints other than having a “hole” in his tooth. The tooth was restored in the manner described earlier using an MTA direct pulp cap, a glass ionomer base, and an amalgam restoration. A 4-year reexamination radiograph showed no adverse findings, and the tooth responded normally to sensibility testing (see Fig. 7-15, B).

CLINICAL PROBLEM

Problem: A 23-year-old female presented with a chief complaint of her tongue being sore because it was being caught in a hole in her last tooth in the upper left jaw. Upon examination, a large carious lesion was present, and it appeared that she had lost a restoration (Fig. 7-14, A). The patient claimed she had not had any tooth pain, but sensibility testing with cold indicated a pulpal condition of reversible pulpsitis (sensitivity without prolonged pain). The patient had limited financial resources but wished to retain the tooth if possible.

Solution: The caries was excavated carefully using both a bur and sharp spoon excavator. When the last vestiges of demineralized dentin were removed, the pulp began to bleed, but the hemorrhage was controlled within a few minutes with chlorhexidine. The pulp was capped with MTA, and the tooth was restored with a composite resin (see Fig. 7-14, B). The patient was lost to follow-up until she returned 3 years later, inexplicably with a fractured amalgam restoration in the same tooth (see Fig. 7-14, C). At that time, sensibility tests gave normal responses. Note the dentinal bridging in the pulpal chamber adjacent to the MTA (arrows).

Problem: A 41-year-old male patient presented with a large carious lesion in the mandibular left second molar. He had experienced occasional episodes of spontaneous pain in the past month that were relieved using mild analgesics. The periapical radiograph indicated the presence of deep coronal caries but no obvious pulp or periapical pathosis (Fig. 7-16, A). Following thorough excavation of caries in the mesial pulp horn area, there was a large carious exposure with a hemorrhagic pulp (see Fig. 7-16, B).

Solution: Treatment and retention of the vital pulp in this tooth was judged to have a poor chance of success, and root canal treatment was completed (see Fig. 7-16, C).
FIGURE 7-12  
A, Mandibular right first molar with a potential carious exposure in an 8-year-old female patient. The tooth was asymptomatic. B, Clinical photograph of same tooth. C, After excavation, a pinpoint exposure of the mesial lingual pulp horn is apparent. D, Placement of mineral trioxide aggregate (MTA). E, Completed composite restoration. F, Postoperative radiograph of the restored tooth. Note the distinct layers of MTA, glass ionomer base, and final composite resin restoration. (Courtesy Dr. Sid Williams.)

FIGURE 7-13  
A, Carious exposure in mandibular right first molar of a 13-year-old female patient. B, Reevaluation radiograph after 3 months. Patient was asymptomatic and tooth responded normally to testing.
FIGURE 7-14  A, Carious exposure in maxillary left second molar of a 23-year-old female patient.  B, Posttreatment radiograph indicating a direct pulp cap with mineral trioxide aggregate (MTA) and final restoration with composite resin.  C, Three-year reevaluation radiograph. Patient sought treatment of a fractured amalgam on the same tooth. No history why the composite restoration had been replaced. The patient was asymptomatic, and the tooth responded normally to testing. Note dentinal bridging (arrows).

FIGURE 7-15  A, Carious exposure in tooth of a 30-year-old male patient. The tooth had preoperative symptoms of reversible pulpitis.  B, Four-year reevaluation radiograph. The patient was asymptomatic, and the tooth responded normally to testing.

Since the probability of pulpal repair is less predictable in mature teeth, large exposures or excessive hemorrhage would be indications to proceed with pulpectomy and complete root canal treatment.

Mechanical (iatrogenic) Exposure
Mechanical, or iatrogenic, exposures are those that occur accidentally in a noncarious area of a tooth (Fig. 7-17). Mechanical exposures that would be appropriate for pulp capping by the techniques described in the previous section would be those that occur in the course of cavity preparation. For example, a pulp horn may be inadvertently exposed in a young tooth because of its relatively high extension toward the occlusal surface. Mechanical exposures that occur on the external surface of the prepared tooth, as in a crown preparation, are discussed in the following section on pulpotomy procedures.
Recent attempts to promote the use of direct bonded composite to mechanical pulpal exposures have met with mixed results. The focus of this approach was to seal the environment from bacterial ingress and thereby minimize or eliminate the demise of the pulp from bacterial influences. If optimal conditions for the preservation of pulpal health are to be ensured, dental restorations should provide an impervious seal against the surrounding tooth structure. However, polymerization shrinkage and contraction stresses induced during setting, as well as a variety of technical difficulties encountered during the clinical operation, often produce less than perfect results. Therefore, modern restorative procedures involving resin and resin-bonded restoratives must still rely on the ability of the pulp to cope with the injurious elements to which it may be exposed during and after the procedure. In this respect, direct placement on the dental pulp and residual dentin thickness appear to be key determinants of pulp responses after restorative dental treatment. In deep and pulpally exposed cavities in posterior teeth, composites have been associated with greater pulpal demise, requiring root canal treatment. Whereas some studies have claimed that pulp capping with bonded resin composites provides the lowest incidence of bacterial leakage, pulpal inflammation, and pulpal necrosis, the prognosis for mechanical exposures in all cases would seem to be quite good if the exposure is treated carefully in an aseptic environment. Even in the hands of a neophyte, success rates for capping mechanical exposures with calcium hydroxide can exceed 90%.

FIGURE 7-16 A, Mandibular left second molar with a gross carious exposure in a 41-year-old male patient. The tooth had been mildly symptomatic. B, Large carious exposure was found with a hemorrhagic pulp after thorough excavation. C, Completed root canal treatment.

FIGURE 7-17 Mechanical exposure of the dental pulp with no evidence of an inflammatory response.
others have found that some bonding systems should be avoided because they were not compatible with the technique and resulted in failure when compared to the use of calcium hydroxide in mechanically exposed pulps. Of major concern with the use of these materials are reports suggesting that hard tissue is often not formed; healing is delayed, resulting in a lingering chronic inflammatory state; the potential exists for deficiency in bonding over time, especially if bridging does not occur; and there are no properly designed clinical trials with adequate long-term follow-ups.

Pulpotomy Procedures

Pulp Exposure from Caries

Pulpotomy is the term for removal of the coronal pulp with the intent of maintaining the vitality of the remaining radicular pulp tissue. Pulpotomy techniques using formocresol on primary teeth have been a standard in pediatric dentistry for decades. The indication was primarily the presence of a carious exposure and desire to retain the primary tooth until exfoliation. However, formocresol has been labeled as a carcinogen, and its use is being abandoned. Other techniques that have been investigated with positive outcomes include the use of ferric sulfate and electrosurgery. Evidence of the effectiveness of MTA pulpotomies in primary teeth is positive and encouraging, in addition to its successful outcomes for permanent teeth. Research must still pursue the conditions in which a pulpotomy is the preferred treatment regimen rather than a direct pulp cap. On an empirical basis, some clinicians currently make the decision based on the amount of pulpal hemorrhage from the exposure.

Pulp Exposure from Traumatic Fracture

Fractures that result in pulpal exposure are mainly limited to the anterior teeth. Although posterior teeth are sometimes traumatically fractured with pulp exposure, root canal treatment is almost always indicated if the tooth can be saved. Traumatic fracture of posterior teeth with open apices is rare, and vital treatment of traumatically exposed pulps is indicated only when the root development of the tooth is immature, exhibiting an open apex and thin root walls. For all teeth with fully developed roots and apical closure, root canal treatment is uncomplicated, predictable, and often necessary for restorative purposes.

There are two significant differences between carious and traumatic exposures. Pulps of traumatically fractured teeth usually have no history of bacterial involvement, and the patients rarely have symptoms prior to the trauma. The prognosis for pulp survival is excellent; even after several days, the superficial layer of the pulp is only slightly inflamed when exposed. However, the longer the exposure time, the smaller the chance for healing, because the quantity of bacteria that...
invasive the pulp and the formation of irreversible inflammatory reactions increase.58

A second difference is that carious exposures generally occur in the depth of a carious excavation. The cavity preparation presents a convenient and effective location for the protection and seal of the pulp with the capping material. On the other hand, traumatic fractures leave the pulp exposed on the surface of the tooth. Pulp capping materials do not adhere to the tooth and present a problem in both retention of the material and prevention of leakage. As with root canal treatment, coronal leakage of bacteria will cause failure of a pulp capping procedure and result in pulpal necrosis.

In addition to time of exposure, other issues that must be considered in the presence of a traumatic fracture are health of the pulp prior to trauma, diameter of the pulp exposure (1.5 mm diameter is the critical but empirical guideline), age of the tooth, no concomitant luxation injury, and the stage of root development.58 To address many of these challenges, a partial pulpotomy (Cvek) procedure27 was developed in which a cavity preparation is cut in the dentin around the exposure site. The depth of the cavity is approximately 2 mm (Fig. 7-19). The original pulp capping material was calcium hydroxide, but MTA would be the current material of choice. The cavity preparation allows for the placement of approximately 1 mm of the pulp capping material with another 1-mm space remaining for a bonded restorative material to seal the cavity (Fig. 7-20), taking care to avoid compaction of the MTA material too forcefully into the prepared canal space. Although the material is well tolerated, the pressure alone may result in pulpal damage (Fig. 7-21). Following this procedure, dentinal bridging is usually observed in the pulp chamber adjacent to the reparative material (Fig. 7-22).

As previously noted, white MTA was formulated to address the problem of discoloration in the anterior teeth. Clinical experience with the white formulation has not always been satisfactory. Although no statistical evidence exists as yet, some cases treated with the white material still develop discoloration due to apparent darkening of the material in the coronal part of the tooth (Fig. 7-23). There are multiple speculations for this occurrence, including the inadvertent presence of residual blood products, interaction with residual bacterial toxins, and interactions with proteinaceous matter from the dentinal tubules. Fortunately, the tooth structure is not stained in the process. The usual remedy is complete removal of the MTA material, since dentinal bridging has usually occurred. The cavity preparation is then restored with a suitable bonded composite resin.

**FIGURE 7-19** A, Small pulp exposure resulting from a traumatic fracture. B, Preparation into the surrounding dentin for partial (Cvek-type) pulpotomy. Cavity preparation will allow for placement of mineral trioxide aggregate (MTA) and a secure protective restoration. C, Favorable repair on an exposed pulp using MTA. Note dentinal bridge. (C, Courtesy Dr. Mercedes Dominguez.)
FIGURE 7-20  A, Two maxillary anterior teeth with vital exposures from traumatic fractures. Note open apices on both teeth. B, Completed Cvek partial pulpotomies with mineral trioxide aggregate (MTA).

FIGURE 7-21  A, Traumatic fracture of a maxillary left central incisor with pulp exposure. B, Cvek pulpotomy with mineral trioxide aggregate (MTA), which was possibly overcompacted into the preparation.
FIGURE 7-22 A, Dentinal bridging observed with partial pulpotomies with MTA after traumatic exposure (DP, dental pulp; MTA, mineral trioxide aggregate). B, Radiograph of two maxillary central incisors showing dentinal bridging (arrows).

FIGURE 7-23 A, Traumatically fractured maxillary right central incisor with exposure of pulp. A partial pulpotomy was completed with white mineral trioxide aggregate (MTA). B, Two-year reevaluation radiograph indicating normal root development and no apical pathosis. Tooth responded normally to all pulp tests. C, Clinical photograph at 2-year reevaluation, indicating midcoronal discoloration. D, Reentry into pulp chamber revealed that white MTA had become discolored but did not stain adjacent tooth structure. Dentinal bridging meant MTA could be safely removed.
REFERENCES


**RECOMMENDED ADDITIONAL READING**


Chapter 8

Problem Solving in Tooth Isolation, Access Openings, and Identification of Orifice Locations

Problem-Solving List

Problem-solving issues and challenges in pulp chamber access addressed in this chapter are:

Critical Factors in Tooth Isolation Within the Standards of Care

Major Problems or Errors in Endodontic Access Openings

Techniques for Safe and Accurate Access Cavity Preparations

Problem-Solving Challenges in Access Openings
- Pulp chamber calcifications
- Use of magnification during access preparation
- Preventing and managing coronal perforations
- Potential problems in access openings through crowned teeth or teeth with excessively large restorations
- Clinical considerations in preventing and managing problems in tooth isolation and access preparation

Problem Solving in Recognizing or Locating Canal Orifices
- Calcification of the dental pulp and pulp canal space
- Maxillary central and lateral incisors and canines
- Maxillary premolars
- Maxillary molars
- Mandibular incisors, canines, and premolars
- Mandibular molars
- Clinical considerations in preventing and managing problems in orifice identification

The first step in the treatment of a tooth . . . is the adjustment of the rubber dam over the diseased tooth to preclude the possibility of the entrance of any germs in the oral secretions into the pulp chamber. This should be the invariable rule.¹⁴

Anonymous, 1900

The first essential in getting at any root-canal is to gain direct access, and not to try to work around corners, whatever tooth-structure may have to be sacrificed.²⁴

R.H. Hofheinz, 1892

The main purpose of a lingual or occlusal endodontic access opening is to develop an unimpeded passageway to the pulpal space and apical foramen of the tooth. This unrestricted opening should be specifically designed for each tooth to facilitate proper canal cleaning, shaping, and obturation. In some cases, a problem-solving approach may dictate the need to initiate the access opening in a surface other than the lingual or occlusal (Figs. 8-1 and 8-2). Although rare, these creative approaches should only be used when standard entries to the canal system are impossible or the loss of tooth structure permits. A properly prepared access opening can eliminate many technical difficulties encountered in root canal treatment.²²,⁴³ In fact, many of the problems discussed in this book regarding locating and negotiating fine and calcified canals, cleaning and shaping, disinfection, obturation,
and revision of treatment may be avoided or eliminated with a proper coronal access opening.

The major consideration in all access openings is that coronal tooth structure should not be retained if its preservation prevents direct pathways to the canal orifices. This admonition does not imply that radical removal of the coronal tooth structure is necessary simply to obtain unimpeded access to the pulpal space; caution is also advised in creating excessively large access cavities for the convenience of operating microscope visualization. Rather, the statement implies that the clinician must be thoroughly knowledgeable about pulpal and external root anatomy and must be capable of proper radiographic assessment of the three-dimensional relationship of the pulpal space within the confines of the tooth. When these factors are all considered, a properly placed and shaped access opening can be made. Failure to approach this initial technical step in root canal treatment in this manner not only invites problems during access opening preparation but also unleashes a plethora of technical problems in all phases of treatment. Subsequently, treatment will be compromised or teeth will be lost unnecessarily.

**CLINICAL PROBLEM**

**Problem:** A 37-year-old female presented with acute pain to biting on her mandibular left first molar. Following diagnostic testing, a diagnosis of irreversible pulpitis with acute apical periodontitis was made. Root canal treatment was initiated on the tooth, and the final radiograph showed poorly filled canals with significant canal space apical to the gutta-percha filling in all canals (Fig. 8-3). The mesial canals were prepared to a size No. 30 K-file and the distal canal to a size No. 35 K-file. The working length was established 1 mm from the radiographic apex, and the final file sizes were used to the full length in the root. The general dentist was concerned about not being able to obturate the canals well, even after the instruments would go to the working length, so the patient was referred to a specialist.

**Solution:** An assessment of the tooth indicates that the roof of the pulp chamber had not been removed (see Fig. 8-3, arrow). Failure to remove this anatomic obstruction forces the clinician to prepare and obturate the canals through the pulp horns. A major constriction of this nature due to an improper access opening significantly influences access to the canals, quality of canal cleaning and shaping, canal disinfection, and obturation. Clearly not all inflamed/infected pulp tissue has been removed, yet the clinician’s problem focused on errors in obturation.

**FIGURE 8-1** A, Rotated mandibular canine. B, Access is made through the facial surface.

**FIGURE 8-2** A, Maxillary molar exhibits extensive buccal cervical erosion and abrasion. B, Initial access is made in a buccal-palatal direction without a dental dam. C, Closer view shows access after the canal orifices are opened.
Critical Factors in Tooth Isolation Within the Standards of Care

Proper tooth isolation is essential to all phases of root canal treatment, particularly patient protection and asepsis. Tooth isolation with a dental dam (formerly known as a rubber dam), using creative approaches to ensure these attainments is often required (Fig. 8-4). Questions or concerns frequently asked include:

“Do I really need to use a dental dam all the time? It is so hard to place.”

“The patient does not want to have the dental dam used in their mouth.”

“I was taught that in dental school, but is it really relevant in dental practice?”

These are important issues because what is being taught in dental education may not be viewed seriously by the dental clinician once in practice. Nevertheless, use of the dental dam is the standard of care in providing root canal treatment.

*References 23, 35, 36, 50, 51, and 57.

FIGURE 8-3  Mandibular molar had been accessed, and clinician could not penetrate canals fully with the filling materials. All the cleaning, shaping, and obturation had been done through the pulp horns, and the roof (arrow) of the pulp chamber had never been removed.

FIGURE 8-4  A, Maxillary premolar with subgingivally fractured palatal cusp. B, An oral sealing agent is placed along the palatal margin. C, A rubber dam is sealed in place. D, Clamping of adjacent teeth facilitates isolation of a tooth prepared for a crown.
Problem Solving in Tooth Isolation, Access Openings, and Identification of Orifice Locations

There are several directives that should be considered for all cases of root canal treatment. Prepare access openings after a well-fitted and disinfected dental dam is placed, isolating the tooth to be treated. This is followed by disinfecting the dental dam with 2.5% sodium hypochlorite or alcohol before access to enhance asepsis (Fig. 8-5). The dental dam will protect the patient’s tissues and seal the mouth from root canal irrigants and disinfectants. This will prevent patient ingestion of irrigants and aspiration of instruments or materials during root canal procedures. The dental dam also facilitates procedures by creating a clear, dry field while enhancing infection control. In some cases, the initial access opening outline can be prepared immediately before placing the dental dam, so long as the tooth is not contaminated further before placing the dam (see Fig. 8-3).

Major Problems or Errors in Endodontic Access Openings

Many problems can occur during access opening preparation that will impact greatly on the subsequent phases of root canal treatment. Major shortcomings tend to occur in the following areas. First, all caries and unsupported weak tooth structure must be removed. This will enable the determination of tooth restorability and identification of any defects such as cracks (Fig. 8-6). Developing straight-line access to the pulp chamber and root canal system and establishing an aseptic environment for treatment procedures are critical.
Problem Solving in Tooth Isolation, Access Openings, and Identification of Orifice Locations

FIGURE 8-6  
A, Apparent small crack on the marginal ridge of a mandibular molar (arrow). B, Same tooth as in A after removal of the restoration. Note the crack line extending almost completely across the pulpal floor. This is an obvious cause of pulpal pathosis but may not be significant in treatment planning if it does not extend apically to the pulpal floor. C, Coronal fracture extending across the pulpal floor. Careful assessment of the periodontal attachment in this area should be done to rule out extension of the fracture below crestal bone. Note the use of Methylene Blue 1% to stain fracture line. D, Large crack on the mesial floor of cavity preparation in a maxillary molar. A large crack at the level of the gingival margin could easily extend apically below the level of crestal bone.

CLINICAL PROBLEM

Problem: A 54-year-old male presented with episodic pain in the mandibular left quadrant. All teeth in this quadrant had extensive restorations. He believed his pain was coming from the first molar, but he was not sure. Pain was evident in response to percussion on the first molar; all other teeth responded normally. Cold elicited prolonged pain on the first molar, with normal responses on the adjacent and contralateral teeth. Periodontal probings and palpation were normal, but an explorer was easily placed under the mesial buccal margin of the crown on the first molar. A radiograph showed an invasive carious lesion on the mesial of the first molar, along with radiolucencies at the apices of both roots (Fig. 8-7, A). The diagnosis was irreversible pulpitis with acute apical periodontitis. The dilemma with this case focused on the access opening. Preparation of an access through the crown creates a situation in which all the previous problems described can occur.

Solution: All potential problems with gaining access to the pulpal space can be prevented with crown removal. In this case, the tooth was isolated, and the crown was cut off using a bur to cut a groove from buccal to lingual (see Fig. 8-7, B and C). Attempting to retain this crown is futile because there is loss of marginal integrity. Complete removal and excavation of the caries provided the opportunity to evaluate the remaining coronal tooth structure (see Fig. 8-7, D and E), which contributed greatly to the treatment plan for this tooth.

steps. Moreover, stable coronal reference points can be established, and loosening of restoration debris that may be pushed into the canal is avoided.48

During the removal of carious tooth structure, the peripheral decay is removed first, and then the carious material is removed inward toward the pulp chamber (Fig. 8-8, A). Penetrating a pulp chamber in which pulp is hyperemic or purulence has accumulated creates the difficulties of working in a confined space in a pool of blood or pus (see Fig. 8-8, B). Attempts to unroof a chamber or enlarge the access at
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**FIGURE 8-7**

A, Radiograph showing apical lesions on both roots and recurrent caries under mesial margin of the crown. B, Cutting of the crown from the tooth. C, Crown has been removed, and decay is evident under the old restoration. D, Removal of the old restoration shows significant decay. E, Final excavation that allows for evaluation of the tooth structure and facilitates direct access to the pulp chamber.

**FIGURE 8-8**

A, Caries around margins and under cusps must be excavated before the endodontic access opening is made. B, Excessive hemorrhage from inflamed pulp tissue can impair visualization of the pulp chamber.
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accentuated manner to enhance straight-line access (Fig. 8-10). This approach also prevents scraping metallic margins with the intracanal instruments and carrying metallic particles into the canal and blocking its pathway. Removal of foreign debris inadvertently carried into the canal is possible with gentle ultrasonic canal instrumentation. In cases in which a temporary restorative material such as zinc oxide eugenol is present, removal of the entire restoration is recommended, except in those areas where avenues of leakage may be opened. However, crown lengthening may be the preferred alternative to leaving deep temporary restorations in place (see Chapter 17). (Indications for restoration removal can be found in Boxes 8-1 and 8-2.)
Oftentimes the crown of the tooth is not in direct alignment with the long axis of the root, so preparation of the access with only the angle of the crown in mind invites a coronal perforation or gouging of the crown. Teeth that normally exhibit significant altered crown-root angulations are maxillary lateral incisors and mandibular first premolars, but any tooth in the mouth may present this anatomic challenge (Fig. 8-11). In molar teeth during access opening in the presence of these altered angulation relationships, misidentification of canals (e.g., mistaking the mesial lingual canal for the mesial buccal canal) may occur. Subsequent searching for the other canals often results in gouging or perforating areas far removed from the true canal orifice(s).

Undermining and weakening coronal or radicular tooth structure is inevitable when anatomic relationships are not readily identified, even if a perforation does not occur. To compound this situation, extra canals are commonly found (Fig. 8-12), and failure to identify and clean these anatomic variants will often lead to treatment failure. The best way to manage such problems is to prevent them. Continuous recognition of deviations thorough periodic radiographic review and the possible use of magnification are essential. See Chapter 3 for additional discussion and examples.

Coupled with a smaller or calcified pulp chamber or canal, failure to take into account altered coronal-radicular relationships will usually lead to irreparable damage to the tooth structure (Fig. 8-13). Additionally, the location of the canal or canals will often be missed. Pulp chamber spaces are generally located in the center of the crown. Many teeth that have had multiple restorative procedures over time exhibit pulpal response to these irritations. The result is usually a reduction in the dimensions of the root canal space

**Figure 8-11** A and B, Two mandibular molars with the occlusal surface at divergent angles to the long axes of the roots. Occlusal surface orientations are indicated by the black lines on both teeth. Root angulations are indicated by the red arrows on both teeth. Penetration perpendicular to the occlusal surface may lead to ultimate chamber/furcation perforation.

**Figure 8-12** A, Both canine and lateral incisors have multiple canals. B, Distal roots of a mandibular molar with two distinct roots/canals.
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that is visible on a good-quality, two-dimensional radiograph.\(^1\) In many cases, especially when large restorations are present, bite-wing radiographs are necessary for proper visualization of the chamber space relative to the alignment of the crown to the root. Often, angled radiographs from the mesial and distal aspects will also be necessary when teeth are rotated or have abnormal root configurations\(^2\) (see Chapter 2).

Access openings in artificial crowns or excessively large restorations also invite possible perforation if the three-dimensional relationship of the pulp chamber in relation to the altered crown anatomy (due to restorations) is not considered.\(^3\)\(^,\)\(^5\) Here again, the use of angled radiographs is most useful for determining relationships prior to preparing an access opening. Additional concerns with access into these teeth are the distribution of metallic or composite debris into the chamber and root canals that may ultimately block the canals or be pushed beyond the end of the root, creating potential long-term sources of irritation and lack of healing of the periapical tissues.\(^3\)\(^,\)\(^6\)\(^2\) High-speed suction and frequent irrigation are essential.

FIGURE 8-13 Access perforation in a mesially tipped mandibular molar with calcified canal orifices. Access was cut through a large composite restoration. Despite its eventual removal, the clinician remained disoriented as to the location of the second mesial orifice. A preoperative bitewing radiograph might have established the true orientation of the long axis of the tooth with the occlusal plane.

FIGURE 8-14 A, Diagram of mandibular molar shows anticipated parameters of the pulp chamber. Access entry must proceed into the center of these parameters (arrow). B, Access entry may be directed to the largest canal (arrow) in cases of tooth misalignment, calcification, or lack of visible pulp chamber. C, With a crown in place and evidence of calcifications in the pulp chamber, a direct-line access opening into the center of this tooth is recommended.

Techniques for Safe and Accurate Access Cavity Preparations

Access opening preparation is a dynamic, three-dimensional process.\(^2\) The old adage in access opening preparation, “Go for the pulp horns,” is reasonable in most cases. The pulp horn areas are targets in the process of early excavation (Fig. 8-14). In more routine cases in which the pulp chamber is visible on the preoperative film, location of the pulp horns is an early confirmation of spatial orientation (Fig. 8-15). In anterior teeth, the lingual surface is penetrated at right angles to the lingual/palatal surface of the crown. After penetration through the enamel (or artificial crown), the bur is reoriented as much as possible to the long axis of the root. Some clinicians describe this as “keeping the bur to the lingual of the initial opening.” From this standpoint, the pulp horns, if present, should be located. Once the pulp chamber has been accessed, the lingual ledge or shoulder is removed by “cutting on the outstroke.” This will establish a straight-line access opening into the root canal (Fig. 8-16). If removal of the lingual ledge is done with a “cutting-in stroke” there is a greater chance for gouging or even a buccal/facial perforation.

Complete removal of the lingual ledge will often uncover extra canals in mandibular incisors, canines, and premolars (Fig. 8-17). Failure to locate these canals often leads to severe postoperative pain or ultimate treatment failure (see Chapter
FIGURE 8-15 A and B, Two molars requiring root canal treatment, each with pulp horns visible even in the presence of some calcifications. Once these pulp horns are reached with a bur, there is initial spatial confirmation of the pulp chamber location and dimensions.

FIGURE 8-16 Access opening in maxillary central incisor demonstrates straight-line access to the pulp space.

FIGURE 8-17 Access opening in mandibular incisor (A) extends lingually. The second canal located under the cingulum is noted. B, Two canals in a maxillary lateral incisor.
The blame for failure of this nature is often transferred to the patient or tooth, when in fact the clinician should have full knowledge and control in these situations. Burs that are recommended for access to anterior teeth include small to medium round burs, tapered diamonds and/or Endo-Z burs for refinement of the access outline, and possibly Gates-Glidden burs or X-Gates to assist in lingual ledge removal (Fig. 8-18: Anterior Access Kit [Dentsply Maillefer, Ballaigues, Switzerland]).

In posterior teeth, failure to remove the entire roof of the pulp chamber is a common problem that precludes locating the wide variety and often complex canal systems in these teeth (Fig. 8-19). Initially the size and depth of the pulp chamber space on the radiograph should be measured by holding the mounted bur in the handpiece next to the image of the crown on the radiograph (see Fig. 8-30); or if a digital image is being used, measurement tools are available for this purpose. After the pulp horns have been identified, remove the dentin between the horns. Once the dentin has been removed, a safe-ended bur can be placed adjacent to the overhanging roof, which is removed by cutting laterally to unroof the overlying dentin and to flare the walls of the access opening occlusally. A No. 17 or No. 23 explorer is used to evaluate the removal of the roof or dentin overhangs, followed by an inspection of the chamber to ensure an unobstructed entry into the canal orifices. Burs recommended for this procedure include medium to large round burs, a safesided diamond bur or Endo-Z bur, and a Gates-Glidden bur or X-Gates for refinement. For both anterior and posterior access openings, various bur access kits have been created to facilitate clinician choice and usage (Fig. 8-20: Posterior Access Kit [Dentsply Maillefer, Ballaigues, Switzerland]), and the instruments within provide a wide range of tried and tested tools to ensure a proper access opening.

Once the pulp chamber of the posterior tooth is opened to good visualization, recognition of the commonly observed anatomic relationships seen on the floor of the chamber is essential to determine the location of the orifices and prevent perforations. Fig. 8-21 depicts commonly seen pulp chamber floor anatomy in a maxillary two-rooted pre-molar, maxillary first molar, and mandibular first and second molars. Recognition of these anatomic designs and integration of this information with the radiographic findings will prevent problems during both access preparation and canal orifice location.

In refining posterior access openings, removing cervical ledges or bulges (Fig. 8-22) is important because these often impede straight-line entry into the canal or cover up additional canals (Fig. 8-23). Removal of the ledges/bulges must

**FIGURE 8-18** Anterior Access Kit (Dentsply Maillefer, Ballaigues, Switzerland).

**FIGURE 8-19** A, Mandibular molar with access opening is shown. Patient is referred for treatment because of constant pain during attempts to enter the canal orifices. Only the pulp horns are exposed, and the pulp chamber roof is intact. B, Ideal access is shown with roof removed.

**FIGURE 8-20** Posterior Access Kit (Dentsply Maillefer, Ballaigues, Switzerland).

**FIGURE 8-22** A, Radiograph of a maxillary molar with cervical ledges (arrows). B, A sectioned maxillary molar that depicts what happens in the layering of irritational dentin and development of ledges (arrows) that may impede access to the canal system.
be performed carefully, using lateral cutting while tapering the internal walls occlusally and avoiding any apical penetration.

**Problem-Solving Challenges in Access Openings**

Not every tooth is amenable to a straightforward access preparation. In fact, teeth with artificial crowns or large restorations usually have significantly diminished pulp chambers and pulp canals as a result of increases in irritational dentin or the presence of pulp stones.\(^1\) Artificial crowns often completely block the view of the chamber space radiographically even on bite-wing radiographs. Large restorations cannot only obscure the pulp chamber radiographically, but also can block the orifices physically (Fig. 8-24). These impediments can make access preparations most challenging. There are at least three issues that come into consideration in these cases: (1) the presence of calcifications in the pulp chamber, (2) the use of magnification during access preparation, and (3) the potential for perforation of the floor of the pulp chamber or its encompassing walls.\(^5\)

**Pulp Chamber Calcifications**

In teeth with diminished or severely calcified pulp chamber spaces (see Fig. 8-24, A), the pulp horns are usually no longer present. Excavation through solid tooth structure cannot be done without being oriented to the external anatomy of the tooth. Once the target areas are reached, the excavation should be inspected (preferably with some level of magnification and good light—loupes or microscope) for calcified discoloration,\(^1\) indicating the previous location of the pulp chamber. Probing with an endodontic explorer is also necessary, and although the canal orifices may not be obvious, they are often soft to probing with the explorer. An ultrasonic instrument for excavation, removal of calcified pulp chamber inclusions, and opening orifices is indispensable\(^4\) (Fig. 8-25, A and B: ProUltra Tips [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]; Fig. 8-25, C: Smart X Tips [Dentsply Maillefer, Ballaigues, Switzerland]). If used without irrigation, the excavation process is easily observed through the operating microscope or loupes. Irrigation during the use of ultrasonic instruments may block visibility, but it also rinses materials, especially calcifications, from the field of operation. Both approaches should be considered in these situations.
**FIGURE 8-24** A, Blockage of diminished pulp chamber by a coronal restoration in a maxillary molar. B, Significant pulp chamber calcifications (arrows) that will impede direct access to canal orifices. C, Crown on the maxillary first molar that completely blocks the view of the pulp chamber.

**FIGURE 8-25** A, ProUltra Tips as a group, showing a wide range of sizes and shapes (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA). B, Four of the more commonly used ProUltra tips. C, Start X Tips (Dentsply Maillefer, Ballaigues, Switzerland).
Use of Magnification During Access Preparation

A special caution is in order regarding the use of magnification in the location of canals that are calcified or difficult to find. Under very high power magnification (×30), the depth of field is very shallow, and the field of vision is very narrow. In this situation, it is easy to become completely disoriented with the external anatomy of the tooth and the actual location of the ongoing excavation. To compound the problem, in a calcified tooth, every speck and slight discoloration can begin to look like the orifice of a canal under high magnification (×30) when using a microscope. This can lead to serious procedural errors. Continued reorientation under low-power magnification is essential during such excavation. This can be accomplished with loupes at ×2.5 or ×3.5 magnification (Fig. 8-26).

Under magnification, the pulpal horns must be distinguished from the canal orifices. In some cases, the bur may need to be directed toward the largest or the only visible chamber and canal space, such as the distal canal of mandibular molars or the palatal canal of maxillary molars (see Fig. 8-14). Time must be spent reviewing the radiograph prior to access to assess pulp chamber morphology—noting the coronal-apical and mesial-distal dimensions of the chamber space—and if possible the position of the orifices as they leave the pulp chamber floor. If calcifications are present, this task is even more challenging (see Fig. 8-24, B).

During access opening under magnification, a radiograph may be occasionally necessary to check the position of the excavated cavity. A second and vitally important technique to the successful location of all canals in a multicanaled tooth is to enlarge each orifice individually as it is located and before excavation is performed to locate others. This technique will help provide proper spatial and visual orientation of the pulp chamber anatomy. Either the location of all canals will be confirmed, or the orientation will act as a guide to the location of the other unidentified canal orifices. Further, the potential of excavating in areas where no canal could possibly be found or (worse yet) perforating the wall or pulp chamber floor will be avoided using the careful stepwise approach.

Preventing and Managing Coronal Perforations

Although many errors can occur during access preparations, the most deleterious is perforation of the pulp chamber space into the oral cavity or periodontal tissues. Attention to the radiographic position of the pulp chamber space before access opening preparation will often prevent this problem. Similarly, maintaining an orientation to the external anatomy and possessing knowledge of the anatomy of the floor of the pulp chamber and the location of the canal orifices will contribute to the prevention of perforations. Other considerations include making the initial bur preparation and access outline form in the tooth prior to dental dam isolation. At any time during the access preparation, the alignment and position of the bur can be verified radiographically (Fig. 8-27). In more difficult situations, such as the patient not having the ability to open the mouth sufficiently, specific portions of the tooth may be removed, such as a wall or cusp. In anterior teeth that are severely lingually inclined, preparation of the access in the facial tooth surface is often a reasonable consideration.

If, however, a perforation should occur, it should be recognized as soon as possible. This can only be done through constant vigilance and assessment during access preparation. Early recognition will prevent needless irritation and further insult to the periodontal tissues. If the perforation occurs above the osseous crest in the gingival sulcus or above the free gingival margin, careful management is essential. Usually any hemorrhage can be controlled with a dry cotton pellet impregnated with a hemostatic agent if necessary (see later). The defect can be sealed temporarily or permanently at that time with a material appropriate for the location of the perforation. Temporary materials may include zinc oxide eugenol (ZOE) or glass ionomer (GI), and permanent materials may include a bonded composite or core paste, a modified glass...
ionomer (compomer), or even amalgam if it will be included in and covered with a full crown.

If the perforation is at or below the osseous crest or into the furcation region, these procedures can be considered. First, attempt to control the hemorrhage with a dry, sterile cotton pellet or the large end of a sterile paper point. A hemostatic agent in small amounts may be considered, such as epinephrine 1:50,000 on a cotton pellet (various percentages of racemic epinephrine—#2 Pellets have 1.15 mg, and #3 pellets have 0.55 mg [Pascal Company Inc., Bellevue, WA, USA]). Ferric sulfate is another option (Cut-Trol [Ichthys Enterprises, Mobile, AL, USA]). Hemostatic agents provided for tissue retraction prior to tooth impressions may also work (Astringedent [Ultradent Products, South Jordan, UT, USA]; Traxodent [Premier Dental Products Co., Philadelphia, PA, USA]). Avoid strong hemostatic agents that may cause significant damage and do not use formocresol. If the perforation is close to a canal orifice, locate the canal orifice and enlarge the orifice as much as possible away from the perforation before repair. Second, once the hemorrhage has been controlled, sealing with a thick mix of mineral trioxide aggregate (ProRoot MTA) (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) would be ideal2,25-27 (Fig. 8-28). If MTA is not available, a thick mix of ZOE can be used. These materials can be covered with a fast-setting glass ionomer. This is essential with the present formulation of MTA to prevent rinsing it from its placement; present formulations take 2 to 4 hours to set firmly. Try to prevent or minimize pushing the repair material into the periradicular tissues. Once sealed, identification of the canal can proceed, and when it is identified, normal root canal procedures should be performed. Generally the prognosis is better with small perforations that are discovered early and repaired immediately.

Internal repairs can be successful with minimal damage to the supporting periodontium. If there has been significant damage to the periodontium, all forms of repair have a very guarded prognosis.

Large perforations in the furcation of premolars and molars are more problematic.20,54 If significant portions of the floor of the pulp chamber have been destroyed, the chance of successful repair is remote (Fig. 8-29, A). Similarly, cases that have been repaired with materials other than MTA20 or ZOE may have poorer long-term outcome owing to the lack of biocompatibility, especially if the material is forced through the defect into the periodontal tissues15 (see Fig. 8-29, B). It is usually impossible to remove the excess nonsurgically, but the attempt is likely to make the perforation larger and irritate the surrounding periodontium.

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**FIGURE 8-28**  
A, Perforation of chamber floor of a mandibular molar during access.  
B, Defect sealed with mineral trioxide aggregate.  
C, One-year reevaluation shows good tissue response, and patient functions without discomfort on the tooth.
Perforations in the coronal third, in particular in the furcation, have a highly guarded prognosis. With adjunctive periodontal, surgical, or orthodontic treatment (see Chapters 17 and 18), management with a simple surgical repair or root extrusion may result in a successful outcome. In some cases, however, internal repair cannot be accomplished, and an external surgical approach must be taken. Even in these cases, extraction may be indicated.

Because crown perforations can be devastating and result in tooth loss, a preventive approach to access opening is always advocated. In some cases, the initial outline form of the access can be made without the dental dam in place. This is especially helpful when there is a discrepancy between the long axis of the crown and the root. Upon placement of the dental dam and as the access opening is being cut, bur alignment can be evaluated with radiographs. Sometimes specific portions of the crown must be removed to facilitate safe access to the chamber. Creative approaches and access preparations done with a sound rationale are highlights of problem solving in this area.

Potential Problems in Access Openings Through Crowned Teeth or Teeth With Excessively Large Restorations

A significant number of all root canal procedures are performed through existing crowns. The presence of these metallic and metalloceramic restorations can add additional problems and challenges to those discussed previously. Most of these concerns can be addressed (problems prevented or challenges met) when preparing an access opening through an artificial crown.

As with naturally occurring crown-root angulations, a thorough radiographic evaluation is necessary to identify divergently angled roots or rotated teeth. This may be difficult if the pulp chamber is not visible. The exact location of the chamber may not be readily seen, and therefore the depth of bur penetration should not be left to chance. Consider measuring the approximate depth by holding the bur against the radiograph to estimate relative positions of both the chamber and the furcation in molar teeth before cutting the access opening (Fig. 8-30).

In all situations, a thorough assessment of each tooth that has a crown and requires a root canal procedure can facilitate good treatment planning. Additional important information can be obtained by using bitewing radiographs (see Chapters 2 and 3). Options exist for crown retention when there is no damage due to caries, with the occlusal surface repaired after root canal procedures. If caries is present under the crown margins or potential avenues of caries under crown margins exist, the extent must be identified and eliminated. This may very often mean removal of the crown, especially when the tooth margins appear subgingival on either a periapical or bitewing radiograph. In the latter cases, crown lengthening may be indicated prior to doing any root canal procedures (see Chapter 18).

When full metallic crowns are present and made of non-precious alloys, access may be very difficult; burs may dull

**FIGURE 8-29** A. Attempted repair of a large access perforation with zinc oxide eugenol cement resulted in acute onset of symptoms. The tooth was extracted. B. There would be minimal chance of successful removal of the excess repair material. Extraction was recommended.

**FIGURE 8-30** Estimation of pulp chamber depth by holding a bur mounted in the handpiece against a radiograph of the tooth to be operated.
In all cases, open the coronal outline of the access slightly greater than a standard-sized access to facilitate identification of possible avenues of leakage or fractures and canal location and exploration if necessary.48 The integrity of the crown resides in the gingival margins, not in the occlusal surface. As previously mentioned, conservation of tooth (crown) anatomy does not preclude using the necessary avenue of access (see Figs. 8-1 to 8-4), especially if restorations are to be remade.

Clinical Considerations in Preventing and Managing Problems in Tooth Isolation and Access Preparation

- Clamping adjacent teeth should be considered if the dental dam clamp cannot be positioned on the tooth to be treated (see Fig. 8-4, D). Further control of moisture can be achieved with dental and medical adhesives, a rubber base, floss, or temporary filling materials.4 Buildups can be done prior to access preparation, but oftentimes these are hollowed out, weakened, result in excess debris that may be pushed into the canals, or redone prior to final coronal restoration.35
- Crown lengthening should be considered before any root canal procedures are performed if isolation can only be achieved by clamping the tissue (see Chapter 18).35
- Temporary crowns should be removed before isolation and access whenever possible. Removal prevents dislodgment during canal preparation, potential contamination during or after treatment, unstable reference points, and leakage of irrigant into the mouth.
- A line can be drawn on the crown to indicate the angle of the root when creating an access opening under a

In the case of artificial crowns (metaloceramic or complete ceramic), if the crown is to be retained, significant care must be taken to prevent fracture of the ceramic material.17,52,58,61 This is especially true if the crowns are of an older vintage. In cases of ceramic-type crowns, use water spray and new high-speed round diamond burs to gain access through the initial layer, which is a porcelain-type material.17 Cut the porcelain in a light, shaving manner as opposed to using heavy pressure and long cutting times. If the crown is metaloceramic, a metal core will be present which requires the use of a Transmetal Bur (Dentsply Maillefer, Ballaigues, Switzerland) (Fig. 8-31, A). This is then followed by a bur of choice to complete the access into the pulp chamber. Then the walls of the access opening are flared to the occlusal side for posterior teeth or the lingual side for anterior teeth to prevent contact with the intracanal instruments. This can be done safely with an Endo-Z bur (see Fig. 8-31, B).

If the crown is zirconium based, the initial cut is made with a coarse, medium to large, round diamond bur or special diamond bur (KS2 turbo-type diamond bur [Axis Dental Corp, Coppell, TX, USA]), which will expose a dense, white zirconia layer.17 The opening should be slightly larger than the anticipated final access opening. Once the initial layer has been penetrated, the thin zirconia substrate can be penetrated with a round diamond bur; it should be smaller than the initial outline to prevent cutting the lateral walls of the opening, which may promote fractures in the veneering porcelain. Advise the patient ahead of time of a possible fracture in these situations. New technologies using air abrasion to access these crowns appear to prevent the problems of damaging the porcelain veneer that overlies the zirconium base.45
response to a continual low-grade irritation (Fig. 8-35). Radiographically, calcification will appear complete, with histologic confirmation of complete canal closure except for a few small areas that contain minimal tissue remnants. Calcification is also known to occur as a result of vital pulp treatment with calcium hydroxide and other materials. See Chapter 7 for examples and discussion of these topics.

Successful identification of the parameters of the pulp chamber and canal orifice in this type of tooth is extremely difficult (see Chapter 13 for canal penetration in the presence of rubber dam. Failure to determine excessive root angulation often leads to a perforation (Fig. 8-32).

- Although their use is effective and indicated in many teeth, care must be exercised in crown penetration when using long-shank or surgical-length burs.

**Problem Solving in Recognizing or Locating Canal Orifices**

**Calcification of the Dental Pulp and Pulp Canal Space**

Dystrophic and excessive linear calcification in the root canal system is a frequently encountered problem in root canal procedures.1,13 The clinician must understand that pulpal calcifications are signs of pathosis, not the cause of them.39,47 The nature of the calcification is often unpredictable and can create significant clinical challenges. Over the life of the tooth, deposition of secondary dentin—whether normal or irritational—occurs in every tooth.1 When the pulp is subjected to rapid, overwhelming bacterial invasion or traumatic insult, little time may be available for normal reparative dentin formation. In these situations, the dental pulp may die rapidly, leaving the canal space patent but full of necrotic and often infected tissue (Fig. 8-33). Clinically and radiographically, the pulp chamber and canal system remain patent and easily accessible. However, if irritants impact the tooth slowly over a long period, both the pulp chamber and the pulp canal system undergo calcific changes that may impede access and canal identification during initial root canal procedures (Fig. 8-34).

The histologic appearance of the calcifying pulp, pulp chamber, and root canal space generally reflects a long-term response to a continual low-grade irritation (Fig. 8-35). Radiographically, calcification will appear complete, with histologic confirmation of complete canal closure except for a few small areas that contain minimal tissue remnants. Calcification is also known to occur as a result of vital pulp treatment with calcium hydroxide and other materials. See Chapter 7 for examples and discussion of these topics.

Successful identification of the parameters of the pulp chamber and canal orifice in this type of tooth is extremely difficult (see Chapter 13 for canal penetration in the presence of rubber dam. Failure to determine excessive root angulation often leads to a perforation (Fig. 8-32).

- Although their use is effective and indicated in many teeth, care must be exercised in crown penetration when using long-shank or surgical-length burs.
of calcifications. Of the numerous techniques available to penetrate the chamber and locate the canal orifices, only those procedures known to be most effective in clinical practice are considered here.

Initially the clinician must mentally visualize and project the normal spatial relationship of the pulp space onto a radiograph of the tooth. Then information from the two-dimensional radiographic image is correlated, if possible, with the three-dimensional morphology of the tooth (Fig. 8-36). Thereafter, access preparation is initiated with the rotary instrument directed toward the presumed location of the pulpal space. Refining this preparation and identifying the location of the orifice is best accomplished using an ultrasonic instrument (see Fig. 8-25) if available. If not, care must be exercised in penetrating farther with a high-speed bur to prevent a perforation. This approach to access and orifice identification requires knowledge of the normal pulp chamber location, root canal anatomy, and long axis of the roots, especially in posterior teeth. Accurate radiographs are essential for preoperative visualization and periodic assessment of bur penetration and orientation. Ultimately, the calcified orifice must be recognized when it has been reached.

For teeth with single canals, textbooks on root canal morphology have often overlooked an important anatomic fact:
the canal space is always located in the cross-sectional center of the root. Similarly, the pulp chamber is (or was, before calcification) located in the cross-sectional center of the crown.

Prior to access preparation in a tooth with a calcified pulp chamber, the distance from the occlusal surface to the projected pulp chamber floor is measured from the preoperative periapical radiograph or preferably from a bite-wing radiograph, which maximizes accuracy. This can also be done using a wide range of digital radiographic systems. An access cavity of normal size and shape is created in the crown to a depth equal to that of the pulp chamber floor in a noncalcified chamber (see Fig. 8-36).

A second important aspect of normal root canal anatomy is the geometric pattern of canal orifices found in the pulp chambers of teeth with multiple canals. These geometric patterns and their potential variations must be mentally projected on the calcified pulp chamber floor with consideration for the direction of the canals as they leave the pulp chamber. This requires an astute integration of two-dimensional radiographic findings with three-dimensional tooth anatomy, coupled with a safe and dexterous movement of the rotary

FIGURE 8-36 A, Normal mandibular molar without dystrophic calcification. Broken lines delineate anatomic central location of pulp chamber. B, A similar tooth with severe dystrophic calcification characterized by obliteration of the pulp chamber and apical recession of the canal orifices. Broken lines delineate the location of the former pulp chamber. C, Access preparation is shown diagrammatically to the precise depth and lateral extension as with a normal pulp chamber.

FIGURE 8-35 A, Mandibular incisors show evidence of severe calcification. B and C, Histologic appearance of what may be occurring in A is visualized. Canal narrowing and blockage is noted. (C, B&B stain ×10.)
instrument or ultrasonic tip on the pulpal floor. To facilitate this approach to the location of fine or calcified canals, the following discussion is a consideration of access preparation of the calcified pulp chamber by each tooth type with canal variations.

**Maxillary Central and Lateral Incisors and Canines**

A maxillary incisor with dystrophic calcification is diagrammed in Fig. 8-37, A. The root canal is located in the cross-sectional center of the root. If aesthetics and structural integrity were disregarded, the ideal location of the access preparation would be through the incisal edge; however, the standard access preparation for this tooth is in the exact center of the palatal surface of the crown, buccal lingually and incisal gingivally (Fig. 8-38, A). At an angle of roughly 45 degrees to the long axis, bur penetration of 3 to 4 mm will generally intersect with the pulp chamber in average-sized teeth (see Fig. 8-38, B). In a calcified chamber, however, continued penetration at 45 degrees to the long axis will eventually pass over the canal entirely and result in perforation of the labial root surface below the gingival attachment. Therefore when the chamber is calcified and the canal has not been located after 3 to 4 mm of penetration, the bur must be rotated to be as parallel as possible to the long axis of the tooth to prevent perforation. Penetration proceeds down the lingual aspect of the access preparation with frequent exploration with the DG-16 endodontic explorer for the orifice. In deep excavations, the bur may be changed to a long-shank No. 2 round bur (or switch to an ultrasonic tip). Visual and radiographic reassessment of direction is frequently necessary. Sometimes the canal is never found, and treatment plans must be revised.

**Maxillary Premolars**

The point of coronal penetration for access begins in the center of the occlusal surface and follows the long axis of the tooth. Because the pulp chamber is wide buccal lingually in both one- and two-canaled premolars, the chamber must

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**FIGURE 8-37** A, Diagram of a maxillary incisor with dystrophic calcification. Broken lines delineate central location of former pulp chamber similar to the previous figure. B, Angle of access penetration is approximately 45 degrees to the long axis of the root. The access opening should extend incisogingivally to include the full middle third of the crown. C, No pulp chamber is found in the calcified canal. Continued bur penetration may result in a facial perforation. D, Facial perforation results from excessive bur penetration without adequate radiographic control for bur angulation and pulp canal depth. E, To prevent perforation, angle of bur is changed from 45 degrees to an angle as close to parallel as possible with the long axis of the root.
be cut wide buccal lingually but should remain narrow mesial distally (Fig. 8-39, A-B, see also Fig. 8-21, A).

Maxillary Molars

The most common design for access preparation is a triangle formed by the orifices of the two buccal canals and the palatal canal. In many molars with calcified chambers or canals, it is common to find one or two orifices initially without much difficulty. However, the other orifices may not be readily identified. In these situations, a mental image of the geometric pattern of the canals is invaluable (Fig. 8-40, A). In the case of maxillary molars, these teeth have a high potential for having four orifices and possibly four separate canals (see Fig. 8-40, B). For a second canal in the mesial buccal root, a slot or trench is usually excavated in a straight line toward the palatal orifice from the primary mesial buccal canal orifice. Generally if a second mesial buccal orifice or mesial palatal is present, it will be anywhere from 0.5 to 5 mm toward the palatal orifice and often located under a cervical ledge. Occasionally the orifice to the fourth canal will actually be located 1 to 2 mm into the mesial buccal orifice or even the palatal orifice (see Fig. 8-23, C and D).

Mandibular Incisors, Canines, and Premolars

The most common canal morphology for mandibular incisors, canines, and premolars is a single canal; a second canal, if present, will almost invariably be found lingual to the first canal (Fig. 8-41, A and B). In the incisors and canines, second canals are particularly difficult to locate (even when minimal calcification is present) because of the angulation of the anatomic crown or the location of the standard access cavity on the lingual aspect (Fig. 8-41). After the main canal

**FIGURE 8-38** A, Central incisor with calcified chamber and questionable canal. B, After deep penetration the canal could still not be found, although it appears visible on the radiograph. Patient opted for periapical surgery.

**FIGURE 8-39** Typical access shape and canal morphology of a single-canal premolar (A) and a two-canal premolar (B). Access is wide buccal lingually and narrow mesial distally.

**FIGURE 8-40** A, Occlusal view of a maxillary molar shows a standard access preparation. By locating and flaring the orifices of two canals, the location of the third canal (X) is consistently and accurately determined. B, After the three primary canals have been located, the orifice of the second mesial buccal canal can be located by troughing 0.5 to 5.0 mm toward the palatal canal orifice. Most second canals will be found 1 to 3 mm from the primary mesial buccal canal orifice (X).
is located and débrided, it is important to widen the orifice lingually and probe for the second orifice using a No. 10 or 15 K-file with an abrupt curve placed 1 or 2 mm from the tip of the file. If the canal is not located with this technique, using Nos. 2, 3, and 4 Gates-Glidden drills or orifice shapers on the lingual surface may be helpful in uncovering the orifice of a lingual canal. The drill is used in the manner of the round bur and is drawn up the lingual surface in a sweeping motion. Breakage may occur during this motion, but the fracture typically occurs high on the shank, and such a position allows easy removal of the segment. If the canal is found with either technique, even a normal-sized second canal is usually as fine as any calcified canal.

FIGURE 8-42 A, Mandibular molar with a two-canal morphology will have both orifices on the mesial distal midline. B, If two canals are located in a mandibular molar, and the mesial orifice is distinctly buccal or lingual to the mesial distal midline, a second canal in the mesial root (X) is probable.

Mandibular Molars

The most common morphology for access preparation in mandibular molars is a trapezoid formed by the two canals in the mesial root and the oval canal in the distal root11,19 (see Fig. 8-21, C and D). The distal canal is commonly found to be wide buccal lingually, with a morphology that requires separate preparation of the buccal and lingual aspects of the canal. In roughly 30% to 50% of cases, the distal canals will be separate, making it necessary to make a wide buccal-lingual excavation in the distal root in calcified canals. A small percentage of second molars will have only one canal in each root. If one canal is located in the mesial root, it is wise to enlarge its orifice as previously described and assess the symmetry of the orifice geometry. In a two-canal morphology, both canals will be in the mesial distal midline (Fig. 8-42, A). If after orifice widening, the mesial canal is asymmetrically located to the buccal or lingual side relative to the distal canal, the mesial root probably has two canals. The second canal can be envisioned as completing the trapezoid initially described (see Fig. 8-42, B). Again, making a groove in excavating for the calcified orifice is recommended because it may be either quite close to the located canal or as far as 3 to 4 mm away. As with the fourth canal in the maxillary molar, the orifice of either the mesial buccal or the mesial lingual canal may be located 1 to 2 mm into the singly identified mesial orifice.

Although the majority of attempts to locate canal orifices in the presence of severe calcification will be successful, the potential for perforation always exists. Probing with the explorer will yield the characteristic “stick,” if in fact the excavation has come too close to the root surface and the explorer is actually penetrating a thin area of remaining dentin. This type of procedural accident must be detected as early as possible to ensure that injury to underlying bone can be kept to a minimum. Another common sign of accidental perforation is bleeding. The clinician must immediately
discern whether a bleeding point is the true canal orifice with a hemorrhagic pulp or a perforation to an external surface. First, a visual analysis of the external and internal anatomy will give an indication if the bleeding point is reasonably close to the position of a canal. Secondly, a radiograph can be made with very small file (.06 or .08) inserted into the bleeding point. This exposure is for location only. No attempt effort should be made to enlarge the orifice until it is confirmed that it is the canal. At the earliest point of discovery of a perforation, repair with MTA should be done.

To assist in the location of a calcified canal and to avoid possible perforation it is often helpful to radiograph the tooth with an endodontic explorer in the excavation. The tip of the explorer should be in the position where the canal is believed to be and the probe should be positioned at the angle at which the excavation is being done. Often, the radiograph will confirm that the direction of excavation is accurate (Fig. 8-43). Occasionally, the direction of excavation is found to be in error. With the aid of the radiograph, the direction of excavation can be corrected and the canal can be located (Fig. 8-44).

Details on the initial and subsequent problem-solving techniques for the penetration of orifices and canals that exhibit calcifications will be found in Chapter 13, which deals with anatomically compromised root canal systems. However, once the orifice has been located, the use of heated

![Figure 8-43](image1.png) **A**, mandibular molar under endodontic treatment with calcified distal orifice. Endodontic explorer is radiographed in excavation to confirm location and direction of access procedure. **B**, Successful location and negotiation of canal.

![Figure 8-44](image2.png) **A**, Maxillary lateral with calcified canal under endodontic treatment. Endodontic explorer indicates aberrant excavation pathway. **B**, Successful completion of root canal treatment after correction of pathway direction and location of canal.
(37°C) sodium hypochlorite (NaOCl) solution is recommended as a soak in the chamber; this will assist in the digestion of any debris with an organic component. While room temperature NaOCl is also effective, a heated solution (even up to 45°C) will act rapidly to assist the clinician in débridement. This may actually include some of the debris located in the orifice, especially if the explorer can begin to penetrate 1 to 3 mm into the canal.

Clinical Considerations in Preventing and Managing Problems in Orifice Identification

- Locating the orifice is best accomplished using a DG-16 explorer. The explorer will not penetrate and stick in solid dentin, but if an orifice is present, firm pressure will slightly force the instrument into the orifice, and it will resist dislodgement or stick.
- The location of the canal can be confirmed radiographically, leaving the explorer in place. Magnification in the form of telescopic loupes or an operating microscope is extremely useful. However, it is often more useful to excavate the area where an orifice is likely to be found under lower magnification to maintain an awareness of the overall anatomy of the tooth.
- The location of the orifice can often be determined by the color of the dentin, sometimes referred to by the term dentinal mapping. The orifice may appear as a whitish spot in a general field of yellowish dentin. If such a location is consistent with the expected anatomic position of the orifice, the area should be firmly probed with the DG-16 explorer.
- Calcifications over the orifice can be removed with the ultrasonic instrument and a probe-type tip. The ultrasonic instrument can be used either wet or dry to excavate calcification. As excavation proceeds, the DG-16 explorer is used frequently to probe for the orifice. If the canal cannot be located, a radiograph of the excavation should be exposed to check the position at the deepest point of penetration. Placing an endodontic instrument or an explorer in the excavation before radiographic exposure will often aid in assessing direction and position.
- Fiberoptic light transmission from the buccal or lingual surface when an artificial crown is not present may also assist in orifice location (Fig. 8-45).
- Using a small amount of methylene blue 1% on the pulp chamber floor (see Fig. 8-6, C) may help identify the pooling of poorly mineralized dentin that may fill a partially calcified orifice. It may also help identify or confirm the presence of fractures.

REFERENCES


FIGURE 8-45 Placement of a fiberoptic light on the buccal wall to enhance intrachamber visibility when searching for canal orifices.
Chapter 9

Problem Solving in Working Length Determination

The healing processes after removal of a pulp occur in the tissue immediately adjacent to the point where the pulp was severed. It is, therefore, of great importance to retain the vitality of these tissues in order to make healing possible.35

R. Kronfeld, 1933

If the tooth is uncomfortable, however, or presents an area of rarefaction, apical access must be obtained in order to negotiate the canal throughout its entire length to reach the periapical tissues.24

L.I. Grossman, 1946

Factors that may influence a difference [in the method used for working length determination] include the quality of radiographs, superimposed anatomic structures, or anomalous positions of root canal foramen.

D.H. Pratten, N.J. McDonald, 1996

Problem-Solving List

Problem-solving issues and challenges in working length determination addressed in this chapter are:

Anatomic Basis for Challenges With Working Length Determination

Apical Root Anatomy and Its Impact on Working Length

Working length determination: radiographic technique
Working length determination: electronic apex locator
Working length determination: other clinical techniques

Controversies and Challenges With the Pulpal and Periapical Status and Their Impact on Working Length Determinations and Choices

Posttreatment Implications and Outcomes of Root Canal Treatment Based on Working Length Philosophies

Anatomic Basis for Challenges With Working Length Determination

The apex of the mammalian tooth is a complex biological unit composed of cementum, dentin, blood vessels, nerves, and connective tissues. One of the factors determining the long-term success of root canal treatment has been shown to be the relationship between instrumentation and obturation procedures and the anatomy of the apex.41,47,53 A clear understanding of the morphology of the root canal system, including the apex, is imperative.

Root formation and development are determined by the Hertwig’s epithelial root sheath (HERS), which maps out the external form of the root. The HERS is a double layer of epithelial cells derived from a proliferation of the internal and external dental epithelium (Fig. 9-1). The rim of this sheath, the epithelial diaphragm, encloses the primary apical foramen. Multirooted teeth form as a result of the division of the primary apical foramen into two or more sections by “tongues” of epithelium growing inwards from the HERS.

For many years, the tooth apex has been the focus of many anatomic and treatment studies.* Anatomic variations in this region have been accepted as the norm, but contemporary treatment parameters involving these aberrations still present challenges and controversies.

*References 2-5, 11, 12, 15, 25, 26, 31, 35, and 36.
Internal morphology at the end of the root canal is determined by the odontoblasts responsible for development of the dentin. The transition from internal to external morphologic features occurs at the cementum-dentin junction (CDJ), delineated histologically by the odontoblasts. Coronal to this position, the tissue is classified as pulp tissue. However, the soft tissue contained within that portion of the canal apical to the CDJ is not dental pulp but a fibrous connective tissue that originates from the periodontal ligament and supplies the vessels and nerves leading to and from the pulp (Fig. 9-1).

Multiple apical terminations pose clinical problems for working length determination, cleaning and shaping, disinfection, and obturation.

Overall view of an immature root that is forming shows a large dental papilla and advancing root sheath, left and right. Arrow indicates remnants of the epithelial sheath.

Chapter 9

Problem Solving in Working Length Determination

The walls of that portion of the canal as it enters the periodontal ligament (PDL) are covered with cementum. The root canal system tapers from the coronal end to its narrowest part, the constriction (minor foramen), which is usually but not necessarily within dentin. Early investigations indicated that the “pulp canal anatomy becomes extremely variable in the apical third.” Contemporarily, the internal morphology of the constriction has been classified into five main types: single constriction point, tapering constriction, multiple constriction, parallel constriction, and blocked (Fig. 9-10). Apical to the constriction, the root canal system diverges again to the major foramen that is within cementum. This hourglass shape dictates that canal cleaning, shaping, and obturation should be confined within dentin and not extend beyond the apical constriction or minor foramen.

The apical portion of the root canal system presents the greatest number of ramifications, with 27.4% of teeth demonstrating accessory and lateral canals or an extensive arborization, also known as an apical delta (Fig. 9-11; also see Fig. 9-9).

**FIGURE 9-8** Radiograph showing apical resorption of the root apices of two teeth. Tooth on the left has an apical invaginating external resorptive defect that alters the position of the cemental-dentinal junction.

**FIGURE 9-9** Root apex following root canal filling (RCF) short of the actual root length. Histologic evidence of hard-tissue formation (black arrows) that has formed from cells of the periodontal ligament (PDL) adjacent to root filling material. Note cementum formation (white arrows) on internal aspect of apical foramen.

**FIGURE 9-10** Multiple possibilities for canal termination at the cemental-dentinal junction.

**FIGURE 9-11** Apical delta formation in a demineralized and cleared tooth. Note presence of pulp stones in multiple small canals.
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9-5). Their existence necessitates the use of adjuncts to mechanical cleaning and shaping to ensure thorough débridement of the root canal system (see Chapters 10 and 11). In all likelihood, the cleaning of these aberrant structures is all but impossible; in actuality, the tissues contained within these ramifications may contribute to ultimate apical healing.

Studies have shown that the major foramina of most human teeth are distant from both the radiographic and anatomic apex (Fig. 9-12). Likewise, the major foramen is distant from the minor foramen or constriction by an average distance of 0.5 mm (see Fig. 9-12, B). All these anatomic variations directly affect clinical decisions made during root canal treatment, such as where shall the root filling end? It is easy to conjecture where this ideal position should be located, but more often than not, achieving this goal may elude the clinician. Ultimate clinical success and radiographic findings usually confirm or disprove this choice in treatment.

Apical Root Anatomy and Its Impact on Working Length

It is frequently impossible to know exactly where the apical foramen and apical constriction are located until after the canal has been obturated. However, knowledge of the possible three-dimensional variations (e.g., resorption or changes due to age, trauma, orthodontic movement, periradicular pathology, or periodontal pathosis) may prevent significant damage during working length determination and instrumentation to the cementum that has formed around the apical dentin and to the periapical tissues. In addition, extrusion of debris, medicaments used in root canal procedures, and obturation materials can be minimized, thereby preventing postoperative complications.

The seventh edition of the Glossary of Endodontic Terms defines the working length of a tooth as the distance from a coronal reference point to the point at which canal preparation and obturation should terminate. To this purpose, the ideal apical terminus of the working length has been identified histologically as the CDJ. This junction is typified by a constriction or narrowing of the canal space (minor constriction) that provides an ideal point to prepare an apical seat in sound dentin. However, as previously mentioned, there can be vast variability in the nature of this constriction that will have an impact on any technique of working length determination.

The distance from the foramen to the constriction depends on a multitude of factors such as increased cemental deposition or radicular resorption (Fig. 9-13, A). Both processes are strongly influenced by multiple factors. Especially in periodontal disease states, the CDJ location has no predictable anatomic appearance or location, owing to resorptive processes or cemental depositions that may extend well into the root canal (see Fig. 9-13, B). The foramen and CDJ position on the root can be highly variable and exist anywhere from the direct radiographic apex up to 3 mm or more coronal to the radiographic apex, depending on a particular root morphology (Fig. 9-14). These potential anatomic variances have had a major impact on the precise region or location for determining the working length and termination of root canal instrumentation and obturation.

FIGURE 9-12 A, Position of apical foramen is coronal to root apex. B, Histologic evidence and verification of this position (H&E stain ×4).
Current concepts of initial canal penetration recommend preflecting techniques for a coronal-to-apical approach to working length determination rather than immediate penetration to the apex region. Emphasis is placed on straight-line access to the radicular third of the canal, and considerable time and effort is spent preparing the coronal two-thirds of the root prior to apical penetration. This eliminates coronal impingements on the working length instrument and enhances penetration to the CDJ.

In curved canals, however, after obtaining straight-line access, the working length can change, especially if debris is packed around the curvature and not removed on a regular basis. Techniques have been advocated for this purpose, and cognizant use of them is recommended. If working length is obtained prior to straight-line access, it may be 1 mm less or even shorter after preparing the coronal two-thirds. Straight-line access eliminates the bend at the canal orifice and places the file in a more upright position closer to the reference point. A more accurate working length will be obtained after straight-line access in the canal is established (Fig. 9-15). This does not preclude obtaining a preliminary working length prior to preparing the coronal two-thirds if necessary to assist in overall knowledge of root shape, canal morphology, foramen patency, and to prevent canal blockage. Knowledge of average tooth length, tactile feel, or the use of digital radiography may provide tools for this purpose. However, once straight-line access is achieved, a more precise working length should be obtained.

During access opening preparation, all caries, unsupported enamel, and faulty restorations are removed in an effort to secure stable reference points as aids in working length determination (see Chapter 8). This is especially helpful when more than one appointment is required to complete treatment. Typical reference points are those that are closest to the file and can be identified accurately as the cleaning and shaping process develops. If significant coronal destruction exists and extensive restorative procedures are

Prior to establishing a definitive working length, coronal access to the pulp chamber must provide a straight-line avenue into the canal orifice, thereby facilitating subsequent canal penetration (see Chapter 8). In anterior teeth, failure to remove the lingual ledge or incisal edge often impedes this straight-line access, resulting in lack of depth penetration to the CDJ, failure to locate all canals present, or instrument penetration into the canal wall with ledge formation. In posterior teeth, primarily molars, or multirooted premolars, failure to remove cervical ledges or bulges results in missed canals or binding of the penetrating instrument in the coronal third of the canal with ledge formation (see Chapter 8). The ability to penetrate unimpeded to the CDJ is crucial to determining the working length of the root canal.

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anticipated, it is helpful to reduce unsupported tooth structure to prevent possible fracture between appointments, which may not only complicate the working length measurement already established but may also prevent associated periodontal and restorative problems should the fracture occur through the periodontal ligament (see Chapter 17).

Pathologic processes resulting in apical resorption can destroy the natural constriction of the CDJ (Fig. 9-16). This will create difficulty in locating a biologically acceptable position at which to establish the working length. The resorptive process generally produces a root end with an uneven, irregular radiographic appearance with few clues about where to prepare an apical stop. While the extent of proximal surface root end resorption may be discernible, the degree of buccal and lingual tooth loss is distinctly ambiguous. Buccal or lingual resorption cannot be discerned until 20% to 40% of the root structure has been demineralized and evidences some type of replacement resorption.1 If apical resorption presents radiographically with a scalloped or uneven proximal margin, significant three-dimensional resorption has already occurred, further complicating working length determination. Creation of an apical stop or enhancing an apical narrowing or

**FIGURE 9-15** When curves are present, as seen in the mesial buccal root, straight-line access is essential.

**CLINICAL PROBLEM**

**Problem:** A 19-year-old male presented with mild discomfort in his maxillary left canine. He had been wearing orthodontic appliances for 18 months. The tooth was slightly tender to percussion and palpation and gave a significantly reduced response to sensibility testing compared to the contralateral canine. A radiograph showed evidence of significant resorption on the mid-mesial surface and a suggestion of resorption at the apex (Fig. 9-17, A). Of concern was the extent of the mesial resorption and whether or not a simple root canal procedure would stop the resorptive process. At issue was the location of the working length termination; invariably these teeth have experienced apical resorption or remodeling at some level during 18 months of orthodontic tooth movement. (Note that adjacent lateral incisor and premolar exhibited extensive resorption.)

**Solution:** The working length of the tooth was determined to be short of the discerned apical resorption (see Fig. 9-17, B). Note the scalloped apex that was enhanced using digital radiography. The root canal was cleaned, shaped, disinfected, and obturated using gutta-percha and sealer staying short of the anticipated resorbed apex. A 6-month reevaluation showed good bony response and cessation of the lateral resorption (see Fig. 9-17, C).

**FIGURE 9-16** A, Histologic demonstration of invasive apical resorption and how it destroys the cemental-dentinal junction. B, Working length established at the most narrow point in the canal when invasive apical resorption is present (arrow).
Improperly placed file stops can significantly alter accuracy of the working length. Constriction in these situations must rely on the clinician’s judgment, drawing on experience, tactile sensation, and reliable diagnostic radiographic techniques. If the root end is wide open from the resorptive destruction, electronic apex locators are unreliable and of little clinical value. Consequently, the coronal-most point on the root above the resorbed apex that exhibits sound radiodensity must be identified. This position is used as the new radiograph apex, and the working length is established 1 to 2 mm coronal to that point. In cases of extensive irregular apical resorption, the new working length can conceivably be 5 mm or more coronal from the original root apex.

A silicon stop is a common aid for evaluating the working length measurement and returning to a secure reference point (see Chapter 10). Care must be taken to assure that the stop is placed on the file and measured at a right angle to the file (Fig. 9-18). Otherwise, differences in length of a millimeter or more between files may occur, leading to either perforation and stripping of the apical foramen or inadequate cleaning and shaping of the apical seat, with corresponding loss of length. Commercially produced stops are teardrop shaped or notched and can be positioned to indicate instrument curvature as dictated by the canal; these are essential in maintaining working length once established. Most if not all intracanal instruments, both nickel-titanium (NiTi) and stainless steel, come with stops already positioned on their shafts.

**FIGURE 9-17** A, Maxillary canine undergoing orthodontic tooth movement. Note the lateral resorptive defect (arrow). B, Working length is determined. C, Six-month reexamination shows a stable environment. Radiographs are digital clear-view enhanced. (Case courtesy Dr. Paul Buxt, Dallas, TX.)

**FIGURE 9-18** Improperly placed file stops can significantly alter accuracy of the working length.

The generally accepted method for establishing the working length of a root canal is to expose a periapical radiograph with an endodontic instrument (stainless steel K-file or NiTi file) placed in the canal. This method provides acceptable results in most instances (Fig. 9-19), especially when using enhanced digital radiographic techniques in the posterior teeth. However, other factors may complicate the decision-making process during this phase of root canal treatment, and this method has several drawbacks or limitations that can affect the ultimate accuracy of the working length used. The primary problem focuses on the

**Working Length Determination: Radiographic Technique**

Radiography is paramount to the successful practice of endodontics during diagnosis, treatment, and postoperative evaluation (see Chapters 2 and 3). Radiographic assessment of the tooth and periapical structures prior to treatment will provide the clinician with essential information necessary to form a mental image of the apical complex.
quality of the radiograph produced, which is a composite of proper film placement, tubehead angulation, exposure time, and film processing (see Chapter 2). Attempts to read and interpret findings (e.g., position of a file tip in a root canal, angle of root curvature) from an exposed film that fails to meet accepted standards for diagnostic dental radiographs immediately alters the quality of the entire root canal treatment. It also destroys the concept of problem solving, which is based on the step-by-step assessment process, identifying variances from accepted standards and eliminating them before the process is completed. Using erroneous data from a nondiagnostic, unreadable, or otherwise unintelligible dental radiograph will result in additional problems during treatment, such as instrumentation beyond the end of the root, canal ledging, loss of length, and associated complications (see Chapters 2 and 3). Often errors in film quality can be attributed to the inability of the clinician to properly manage factors such as a patient gag reflex, macroglossia, shallow floor of the mouth, or shallow palate. These can only be managed by initially identifying that these problems may exist. Technical skill, authority, and assurance will more often than not overcome these potential impediments to obtaining a quality dental radiograph, especially when the dental dam is in place. Failure to do so often leads to unnecessary exposure of the patient to additional radiation.

Dental radiographs also have inherent limitations, perhaps the most important being that they provide only a two-dimensional image of a three-dimensional object. Coupled to the anatomic variability of the apical foramen and the apical constriction relative to the root end, radiographs fall far short of the ideal tool for determining the working length. Additionally, radiographs are subject to the superimposition of normal anatomic features and pathologic changes on normal apical tooth anatomy. The presence of a radiolucency can aid in the interpretation of a radiographic image because of the change in density it produces. Likewise, the presence of a radiopacity such as the zygomatic arch (Fig. 9-20) can obscure the maxillary first and second molar apices. This occurrence has been shown to affect 20% of the first molar apices and 42% of the second molar apices.

Regardless of these problems, the radiograph is an indispensable part of root canal treatment, and a variety of ways have been identified to determine the working length. In the method described by Ingle, an estimated working length is initially established by measuring from an accurate preoperative radiograph. A file, preferably ISO size 15 or greater, is then placed to the estimated working length, and a second
radiograph is exposed. If the tip of the file is within 1 mm of the ideal location, the radiograph can be accepted as an accurate representation of the tooth length. Other investigators have recommended reconfirming working lengths with a new radiograph if adjustments of 2 mm or more have to be made. This method usually provides acceptable results, especially when the pulp is inflamed yet vital.

Controversies still exist, however, when the pulp is considered nonvital, especially in the presence of an obvious periapical radiolucency and/or when the patient is experiencing pain (Fig. 9-21). The success of the approach to working length determination is predicated on two things: (1) the accuracy of the radiograph exposed with the file in place in the canal and (2) ensuring that the file does not move from its original position before it can be removed safely from the canal after examining the working length film. It is incumbent upon the clinician to examine the working length film not only for the position of the file in the tooth but also for proper angulation, eliminating films that are foreshortened or elongated as being nondiagnostic. For rapid access to clear and diagnostic films, digital radiography that can provide enhanced imaging is preferred (see Chapter 3).

Once a quality working length radiograph is obtained, the major challenge facing the clinician is interpreting the findings. Numerous studies have identified problems in radiographic interpretation, both in inter- and intra-examiner reliability. Films exposed using a right-angle paralleling technique may result in magnification of the findings; some believe that using a paralleling device coupled with a grid for the pretreatment radiograph provides a consistent method for measurement control. Using the bisecting-angle technique, the radiographic distance of files placed in teeth from the apical vertex was 0.7 mm shorter than the actual anatomic file position.

Radiographic working length determination for single rooted teeth is usually a simple task of exposing a film that is parallel to the front surface of the x-ray tubehead (Fig. 9-22). Few if any anatomic structures are superimposed on the root in this situation, and length determination is straightforward. With multirooted teeth, the superimposition of files on one another and the presence of anatomic structures may often impede easy assessment of the working length.

An often misunderstood method of radiographically assessing the working length is the buccal object rule or SLOB (same lingual, opposite buccal) rule, in which buccal or lingual anatomic structures can be placed predictably on the x-ray film (see Chapter 3). By using this rule, individual files in the buccal and lingual roots of many anterior teeth with two canals or roots and all posterior teeth can be visualized and distinguished from each other (Fig. 9-23). Mesial buccal and distal buccal roots of maxillary premolars and molars can be shifted to expose the palatal root, and the zygomatic arch can be displaced from molar root apices for clear viewing of working length files (Fig. 9-24).

Clinical experience suggests that the major reason for not using the buccal object rule is the inability of the clinician to rapidly and easily interpret the findings. Simply stated, when the x-ray tubehead is moved in any direction, the file or structure to the lingual will move with the tubehead. Likewise, if the tubehead is moved to a mesially or distally angulated position, the buccal object will move in the opposite direction, or to the distal or mesial, respectively. A slight shift of 20 to 30 degrees will in most cases allow an unobstructed view of the desired target. This rule works equally well in the horizontal or vertical plane. For example, with working length files in the mesial buccal and mesial lingual canals of a mandibular molar, and a horizontal shift of the x-ray tubehead 20 to 30 degrees to the mesial, the lingual canal (file) will move to the mesial—the same direction as the tubehead (Fig. 9-25). The buccal canal (file) will move opposite the tubehead or to the distal. Likewise, because the zygomatic arch is located buccal to the root apices of the maxillary molars, a decrease in the tubehead vertical angulation to a
A mandibular canine that has a periapical radiolucency is presumed to be nonvital. Many clinicians would subscribe to the penetration of the apical foramen and filling to the root length in these cases, claiming that healing will not occur without this approach. B, Working length is established short of the root length but at the natural constriction, and the canal is filled. C, Twelve-month reexamination shows evidence of healing, and the patient is symptom free. (Case courtesy Dr. Erick Menegazzo, Dallas, TX.)

Using a parallel technique and constant reproducible angles, a slight 20- to 30-degree horizontal or vertical tubehead shift can predictably shift roots and structures to aid in accurate working length determination. Although it takes time and experience to develop this reliable technique, once mastered it greatly simplifies working length determination by minimizing problems encountered in the interpretation of undiagnostic radiographs. Hence the quality of root canal treatment can be enhanced.

**Working Length Determination: Electronic Apex Locator**

Electronic apex locators (EALs) have been available for almost 40 years for measuring the length of the root canal. These instruments work on the principle that the resistance between
Applying the buccal object rule or SLOB (same lingual, opposite buccal) rule using enhanced clear-view digital radiography to determine the working length for a maxillary premolar with two aligned roots. A, Preoperative, using digitally enhanced clear view. B, Radiograph taken with a slight distal inclination of the radiographic beam using clear view.

Mandibular molar working length radiograph taken with the cone angled from the mesial, with the beam going distally.

The periodontal membrane and the oral mucosa is a constant 6.5 kilo-ohms. More recently, the resistance-type apex locators have been superseded by impedance and frequency-type instruments which have been reported to be accurate to within 0.5 mm greater than 90% of the time.51 Apex locators can be used as an adjunct in determining working lengths where problems with anatomic variations obscure visualization of the periradicular area.40 In addition, they may be used to determine perforations or in patients where radiation exposure needs to be reduced.23

One issue of concern with EALs was their ability to work in the canal in the presence of various fluids such as blood and irrigants. Initially this was a problem, but most EALs have resolved this issue.19 Another issue was the size of the root canal, in particular the size of the apical constriction and the use of various file sizes. For best results, the use of a file that closely approximates the width of the constriction is recommended.32,33 What must be recognized, however, is
that apex locators are no substitute for high-quality radiographs that yield invaluable information regarding root morphology and curvature, calcification, number of canals and roots, and anatomic anomalies.

A comparison between radiographs and the apex locator found the apex locator to be significantly more reliable than the radiograph for determining working length. These findings suggest serious consideration be given to the use of apex locators as the primary means of determining the working length during endodontic procedures.

**Working Length Determination: Other Clinical Techniques**

Two other techniques have been advocated for determining the working length of the root canal: (1) the use of paper points and (2) tactile sensation as a small instrument is placed slowly in the canal. Paper points may be helpful in determination of the canal exit if the canal can be dried of any periapical fluid. Inflamed tissues will moisten the tip of the paper point at the level of the canal exit (Fig. 9-26). If, however, there is significant bleeding or the paper point is not made of tightly compacted paper, it may absorb a lot of blood and not provide a reasonable accurate indication of the position of the constriction. This technique is empirically based and has no scientific evidence to support its routine use.

The use of tactile sensation also has the potential for significant variables, especially in light of the wide variety of apical constrictions that may occur. The first file to bind in its apical movement may not define the constriction accurately. To overcome this problem, initial flaring or preflaring of the canal is recommended to eliminate any false coronal interferences to instrument passage apically and enhance tactile sensation apically.

There is no one technique that will work in all situations. Often, using more than one of the available techniques in a particular case will be necessary to achieve a reasonable estimate of the working length. Even then, anatomic factors that may influence the determination of working length may not always be evident or identified.

**FIGURE 9-26** Digital radiographic series of a mandibular molar using the clear-view option. Pulp is vital and inflamed. A, Preoperative. B, Working length with files positioned at the natural constriction protecting the vital tissue at the root apex. Patency filing is NOT used in these cases; there is no scientific evidence to support its use. C, Obturation to the natural constriction.
Controversies and Challenges
With the Pulpal and Periapical Status and Their Impact
on Working Length Determinations and Choices

The wide range of anatomic variables and technical interpretations regarding the apical location for determining the working length have been identified. Because the location of this variable terminal position for working length, cleaning, shaping, and obturating the root canal has resulted in significant clinical opinions, applications, and advocacies, at least two camps of polarized thought and a vast array of multiple outliers have evolved. Advocates have been driven by passion, concern for radiographic appearance, and incorporation of cognitive dissonance into their decision making and proffering. One major philosophy is to retain all procedures within the confines of the root. As determined by the position of the apical constriction, while the other philosophy espouses confining the determination of working length, cleaning, shaping, and obturation to the anatomic root apex or root length. In most teeth, overlap or agreement may occur in some cases, but these two philosophies are incompatible. In light of the controversy, there seems to be a middle-of-the-road position that most clinicians can travel comfortably and that will yield success. While the choices can vary, it would seem to be dependent on the status of the dental pulp, access to the end of the root, and the clinician’s skill, expertise, and experience that demonstrates that particular choices provide positive outcomes in the majority of cases. However, there does not appear to be any evidence-based data at the highest level to verify this approach, and therefore it is empirically driven.

If the dental pulp is vital (inflamed; irreversible pulpitis, see Chapter 1), the working length is established clinically as close to the constriction as possible, and all procedures are retained within the root canal. This position has been advocated as approximately 1 mm from the radiographic apex, but this dictate is flawed. The thought behind it is that the tissue that invaginates into the canal from the periodontal ligament (periodontal in nature) is not disturbed by the subsequent cleaning, shaping, and obturation accomplished within these confines (Fig. 9-27). This recommendation is based on sound wound-healing principles in that severance of the tissue at its narrowest point will create the smallest wound possible for healing. It also encourages the potential for tissue regeneration, not just repair, with the formation of cementum as opposed to only fibrous connective tissue or persistent chronic inflammation.

If the dental pulp is nonvital (obvious necrosis; presence of a periapical radiolucency), the working length is initially established as close as possible to the canal exit or slightly short of the apical foramen to clean the entire length of the canal, thereby eradicating bacteria as much as possible and removing the substrates that could encourage bacterial regrowth and multiplication. This is an empirical and contemporary approach to working length determination (including cleaning and shaping; see Chapters 10 and 11) that is promulgated by many in today’s practice of endodontics. However, because the root apex can be highly irregular, especially in the presence of obvious or even unidentified apical resorption, files placed to the apical extent of the root as viewed radiographically will likely be outside the confines of the canal and create potential damage to the root anatomy at that point. It is also possible that this technique may serve to inoculate the apical tissues with bacteria and material debris. Here also, a middle-of-the-road philosophy has been proposed: clean and shape the canal to the entire length of the root, then (1) back up or retreat into the canal sufficiently to develop a constriction or (2) stop inside the root for further intracanal procedures. However, even with this choice, the movement of materials past the root apex into the periapical tissues usually cannot be prevented.

CLINICAL PROBLEM

Problem: A 52-year-old male presented with a large swelling over the maxillary right lateral incisor, with drainage evident from the sulcus. The tooth was painful to touch, and he was told he had a cyst that would require surgery or extraction. The tooth had been opened and left open by the referring dentist to “drain the cyst.” A radiograph showed a significantly large area of bone loss (Fig. 9-28, A). The patient was provided with a number of options, including an immediate root canal procedure followed directly by surgical procedure. After discussing treatment options, the patient chose to try to save the tooth with a nonsurgical root canal procedure and would consider surgery if this first choice did not work. The lesion failed to heal.

Solution: The tooth was isolated and irrigated extensively prior to placing any instrument in the canal. The working length was determined at 1 mm short of the radiographic apex (see Fig. 9-28, B). The canal was cleaned again with small files to the terminus of the root, then further cleaning and shaping occurred at the chosen working length. The patient failed to show for his appointments for the next 7 months. When he returned, the canal was again cleaned and shaped to the working length, followed by disinfection and obturation during which a small amount of sealer was extruded beyond the apical foramen. The 1-year reevaluation (see Fig. 9-28, C) shows significant healing, with the residual filling material being compacted against the root end by the inwardly advanced bone. Under these circumstances, the clinician would consider this outcome a success, especially if the patient functions symptom free. However, the residual material will unlikely encourage a regenerative response in the tissues and may serve as a focused area of chronic inflammation for a long period of time (Fig. 9-29).
FIGURE 9-27  
A, Histologic evidence for healing at the apical foramen when intracanal procedures are maintained inside the canal (RCF, root canal filling; PDL, periodontal ligament; C, new invaginated cementum into the root canal foramen and layered on the root surface [H&E stain ×10; canine model, 120 days]).  
B, Pushing obturation materials beyond the apical constriction, with resultant periapical chronic inflammatory response (CIR). Yellow arrow shows extent of root filling and an attempt at fibrous encapsulation. No cementum is formed (H&E stain ×10; canine model, 120 days).  
C, Histologic evidence for healing at the apical foramen when procedures and materials are retained in the root canal (RCF, root canal filling; C, cementum; PDL, periodontal ligament). Arrow indicates the presence of a cemental barrier that has formed from the cells of the periodontal ligament. If the filling had gone beyond the constriction, the PDL cells would not have been able to differentiate and form a new cemental layer (B&B stain ×4; human specimen).

FIGURE 9-28  
A, Maxillary lateral incisor with significant periapical bone loss.  
B, Working length determination; patency filing was NOT used.  
C, Twelve-month reexamination; healing stable but not complete. In these situations it is not uncommon to have healing with fibrous scar tissue. (Case courtesy Dr. John Kostohryz, Dallas, TX.)
support either position is elusive and unfounded, except for information gleaned from outcome studies that take into account all phases of root canal procedures. Many of these studies are retrospective, however, and have questionable bearing on contemporary practices. Lengthy and thorough assessments of outcomes relative to termination of the working length, cleaning, shaping, and obturation of the root

![Image](https://example.com/image1)

**FIGURE 9-29** Histologic evidence for an adverse tissue response with the expression of material beyond the confines of the root canal (RCF, root canal filling, CIR, chronic inflammatory response [H&E stain ×10; canine model, 120 days]).

**CLINICAL PROBLEM**

**Problem:** A 55-year-old male requested a second opinion regarding his maxillary right second premolar. He had been advised to have the tooth removed and replaced with an implant. The tooth had a broken post, the fractured tooth margins were below the soft tissue, the root canal did not appear to be adequately filled, the apex was open, and a large periapical lesion was present (Fig. 9-30, A). The patient was experiencing minimal symptoms but did want to retain the tooth if possible.

**Solution:** The challenges in this case were many, such as post removal and management of the tooth margins and open apex. A crown lengthening procedure was performed, and the post was removed (see Chapters 14 and 17). The working length was established short of the root apex, and all cleaning and shaping were confined to this length (see Fig. 9-30, B). A custom gutta-percha cone was used along with a sealer that contained some MTA (mineral trioxide powder only); the canal was filled to the working length with minimal to no extrusion of sealer (see Fig. 9-30, C). The tooth was restored with a post, core, and crown. Reevaluations at 3, 7, 12, and 20 months indicated a symptom-free patient with a functioning tooth and evidence of bony healing around the root end, possibly into the open apex (see Fig. 9-30, D). This case highlights the variability of working length determination based on anatomic treatment factors and choices based on experience and skill.

![Image](https://example.com/image2)

**FIGURE 9-30** A, Maxillary premolar with broken post, periapical lesion, and poor root canal filling with open apex possibly due to resorption. B, Post is removed and working length is established short of the end of the root. C, Root canal filled, staying short of the resorbed apex. D, 20 months. Patient is symptom free, tooth is functional, and the periapical lesion appears to be healed.
canal system suggest that “No scientific basis exists in the literature to support the notion that the apical foramen should be pierced and root canals be overfilled for a successful outcome.”

### Posttreatment Implications and Outcomes of Root Canal Treatment Based on Working Length Philosophies

Historically, great emphasis was placed on proper management of the root apex during root canal treatment. Philosophically, most authors and clinicians were in agreement that the tissues beyond the apical constriction must be protected and not injured with excessive instrumentation or caustic drugs. Authors such as Grove, Blayney, Coolidge, Kronfeld, and Davis all agreed that termination of root canal procedures should occur in a manner that would allow for proper healing, that is, deposition of cementum at the root apex to secure a complete biological seal (see Figs. 9-9 and 9-28). Hatton probably best summed up the philosophy of the time by saying:

> Because the smaller accessory foramina react in all respects like the principal ones, the assumed risk of inserting pulp-canal filling into canals with tortuous accessory or terminal foramina may be considered discounted, and root-canal filling need not, therefore, be condemned because all accessory canals and the apical portion cannot be reached. . . . It is not wise to assume that a partial filing of pulp canals is a safe and justifiable routine procedure. The junction of the cementum and the dentin of the apex is the ideal termination of such a filing. . . . Such regeneration as the preceding must be greatly hampered by unnecessary injury of the apical structures by instrumentation or the corrosive action of many drugs used in root canals. A rigidly aseptic, gentle and accurate root-canal technic should favor these restorations.

The ideal healing response in the periapical tissues following root canal treatment would result in deposition of cementum over the apical foramina (see Fig. 9-28, C), with regeneration of the periodontal apparatus. However, repair, not regeneration, is the usual outcome. Most obturation materials available today possess no regenerative potential, having neither inductive nor conductive properties. Studies have demonstrated the negative effect of gutta-percha and calcium hydroxide on the extracellular matrix tissues and on alkaline phosphatase activity. Therefore, it would appear logical that extrusion of obturation material beyond the confines of the root canal system will further irritate the periradicular tissues and delay healing.

Controversies will continue to surround the management of the root apex, even though contemporary root canal treatment has a high rate of clinical success. With patients demanding a greater degree of tooth retention using modern treatment modalities, there will be continued efforts to identify an all-comprising technique and material to achieve the goals of successful treatment on a predictable basis. These expectations can only be achieved by establishing an evidenced-based and problem-solving approach to treatment that reflects a biological basis for the therapy rendered.

### REFERENCES


RECOMMENDED ADDITIONAL READING

Chapter 10

Problem-Solving Clinical Techniques in Enlarging and Shaping the Root Canal

In attempting to assign the success or failure of operations upon diseased teeth to their proper causes, factors of the greatest importance are frequently left out of account, and the results ascribed to some agent which may have been entirely indifferent. One of these factors, which forms the very foundation of successful root-treatment, is the manner in which the mechanical cleansing of the canal is carried out.24

R.H. Hofheinz, 1892

Problem-solving principles in enlarging and shaping the root canal system are predicated on the guidelines presented in Chapters 8 and 9: access to the canal and establishing a proper working length. Application of these concepts will minimize or prevent problems that may be encountered in enlarging and shaping the root canal system. Even though the principles of canal enlarging imply that cleaning is being done, true cleaning occurs through the use of irrigants, important enough to be addressed in a separate chapter (see Chapter 11). But while addressing the principles of enlarging and shaping, be cognizant that they go hand in hand with using irrigants and methods of debris and irritant removal that cannot be achieved with instruments alone. This concept has been firmly established in the endodontic literature.10,34,41,43,44

Application of traditional techniques in canal enlarging and shaping using stainless steel root canal instruments has received volumes of attention historically.35,50 Likewise, there are abundant articles and textbooks detailing these traditional approaches to enlarging and shaping.37,45 The global population of dental clinicians has either adopted or is moving forward with contemporary techniques using newer instruments and philosophies of canal treatment,36,57 so minimal time will be spent on problem solving the traditional approaches to treatment. However, the reader should not feel that these principles are being neglected. These concepts and their solutions have served the clinician well for decades and are just as important today for anyone who picks up a stainless steel file and inserts it into the root canal at any time during treatment. Even with the advent of rotary nickel-titanium (NiTi) instruments and their global adoption for routine root canal procedures, in almost all cases, the use of stainless steel instruments is still indicated at some time during the procedures (e.g., pathfinding, initial penetration, severely curved canals, etc).
Prevention of Procedural Errors in Canal Enlarging and Shaping Using Traditional Techniques and Stainless Steel or Nickel-Titanium Instruments

The safe and efficacious practice of endodontics, specifically root canal procedures, is based on both biological and clinical parameters, with prevention being the operative word. This discussion precludes a focus on management of problems. Most if not all can be prevented with a knowledgeable and thoughtful approach to providing care at all times. In the discussion of endodontic outcomes, only too often when cases fail, they are labeled as “endodontic failures,” or the “persistence of what is generically termed endodontic disease.” In actuality, clinician failure is responsible for the vast majority of cases in which there is persistent pathosis, newly developed inflammatory processes, or patient symptoms. Clinician failure constitutes not practicing in a preventive manner, not applying sound principles of diagnosis, and not adhering to appropriate treatment planning and treatment. A procedural error in itself may not be the cause of the failure but rather serve as an impediment to positive outcomes. Sadly, this scenario may not be identified by the clinician, and in fact the clinician only too often informs the patient the treatment did not work and recommends extraction in favor of a fixed prosthesis (primarily implant). This message is for all who choose to do endodontic procedures: heed the signals, assess what has caused the problems, and change clinical practice procedures to prevent these unfortunate occurrences. Moreover, recommend these cases of clinician failure be sent to a specialist for revision considerations (see Chapter 14).

Loss of Working Length

Loss of working length during cleaning and shaping is a common and frustrating procedural error. The problem is often only noted on the master-cone radiograph or when the master apical file (MAF) is short of the intended or initial working length. Even worse, it is often not noted until the canals are filled and a crown is placed. Too many times it is never noted (Fig. 10-1). Assuming that a clean, dry canal with proper shape has been developed, reestablishing canal length becomes time consuming, tedious, and often hopeless. Loss of working length may be secondary to other procedural errors (e.g., canal blockages, ledges, perforations, fractured instruments) which occur during the canal enlarging and shaping process and can be identified early in the procedures (Fig. 10-2). In most instances, however, the loss of working length is due to the packing of dentin chips in the apical third of the canal. The occurrence of this problem, with some subtle exceptions, is almost exclusive to the use of hand stainless steel instruments in the root canal. The main shortcomings that promote loss of working length are listed below, and logic would support preventing the problem by eliminating these shortcomings.

- Failure to irrigate frequently and copiously with a tissue-dissolving irrigant (sodium hypochlorite [NaOCl])
- Failure to recapitulate (Fig. 10-3) (periodically passing a small file to the desired working length to ensure debris is not being packed); in some circles, referred to as apical clearing, defined as removal of debris from the apical portion of the preparation but not going past the canal constriction
- Failure to radiographically verify the working length during the enlarging process if necessary
- Malpositioned instrument stops (Fig. 10-4, A)
- Failure to record and regularly use stable reference points (see Fig. 10-4, B)
- Skipping instrument sizes, especially in curved canals
- Fracturing an instrument without realizing it has occurred
- Aggressive use of instruments in small, tight, and curved canals

Each one of these errors is easily avoided with (1) attention to detail during instrument application and (2) generous use of irrigants during enlarging and shaping.

If nickel-titanium (NiTi) rotary instruments are used properly during canal enlarging and shaping, the same shortcomings may enter into the process, but loss of working length occurs infrequently. The major cause of loss of working length with NiTi rotary files appears to be excessive use of these instruments, retaining them in the canal for longer than 1 to 3 seconds while they are achieving their goals apically.
particles and canal wall; see Fig. 10-5, C). Once the catch is felt, the file is carefully rotated in a stem-winding fashion along with a slight in-and-out motion until the tip of the instrument bypasses the obstruction and negotiates the canal to length. Placing a relatively straight instrument into a milieu of metallic filings or dentin debris may push the particles and canal wall; see Fig. 10-5, C). Once the catch is felt, the file is carefully rotated in a stem-winding fashion along with a slight in-and-out motion until the tip of the instrument bypasses the obstruction and negotiates the canal to length. Placing a relatively straight instrument into a milieu of metallic filings or dentin debris may push the
particles more apically into the canal or periapical tissues, making them irretrievable. All recovery procedures should be performed with a lubricant in the canal.

Once the instrument begins to advance further into the canal, or if it expediently reaches the estimated working length, a radiograph is obtained to verify the position of the file. The instrument should not be removed until it can be used in small-amplitude strokes, moving circumferentially to dislodge the packed debris. When sufficient space has been developed through or along the side of the blockage, a smaller-sized Hedström file can be placed to length. Moving this instrument on the outstroke will eliminate the debris. To bore through dense blockage with dentinal chips, chelating agents such as RC-Prep, REDTAC, or liquid ethylenediamine tetraacetic acid (EDTA; see Chapter 11) may be used to soften the plug to facilitate penetration. If the plug has not been penetrated, the file may be creating a false canal in the dentinal wall.

Whenever there is failure to penetrate or bypass blockage, complete enlarging and shaping at a new working length coronal to the blockage (Fig. 10-6) are recommended. Variations in obturation techniques such as diffusion, thermoplasticized gutta-percha, warm vertical compaction, or core-carrier procedures can be used to enhance penetration of the gutta-percha and sealer around or through the blockage (see Chapter 12). Periodic reassessment is necessary, and if further treatment is deemed appropriate, surgical intervention to correct the problem may be warranted (Fig. 10-7). If surgery is not feasible, intentional replantation or extraction and replacement with an artificial prosthesis such as an implant may be indicated if symptoms persist.

Many authors and clinicians would also list separation or breakage of intracanal instruments, especially in curved canals, as a major cause of canal blockage or loss of working length (Fig. 10-8). This problem has been addressed in Chapters 5 and 14. However, during the application of NiTi rotary instruments, there are unique circumstances that tend to predispose to instrument separation and canal blockage (Fig. 10-9). In many respects, the concern for instrument breakage has prevented many clinicians from adopting the use of rotary NiTi instruments. This is unfortunate because the minimal potential for instrument separation does not have to be a deterrent to usage if some basic principles are followed. First, these instruments are always to be used in a crown-down technique after a tapered pathway for the instruments has been developed. The pathway will ensure ease of

![Figure 10-5](image1)

**Figure 10-5** A, Diagram showing dentinal chips and tissue debris packed in the apical portion of the canal. B, A stiff file is curved in the apical 1 to 3 mm at a 30- to 45-degree bend and placed to the level of the blockage. C, The file is rotated slowly until it catches in the debris then advanced slowly in millimeter strokes to remove the blocking debris. D, Once the catch is felt, the file is carefully rotated in a stem-winding fashion along with a slight in-and-out motion until the tip of the instrument bypasses the obstruction and negotiates the canal to length.

![Figure 10-6](image2)

**Figure 10-6** A, Note the block (most likely a ledge) in the mesial canals of a mandibular molar. B, After placement of a 45-degree bend, one of the canals was penetrated and negotiated to the working length. The other canal could not be penetrated, or possibly it joined the patent canal. C, Obturation with a softened gutta-percha and sealer technique.
movement with minimal pressure, binding, and torque on the instrument during canal penetration. The pathway can be created with stainless steel hand K-files (No. 06 to 20) intended for this purpose or with NiTi rotary PathFiles (Dentsply Mâìllefer, Ballaigues, Switzerland). The pathway that is developed favors variably tapered NiTi instruments and small constant-tapered instruments (0.04 to 0.06, Nos. 15 and 20). When time is taken to develop the pathway, additional important information is identified by the clinician, such as canal curves, the joining of canals, rapid deviations, and multiple canals. In light of these findings, most causes for loss of working length can be prevented.

A final note on this issue concerns the cost of the newer NiTi instruments and their value in problem prevention and the quality of the final enlarging and shaping process. While stainless steel instruments can still be used for these procedures, the higher incidence of errors and problems that occur would seem to compel the clinician to switch to instruments that can prevent these problems, thereby minimizing unacceptable treatment, need for revision, or the wholesale extraction of teeth. A word of caution to the clinician who continues to use the stainless steel file for canal enlarging and shaping, especially in curved canals: When using stainless steel instruments, placing a small, accentuated curve in the apical 1 to 3 mm is essential prior to placement in any canal during initial penetration and canal negotiation.

**Deviations from the Canal Anatomy**

Deviations from the normal canal anatomy are usually in the form of ledges that can occur anywhere along the length of the canal (Fig. 10-10): zips, that usually occur at the apical extent of the canal (Fig. 10-11); false canals, which occur if a ledge is accentuated with aggressive instrument activity of the instrument tip against the wall until the instrument creates its own exit out of the root (some refer to as a root perforation) (Fig. 10-12); or strip perforations that occur with the lateral cutting of an instrument anywhere along the root wall (primarily in areas of root wall thinness or natural external root invaginations), resulting in a longitudinal laceration of the root structure (Figs. 10-13 and 10-14).*

As with the loss of working length, these errors occur primarily with the use of stainless steel hand instruments (K-files). However, in any given root canal anatomy, these problems may also occur when using NiTi rotary instruments with lack of attention during instrument application. In this regard, deviations with NiTi instruments are prevented by (1) developing a smooth, clean pathway in the canal before placement of specific NiTi instruments used for enlarging and shaping, and (2) using the instruments only to their desired length for only a few seconds. Repeated placement of these instruments to length or holding them at length during rotation will result in canal deviations and possible breakage, especially if excessive pressure is placed on the instrument by the clinician.

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*References 5, 22, 26, 34, 42, and 55.
Diagrammatic representations of the four most common reasons for breakage of any endodontic intracanal instrument: canal convergence (A), S-shaped canals with multiple curves (B), abrupt canal deviations (C), and severe and rapid apical curvatures (D). These anatomic complexities are especially important in the application of NiTi rotary instruments. E, Histologic evidence for the complexities in the case of the severe apical curvature. F, Radiograph showing the severe apical curve in the distal root of the second molar. G, Radiograph shows three of the four anatomic challenges. In the mesial root of the first molar, there is evidence of canal convergence (black arrow) and an S-shaped apical curve below the convergence (white arrow). The mesial root of the second molar has an abrupt deviation (white arrow) of the root and canal anatomy in the mesial root (highlighted in red).

Inadequate or Inappropriate Enlarging and Shaping That Hinder the Provision of Quality Treatment

Enlarging and Shaping Beyond the Canal Terminus

The excessive movement of instruments (overinstrumentation) beyond the apical constriction violates the periodontal ligament and alveolar bone. Many problems may arise from this error. Loss of the apical constriction creates an open apex with an increased likelihood of pushing debris past the confines of the root canal, or overfiling, lack of an adequate apical seal, and pain and discomfort for the patient. Excessive instrumentation beyond the constriction may be recognized when hemorrhage is evident in the apical portion of the canal, with or without patient discomfort. Another way some clinicians recognize this problem is the presence of what is referred to as a weeping canal, which results from tissue fluids backing up into the canal due to damage to the
periapical tissues. With an apical foramen that has been opened arbitrarily, the fluid can back up into the canal and make obturation and sealing of the canal challenging. Furthermore, if the tissues have been inoculated with bacteria from the root canal, persistent weeping may be due to localized tissue destruction from bacterial invasion. If the apical environment is bacteria free, the trauma of overinstrumentation should not affect the ultimate healing potential of the tissues. Thus performing all instrumentation within the confines of the root system is imperative, especially in cases of a necrotic pulp.

Prevention is key to this problem. First, good radiographic techniques should be used to accurately determine the apical constriction of the root canal, and sound reference points should always be used (see Chapters 2 and 3). Using stable instrument stops placed perpendicularly to the shaft of the instrument is essential and will allow predictable retention of all instruments within the confines of the canal system. Occlusal reduction or refinement are always done before working length determination, enlarging, and shaping. Subsequent to working length determination and some initial enlargement, the working length can be verified when necessary. Attention to detail during all enlarging and shaping procedures is the modus operandi.

If the apical constriction has been lost after excessive instrumentation, there are a number of ways to manage this dilemma. First, a new apical stop can be established within the confines of the root canal. This position will be approximately 1 to 2 mm from the radiographic apex; the stop is equivalent to two to three sizes larger than the first file used to bind at that position. Second, a plug of dentin chips or pharmaceutical-grade calcium hydroxide (Ca(OH)₂) can be placed apically to control the movement of gutta-percha and sealer during compaction procedures (Fig. 10-15). A Hedström file can be used short of the working length in a dry canal to obtain the dentin chips during canal enlarging and shaping and in the middle and coronal thirds of the canal. The chips are packed apically to the working length with a paper point or small plugger. If the dentin chips are contaminated, a plug of mineral trioxide aggregate (MTA), such as ProRoot MTA (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), can be placed apically. A measured plugger that fits in the canal to the desired length is used to carry the material apically to the desired depth, followed by gentle apical compaction.

Some clinicians and authors recommend the use of patency filing. This is described as the passage of small instruments (No. 08 to possibly even a No. 20 K-file) beyond the canal terminus. The rationale for this procedure varies and is empirical; there are no substantial studies that support the concept and technique. In fact, the repeated movement beyond the canal terminus with larger instruments and in the presence of canal curves may or may not alter the canal anatomy sufficiently to make

**FIGURE 10-10** Diagrammatic representation of a ledge (see Fig. 10-2, B for a radiographic image).

**FIGURE 10-11** A, Diagrammatic representation of a zip. B, Cleared tooth specimen showing a zip (red arrow) with narrowing (elbow black arrow). C, Radiograph with canal zip in the apical portion of the distal canal of the first molar.
perforation of the apical constriction. A rotary NiTi file may not cause the problems associated with variably tapered instruments but may create problems associated with constant-tapered instruments, especially if left to rotate in the canal longer than 1 to 2 seconds.

There are studies that claim that unless the apical portion of the canal is taken to larger sizes, it will not be clean with regard to surface cleaning and bacterial removal or reduction. Larger, however, is not always better for many root canal systems as far as the final apical diameter—unless this can be done using instruments with larger tapers but not necessarily larger diameters. For example, an apical size 50 prepared with a K-File will develop a 2% taper, but a variably tapered instrument that is only a size 30 apically may have as much as a 9% taper. In the former case, more tooth structure may have to be removed that may not align with the external root anatomy. In the case of the latter, the shape follows the external anatomy, and the size still allows for good cleaning with irrigants and disinfectants; the progressive size apically is 30 at the tip, 39 one millimeter coronally, 48 two millimeters coronally, and 57 three millimeters coronally. With the size 50 K file, it will only be a size 56 three millimeters coronally from the apical working length. Another solution would be to retain the smaller sizes in the apical portion of the canal using rotary instruments, and then to further clean the apical 1 to 3 mm with hand instruments that can be curved subtly if necessary to contact the canal walls.

Overpreparation is a special concern in the apical portion of the canal system, but it can easily occur in the middle and coronal portions of the canal as well. Excessive canal flaring or shaping increases the chances of stripping and perforation. When flaring the canal, a step-back or step-down procedure is recommended to create a continuously tapering funnel preparation for obturation with gutta-percha. If necessary, careful and conservative use of rotary instruments (e.g., variably tapered NiTi files) can be considered to assist in refining canal shape. Excessive removal of tooth structure is not necessary; overprepared (overflared) canals are potentially weaker and subject to fracture during compaction and restorative procedures.

Excessive Removal of Root Dentin

Excessive removal of tooth structure (overpreparation) in a mesial distal and buccal lingual direction can result in root weakening, laceration of the root wall, or perforation. During canal enlarging and shaping, the size of the apical preparation should correspond to the respective size, shape, and curvature of the root. For example, attempts to produce an apical seat equivalent to a No. 40 K-file in a moderately curved (10 to 20 degrees) mesial buccal canal of a mandibular first molar are likely to cause not only zipping of the root apex but also complete cleaning and obturation difficult. Each case is dependent on the three-dimensional apical anatomy and clinician application of the instruments. Furthermore, instrumentation into the apical periodontal tissues may impair or delay positive outcomes, depending ultimately on the nature and impact of the root filling material.

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Figure 10-14 A, Mandibular molar with signs or symptoms requiring treatment. Note the root invagination on the distal surface of the mesial root. B, Two years later, the tooth exhibited significant bone loss apically and in the furcation. C, Working length determination. D, Obturation with strip perforation. E, Nonsurgical removal of the protruding gutta-percha cone and placement of mineral trioxide aggregate. F, Nine-month reevaluation shows good healing.

Figure 10-15 A, Diagrammatic representation of a root canal in which the apical constriction has been violated and the canal has been overinstrumented to a large size. B, Preparation of a new apical constriction 1.5 to 2 mm inside the root.
Failure to Properly Enlarge and Shape the Canal

Failure to remove pulp tissue, dentinal debris, and microorganisms from the root canal system (underpreparation or inadequate preparation) is a common error in root canal procedures, even with the vast array of NiTi instruments available. If the canal system is improperly shaped, it can prevent three-dimensional obturation unless possibly a softened core-carryer technique is used (see Chapter 12). This problem is usually not present when using greater-tapered NiTi instruments to the working length, unless the instruments are not applied properly to the canal anatomy. For example, some studies have questioned the ability of rotary NiTi instruments to enlarge and shape canals that are wide buccal-lingually. It is not the inability of the instruments during application that falls short of ideal, but rather how they are used by the clinician.

Inadequate preparation (which includes enlarging, shaping, cleaning, and disinfecting) of the canal system occurs in one or more of the following ways:

1. Insufficient preparation of the apical dentin matrix or apical third of the canal to control filling materials in the canal. This occurs when the shape of the apical portion of the canal is irregular, and minimal instrumentation is done in favor of small apical sizes; when the canal is reasonably round, and the enlarging is insufficient to contact all the canal walls; or when NiTi rotary instruments are only used in a vertical direction—a major flaw in using NiTi rotary instruments, not understood by many clinicians— and not used in a lateral or shaving motion when the canal anatomy indicates this type of enlarging and shaping are necessary.

2. Insufficient use of tissue-dissolving and bactericidal irritants (NaOCl) or their inability to reach the apical third because of inadequate shaping due to small apical sizes with minimal tapers. In such a case, the canal will be underprepared.

3. Inadequate canal shaping (flaring) that prevents depth of spreader or plugger penetration during compaction. In this case, there will be incomplete obturation with voids.

4. Establishing the working length short of the apical constriction, especially in cases of pulpal necrosis.

5. Inadvertent development of ledges and blockages that prevent complete canal preparation.

Inadequate canal preparation can generally be prevented by adhering to the principles of problem solving previously discussed in this chapter. The existence of this problem is usually identified at the time of obturation when the compacting instruments cannot be placed to the appropriate length for the filling technique chosen; when the master apical file cannot reach the working length; or when the master apical file penetrates beyond the established working length, with subsequent apical perforation (lack of apical stop and constriction).

Underprepared canals are best managed by adhering to sound principles of proper length determination, canal enlarging and shaping, and recapitulation when necessary. Copious irrigation, with proper irrigation needle penetration (see Chapter 11) and attention to detail during instrumentation will ensure a properly cleaned canal. Before obturation, spreaders and pluggers must be fitted to determine their depth of placement and ensure proper canal shape. A critical assessment of the preparation can often be made only by evaluating the final obturation, but this will not provide a true three-dimensional appraisal of the overall accomplishment, especially the cleanliness of the root canal system.

Prevention and Management of Procedural Errors in Canal Enlarging Using Contemporary Techniques and Rotary Nickel-Titanium Instruments

The introduction of NiTi alloy to endodontics is purported to have problem solved many of the negative features associated with stainless steel instruments, even in the hands of neophytes. Endodontic files made from this superelastic alloy are significantly more flexible and highly resistant to fracture and corrosion. This is particularly true with the newer instruments that are made of M-wire (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), a technologic improvement over the superelastic wire that was used initially for these types of instruments. M-wire files include Dentsply’s ProFile Vortex; GT Series Xfiles. Other new developments include heat-treated metals that change the crystalline structure of the metal (R-phase [SybronEndo, Orange CA, USA]), resulting in more durable instruments, and Twisted Files or instruments with asymmetrical cross sections that increase flexibility and decrease stresses during application (Micro-Mega, Thônex, Switzerland). The advantages of NiTi files for canal cleaning and shaping seem to be enhanced canal negotiation, especially in curved canals; decreased canal transportation and ledging; reduced chance for breakage; faster and more efficient instrumentation; and no requisite precurving as for stainless steel instruments.

The clinician must understand that NiTi instrumentation is not without its problems. A long learning curve may be necessary, and many unknowns remain. This is especially true as many newer instruments are appearing in the marketplace on a regular basis. For example, when stressed, these instruments undergo a microscopic phase transformation and become structurally weaker. However, no visible or macroscopic indication that the metal has become fatigued is usually exhibited. Thus a NiTi file may break without warning (unwinding), especially if used improperly.
K-files, Hedström files, S-files, Flex-R files, reamers, and compactors are available in NiTi alloy, but because of their extreme flexibility are not designed for creating a pathway in the canal, for negotiating small, calcified curved canals, or for bypassing ledges. Stainless steel instruments should be used initially for pathfinding because of their enhanced stiffness. The recent introduction of the C+ file or ProFinder files (DentsplyMaillefer, Ballaigues, Switzerland) exclusively for this purpose supports this need.

Once the canal has been negotiated or the ledge has been bypassed and removed, NiTi instruments can then be used. Because a reduced tactile sensation may exist when NiTi hand instruments are used, the clinician may feel that the file is not cutting. On the contrary, NiTi files can be as aggressive as stainless steel files, and excessive removal of root dentin can occur if filing pressures and instrumentation times are not carefully monitored. If NiTi hand files are used in a conventional push-pull or filing motion, especially K-files and S-files, deviations in anatomy may occur, with a tendency of the outer wall of the preparation to belly out below the height of curvature. This is probably attributable to the file’s predisposition to unflex or straighten out during application. Research suggests that NiTi files may function best and cause less transportation and deviation in anatomy when used in a reaming or rotary motion, as that found with hand greater-taper (GT) files or hand ProTaper instruments. In turn, the evolution of mechanized or rotary instrumentation, using specially designed NiTi files in gear-reduction or electrically driven high-torque hand pieces, has revolutionized root canal procedures because of their speed (ranging from 250 to 500 rpm) and efficacy in canal shaping and maintaining canal curvature. Although such variably shaped NiTi files are quite flexible, NiTi metal, like any other metal, will eventually fail when rotated in a curved canal and definitely in a multicurved canal. Strict monitoring of instrument use should be maintained so that NiTi files can be periodically disposed of before failure. In addition, care must be taken to use these systems per the manufacturer’s instructions (e.g., a crown-down approach with light pressure is essential when using most NiTi rotary instruments). These systems require a significant learning curve to achieve mastery. Rotary NiTi instruments are used in the coronal-to-apical technique or crown-down technique, thereby eliminating many of the previously discussed problems with stainless steel instruments.

**Importance of the Crown-Down Technique**

The clinical benefits of using the crown-down technique are many and greatly influence the achievement of predictable success with nonsurgical root canal procedures. These benefits can be achieved with all instrument types, but efficiency favors rotary NiTi instruments. However, integrated enlarging and shaping techniques with a wide range of instruments will often be necessary, given the anatomic challenges posed by the root canal system. These benefits include:

- Easy removal of obstacles that prevent access to the root apex (e.g., pulp stones)
- Enhanced tactile feedback with all instruments by removal of coronal interferences
- Enhanced movement of instruments apically into the canal
- Enhanced working length determination as a result of minimal tooth contact in the coronal third
- Increased space for irrigant penetration and débridement
- Rapid removal of the bulk of dental pulp tissue located in the coronal third
- Straight-line access to root curves and uniting canal junctions
- Enhanced movement of dentinal and soft-tissue debris coronally
- Decreased deviation of instruments in canal curvatures by reducing root wall contact
- Decreased canal blockages
- Minimization of instrument separation by reducing contact with the root canal walls
- More ideal canal shapes that facilitate and promote enhanced canal obturation
- Predictable levels of quality canal cleaning and shaping
- Facilitation of one-visit root canal procedures within a reasonable period

Biologically, many of the benefits attained with the crown-down technique mirror or complement the clinical benefits and ultimately contribute significantly to the overall case success. These include:

- Rapid removal of contaminated, infected tissue from the root canal system
- Removal of tissue debris coronally, thereby minimizing the pushing of debris apically
- Reduction in postoperative pain that may occur with the apical extrusion of debris
- Better dissolution of contaminated tissue, with increased irrigant penetration
- Easy smear layer removal because of better contact of chelating agents with canal walls
- Enhanced disinfection of canal irregularities as a result of irrigant penetration in patent canals and patent tubule orifices after removal of the smear layer
- More accurate management of the working length, canal cleaning and shaping, and control of obturation materials with respect to the biology of the apical root tissues and surrounding periradicular tissues

A collage of cases that highlight the more common errors encountered in canal enlarging and shaping when the dictates of prevention described in this chapter are not adhered to is seen in Fig. 10-16.
FIGURE 10-16  A, Fractured NiTi instrument segment in the apical portion of a significantly curved canal; removal not recommended. B, Maxillary molar and premolar with poorly shaped and obturated canals short of ideal. Patient has had continuous pain for weeks after treatment; revision recommended. C, Mandibular molar with poorly shaped and obturated canals and broken instrument in the mesial buccal canal. All canals short of ideal; revision recommended. D, Maxillary molar with poorly shaped and obturated canals short of the ideal; revision recommended. E, Mandibular molar with multiple enlarging and shaping errors, strip perforation in the mesial root, broken instrument in the mesial root, and post perforation in the distal root; extraction recommended. F, Even with NiTi instruments, major errors can occur when not paying attention to detail. Note strip perforation in the mesial buccal root (red arrow), apical deviation in the mesial buccal root (white arrow), and failure to gain full length in the palatal root (black arrow). The palatal curves to the buccal approximately 85% of the time.
REFERENCES


43. Schäfer E, Schlingemann R: Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 2. Cleaning effectiveness and shaping ability in severely curved

RECOMMENDED ADDITIONAL READING
Problem Solving in Cleaning and Disinfecting the Root Canal System

One of the most neglected phases of endodontic treatment is the removal of minute fragments of organic debris and dentinal shavings from the root canal. It is an axiomatic principle of surgery that before a wound is ready for chemotherapy, all necrotic material and debris must be removed. Many dentists have failed to appreciate the importance of this basic rule of surgery and have relied principally on drug therapy rather than on thorough cleansing and irrigation of the root canal.26

L.I. Grossman, 1955

The concepts of cleaning and shaping the root canal system have been with us for years. In many respects, the two activities are incompatible when there is sole reliance on intracanal instruments to accomplish these goals. Instruments can shape the canal, but true cleaning relies on irrigants.

What Is the Key Role of and the Rationale for the Use of Intracanal Irrigants?

The key role of root canal irrigants is to clean the canal during the enlarging and shaping process. Specifically, the objectives of the cleaning and shaping process are to remove the vital or necrotic dental pulp tissue and neutralize or eliminate bacteria and their associated metabolic byproducts. Although the shaping of the root canal has been enhanced with advances in metal technology, the actual cleaning of the canal still relies heavily on the adjunctive use of chemical rinses and soaks to achieve these goals because of the anatomic complexity and irregularity of the tooth (Fig. 11-1). In this respect, the use of irrigants that possess multiple characteristics, such as tissue-dissolving attributes and bacteriostatic or bactericidal capabilities, is warranted at all times. Other advantageous properties include rinsing away debris created during cleaning and shaping, lubricating the instruments, and demineralizing and removing the smear layer.

No one solution as yet possesses all the properties of an ideal irrigant, but it is important to emphasize that the use of neutral solutions for the irrigation process (e.g., water, saline, anesthetic solutions) serves no useful purpose in the root canal system.

The effectiveness of NaOCl in cleaning and disinfection depends on the concentration of available chlorine and the pH of the solution. Hypochlorous acid (HOCl) is a weak acid and dissociates to the hypochlorite ion (OCl⁻) and...
Problem Solving in Cleaning and Disinfecting the Root Canal System

Chapter 11

susceptible to percentages as low as 0.5%, but these species may not reflect bacterial populations found in the tooth with a necrotic infected pulp. Clinical use for both bacterial control and tissue dissolution favors percentages from 1% to 6%, with studies claiming various levels of superiority with a particular percentage. Manipulations that enhance the efficacy of NaOCl include warming the solution to at least 37°C. Within the bacterial species studied, bactericidal rates for NaOCl more than doubled for each 5°C rise in temperature in the range of 5°C to 60°C. In particular when using steady-state planktonic E. faecalis cells, a temperature rise of 25°C increased the efficacy of NaOCl by a factor of 100. Within this framework of heating NaOCl, the capacity of a 1% solution at 45°C to dissolve human dental pulps was found to be equal to that of a 5.25% solution at 20°C. While apparently effective in a laboratory setting, there are no evidenced-based clinical studies to verify this efficacy as it relates to successful outcomes.

Using the NaOCl solutions for periods of 5 to 30 minutes in the root canal has also been advocated to enhance its effectiveness, but optimal times have not been determined. The application of sonics and ultrasonics to the NaOCl solution have also been advocated, but the efficacy of these combinations has shown mixed results.

FIGURE 11-1 A, Tissue debris sandwiched in the anastomoses between the mesial buccal and mesial lingual canals of the mandibular molar after cleaning and obturation. B, Tissue debris that remains in a C-shaped canal system after cleaning and shaping (H&E stain ×10). C, Scanning electron micrograph (SEM) shows the smear layer that is present during the shaping of the root canal is packed with tissue debris, dentin chips, and bacteria (×750). D, SEM showing surface tissue debris in anatomic irregularities after shaping and cleaning the root canal with irrigants (×2000).

CLINICAL PROBLEM

Problem: What is the best irrigant to use during root canal procedures and why?

Solution: The best irrigant is sodium hypochlorite (NaOCl) in various concentrations. NaOCl is a highly effective irrigating solution that is both antimicrobial and has tissue-dissolving capabilities. Additionally, it possesses bleaching and lubricating properties and has been shown to inactivate endotoxins, although calcium hydroxide is much better in this latter regard.

The concentrations of NaOCl that are used during root canal procedures vary among clinicians and may very well be chosen empirically. Some bacterial populations are susceptible to percentages as low as 0.5%, but these species may not reflect bacterial populations found in the tooth with a necrotic infected pulp. Clinical use for both bacterial control and tissue dissolution favors percentages from 1% to 6%, with studies claiming various levels of superiority with a particular percentage. Manipulations that enhance the efficacy of NaOCl include warming the solution to at least 37°C. Within the bacterial species studied, bactericidal rates for NaOCl more than doubled for each 5°C rise in temperature in the range of 5°C to 60°C. In particular when using steady-state planktonic E. faecalis cells, a temperature rise of 25°C increased the efficacy of NaOCl by a factor of 100. Within this framework of heating NaOCl, the capacity of a 1% solution at 45°C to dissolve human dental pulps was found to be equal to that of a 5.25% solution at 20°C. While apparently effective in a laboratory setting, there are no evidenced-based clinical studies to verify this efficacy as it relates to successful outcomes.

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this approach have been detailed in literature, but here again, meaningful clinical studies are lacking. Even with longer time periods, replenishment may be necessary to increase its effectiveness, especially in the presence of significant amounts of tissue and bacteria that may be encountered in highly irregular canal anatomies in cases of long-standing necrotic pulp. Similarly, when NaOCl has been used for long periods, the potential for altering the physical properties of dentin that have been highlighted in vitro but not clarified in vivo. When used in conjunction with ethylenediamine tetraacetic acid (EDTA) or 10% citric acid, its antibacterial properties are not necessarily enhanced. When these solutions are used alternatively during canal cleaning and shaping, bacterial loads may be efficiently reduced.

NaOCl should always be delivered passively to the canal to prevent a forceful extrusion beyond the apical foramen. This delivery is best accomplished by avoiding wedging the delivery needle in the canal, expressing the solution slowly, and using specially tipped side-delivery needles that enhance the cleaning of the dentin walls while minimizing potential risks during its use (Fig. 11-2). The passive movement of small amounts beyond the apical foramen should not create problems for the patient. Forceful movement of greater volumes of NaOCl will, however, be deleterious, and the literature is replete with “sodium hypochlorite accidents.”

Newer technologies that prevent this extrusion but at the same time are effective in removing the smear layer include the intracanal aspiration technique, in which the irrigant is delivered from the tip of an injection needle connected to an electric apex locator (EAL) placed 2 to 3 mm short of the root end. Studies indicate that there is limited extrusion of the irrigant when applied in this manner. A further development is the EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA). This innovative device agitates irrigation solutions during endodontic treatment. Evidence has indicated that dynamic movement of the irrigant significantly improves débridement. The system is designed to safely energize the hydrodynamic phenomenon. Claims are made that activated fluids promote deep cleaning and disinfection into lateral canals, fins, webs, and anastomoses, with minimal apical extrusion because the activator tip is placed short of the working length in the canal.

Claims have also been made relative to the application of ultrasonic irrigation devices alone and during canal cleaning and shaping. Significant débridement of canal irregularities and bacterial reductions have been noted, but the exact nature of the process has been challenged as to mechanism of action.

A development that has claimed to eliminate problems with the delivery of NaOCl is the EndoVAC (Discus Dental, Culver City, CA, USA). The device offers an apical negative pressure system that uses microcannulas to deliver irrigants to the canal and draws fluid away by evacuation. Claims are made that cleaning occurs to within 1 mm of the apex, without apical extrusion of solution. However, there are no data available at this time to indicate what happens in the last millimeter of the canal, or if this activity can penetrate into the dentinal tubules to eliminate biofilms, bacteria, or embedded endotoxins.

The most recent addition to this foray of irrigation devices is the ProUlta PiezoFlow irrigation device (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA). ProUltra PiezoFlow Ultrasonic Irrigation Needles are used to deliver irrigants by application of ultrasonic vibration. The PiezoFlow irrigation needles are used in conjunction with a piezo-electric ultrasonic energy-generating unit to provide the energy for tip oscillation. A syringe or other irrigation source is attached to the Luer-lock connection on the ultrasonic needle. Removal of irrigant is through the operatory vacuum source. Compatible irrigants include sodium hypochlorite (up to 6%), EDTA (up to 17%), Chlorhexidine (up to 2%) and BioPure MTAD, however working times with each irrigant may vary.

NaOCl contact with dentin has been questioned as to its impact on the mechanical, chemical, and structural composition of dentin. Evaluations were done ex vivo using different concentrations and different time frames to determine the impact on the inorganic phase of dentin. While higher concentrations of NaOCl affected the elastic modulus and the flexural strength of dentin, no clinical relevance has been drawn or shown from these studies.

NaOCl should not be used as the final rinsing agent when resin-based bonded root canal filling materials are planned for canal obturation. The bonding of the sealer to the dentin may be altered. Alternatives are to finish with EDTA, chlorhexidine (CHX), or BioPure MTAD (Dentsply Tulsa Dental Specialties, Tulsa OK, USA). Studies have shown that a soft chelating solution (1-hydroxyethylidene-1, 1-bisphosphonate [HEPB]) not only removes the smear layer effectively but also enhances the bond strength of intracanal resins. However, the use of EDTA or MTAD as a final

![FIGURE 11-2 Side-delivery needle enables delivery of irrigating solutions to the root canal walls to enhance canal cleaning. (Courtesy Dentsply Maillefer, Ballaigues, Switzerland.)](image-url)
What Is the Purpose of and the Rationale for the Use of Chelator Solutions in Root Canal Procedures?

Chelates are stable complexes of metal ions with organic substances as a result of ring-shaped bonds. The stability is a result of the bond between the chelator, which has more than one pair of free electrons, and the central metal ion. Chelates bind and inactivate metallic ions, in particular during their demineralizing effect on dental hard tissues when used in the form of EDTA. Detergents have been added to solutions of EDTA to reduce the surface tension of the chelate, thereby facilitating the wetting of the root canal wall and increasing the chelator's ability to penetrate the dentin. Citric acid has also been used for this purpose but may be more aggressive than EDTA. In essence, these solutions soften and dissolve inorganic dentin particles, thereby either preventing the accumulation of debris on the root canal walls or removing it once it is present.

For root canal procedures, chelating agents are available commercially in liquid and paste forms. These substances may assist in penetrating calcified orifices and root canals, enhancing the removal of the smear layer during cleaning and shaping and serving as excellent lubricants for both hand and rotary instruments (Figs. 11-4 and 11-5). Chelating agents are used primarily as "soaks" in the root canal after cleaning and shaping, or alternating with NaOCl during the cleaning process. Their application with ultrasonics appears beneficial even in the apical portion of the canal. When used in conjunction with NaOCl for 1-, 3-, and 5-minute periods in laboratory studies, the smear layer was effectively removed. These solutions have relatively limited antiseptic capacities but may assist in bacterial reduction through the removal of debris on the canal wall, possibly including biofilms. Both clinically relevant solutions (EDTA and 10% citric acid) do have an impact on the effectiveness of NaOCl by immediately reducing the available chlorine, thereby rendering the NaOCl ineffective against bacteria and necrotic tissue. The same is true for chelates in paste form, such as RC-Prep (10% urea peroxide, 15% EDTA, and glycol in an aqueous ointment base [Premier Dental, Plymouth Meeting, PA, USA]), Glyde file (15% EDTA and 10% urea peroxide in an aqueous solution [Dentsply, Surrey, UK]), and File-EZE (19% EDTA in an aqueous, water-soluble solution [Ultradent Co., South Jordan, Utah, USA]). Recent studies have identified other chelators that may be more effective than EDTA, but there are no clinical data to support their efficacy or outcomes.

An additional solution designed to remove the smear layer (in conjunction with NaOCl) is BioPure MTAD (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), which is a mixture of tetracycline (doxycycline) and acid detergent (citric acid). Because of its components, it also qualifies as a disinfectant. Studies have shown mixed results in its efficacy.
FIGURE 11-4  A, Apical calcifications in a cleared root apex will require the use of chelating agents to assist in removal and canal penetration. B, Calcifications in the midroot portion in small, irregular canal areas make cleaning very difficult. C, Multiple canal closures and narrowings (arrows) due to increased formation of irritational dentin (B&B stain ×100).

FIGURE 11-5  A, Scanning electron micrograph (SEM) showing cross-section of dentin on which a thick smear layer has formed when irrigants and chelating agents are not used during cleaning and shaping. The degree of smear layer formation is increased with the use of rotary instruments (×2000). B, Longitudinal SEM appearance of smear layer that covers the dentinal tubules and harbors undesirable irritants (×1000).
What Are the Best Disinfectants and How Should They Be Used to Achieve the Goals of Root Canal Disinfection Without Causing Problems?

Historically, root canal procedures relied heavily on a wide range of phenolic and formaldehyde preparations to disinfect the canal. Sadly, little effort was expended in tissue removal from the canal; the disinfecting agents alone were relied on to sterilize the canal. More often than not, these agents created significant problems for the patient and a false sense of achievement for the clinician if the patient appeared symptom free.

Within the modern tenets of root canal treatment, tissue removal is still the first step in root canal disinfection. When

What Is the Role of Disinfectants in Root Canal Procedures?

Disinfectants are to be used to minimize or eliminate bacterial populations in the shaped root canal system. The ability of disinfectants to achieve their goals during root canal procedures is predicated on the removal of the gross debris in the canal system and the effective dissolution of the remaining pieces of tissue and fragmented predentin following canal shaping. This is accomplished most effectively with NaOCl when the canal has been opened and shaped sufficiently to allow for a proper flow of irrigants apically and into irregularities. Disinfectants are also more effective when the smear layer has been removed, in particular with disinfection of the exposed dentinal tubules. Finally, disinfectants will only be effective in a canal system that is sealed from oral fluids.

FIGURE 11-5, cont’d C, Use of appropriate irrigants and chelating agents during cleaning and shaping can reduce the smear layer to loose particles (rather than the matted layer seen in B) that can be removed from the canal with copious soaking and rinsing with chelating agents (×1500). D, SEM showing complete removal of the smear layer in the apical portion of the canal (×1000). Note the fewer tubules and greater amounts of peritubular and intertubular dentin. E, SEM showing complete removal of the smear layer in the coronal portion of the canal with patent dentinal tubules (×1200). F, Low magnification of the root canal and dentin wall after the smear layer has been removed (H&E stain ×10).
performed with NaOCl as the irrigant, significant disinfection is achieved; only in cases in which additional agents are warranted are disinfectants indicated. This includes teeth with necrotic pulps that are being treated in more than one visit and teeth that are undergoing revision of failed root canal procedures.

For teeth that have suffered luxation or avulsion trauma, the use of disinfecting agents will be discussed in Chapter 19; for teeth undergoing apexification see Chapter 13.) Common agents indicated for use during routine root canal procedures include:

- **Calcium hydroxide**: Can be mixed in sterile water to create a water slurry that is carried to the root canal or is available premixed in a syringe (Calcigel [Dental A2Z Ltd., UK]; Pulpdent Paste/Forendo Paste [Pulpdent Corp., Watertown MA, USA]; Calasept Plus [Nordiska Dental, Ängelholm, Sweden]; Vitapex [Neo-Dent International Inc., Federal Way, WA, USA]). Calcium hydroxides have a range of pH, but ideally the higher the pH, the more effective the material. They will kill bacteria on contact and are effective in tissue dissolution.

- **Iodine**: When used in the form of iodine potassium iodide (IKI 2%), it is very effective and efficacious but not available in a commercial form.

- **Ledermix paste**: A composition of 3.21% demethylchlortetracycline and 1% triamcinolone acetonide is available in a water-soluble cream. Not approved for use in the United States.

- **Chlorhexidine**: Commonly used as a 2% solution of chlorhexidine gluconate, CHX has been shown in some studies to be efficacious when mixed with calcium hydroxide in the root canal for initial treatment, and revision, while others have indicated that CHX was more efficacious alone. Heat can enhance the antibacterial activity of both substances individually.

Basically, three disadvantages are found with all presently used disinfectants. First, if the smear layer is not removed, the agent has no access to the dentinal tubules and the bacteria that may be present within (Fig. 11-6). Second, movement of the disinfectants beyond the apical foramen into the periradicular tissues may cause adverse sequelae. Therefore, all disinfectants are to be placed carefully in the canal without application of pressure. This may be a challenge with those products that come in syringes and have long needles or tips for delivery to the canal. The delivery tips must not be bound against the canal wall. Ideally, if the materials are placed in the coronal third of the canal, a hand K-file can be used to safely carry the material apically. Likewise a rotary NiTi instrument that fits loosely in the canal can be used to place the material apically; the file is placed only to the middle third, and the rotary action will carry the material apically. Also, there are rotary instruments (PacMac Condensor [SybronEndo, Orange, CA, USA]) designed to carry the materials (primarily calcium hydroxide slurries) apically. Third, although disinfectants are not designed to be used as canal irrigants during cleaning and shaping procedures, some clinicians use various concentrations or gels of CHX (predominately 0.12%) as the irritant of choice. This solution will not dissolve tissue, chemically clean the root canal system, or have an impact on bacteria embedded in tissue debris in the canal. Therefore, the efficacy and safety of this

![Figure 11-6](image)

**Figure 11-6** A, Gross movement of bacteria into the dentinal tubules (B&B stain ×40). B, Necrotic pulp (NP) and infected canal space, with movement of bacteria into the tubules (Brown & Brenn stain ×100).
choice has not been demonstrated, and its use reflects a lack of understanding regarding the procedures of cleaning, shaping, and disinfecting the root canal system. Because the disinfectants available to the contemporary clinician are effective in achieving their goals in the root canal, the use of phenolic agents and formaldehyde products in the root canal system is not indicated and should be abandoned.

Future projects for the elimination of bacterial species include applications of ultrasonic energy during final irrigation protocols \(^{10}\); light-activated/photo-activated disinfection (PAD) \(^{34,36,65}\); and ozonated water or gaseous ozone. \(^{16}\) All initiatives require significant development and both laboratory research and clinically relevant prospective studies. In addition to attempts to eradicate bacteria, further attempts have also been made to eliminate bacterial biofilms that tend to be present when bacteria are present in the root canal spaces over long periods of time. \(^{47}\) Attempts at biofilm elimination have included dynamic irrigation protocols, \(^{60,63}\) varying irrigants and times of application, \(^{2,44,66}\) and using alkaline hypochlorites and chlorosulfamates \(^{22}\) or newly developed irrigants. \(^{24}\)

REFERENCES

Chapter 12

Problem-Solving Challenges in Root Canal Obturation

Problem-Solving List

Problem-solving challenges and dilemmas in obturation of the enlarged, shaped, cleaned, and disinfected root canal system addressed in this chapter are:

Root Canal Sealers: Their Role and Use
Gutta-Percha Obturation Techniques
   Lateral compaction
   Vertical compaction
   Thermoplasticized injection techniques
   Thermoplasticized core-carrier techniques

Resin-Bonded Obturation Techniques
Guiding Principles for All Obturation Techniques
Problems Preparing to Obtrurate the Canal
Problems During Canal Obtruration
Problems Identified After Obtruration

Gutta-percha . . . for convenience, utility, and harmlessness withal, it is invaluable.19

A. Hill, 1848

Perhaps there is no technical operation in dentistry or surgery where so much depends on the conscientious adherence to high ideals as that of pulp-canal filling.17

E.H. Hatton, 1924

The evolution of root filling materials and techniques has a long and challenging history, but not much has changed in this regard. Gutta-percha, the use of which is credited to Dr. Asa Hill in 1847, is still being used to obturate prepared root canals.19 Many teeth have been retained in symptom-free function thanks to this material filling the root canals, and any failures were not due to the material. During the past 80 years, there have been efforts to change the way root canals are filled. Materials have included paste fills, silver cones, synthetic gutta-perchas, and resin-bonded materials. In each case, there must have been a clinical problem the dental clinician faced that prompted the need for a better product or an easier and more thorough way to achieve the goal of root canal obturation. That goal: to fill completely and seal the enlarged, shaped, cleaned, and disinfected space created when the dental pulp of the tooth was removed. What were those problems, those challenges? What were their effects on what is done today? Have the problems been rectified? Is the clinician in a better position to provide predictable outcomes with the present-day obturation materials and techniques?

Dr. Neil Postman, a noted author and professor of media and communications at New York University, once posed a very useful question in an interview on PBS: “When confronted with a new technology, whether it’s a cellular phone or high-definition television or cyberspace or Internet, the question, the one question, should be What is the problem to which this technology is the solution?” Later in the interview, he concludes with the observation, “It is very easy to be swept up in the enthusiasm for technology, and of course all the technophiles around, all the people who adore technology, are promoting it everywhere you turn.”33

Turning these concepts to root canal obturation, pastes were developed to speed the tedious process of obturation and more effectively move filling material into canal irregularities.16 Innovative clinicians, who were also dabbling scientists, thought they could create a more biological filling material, one that would destroy bacteria while sealing the root canal. Silver cones were brought to the clinician to enhance bacterial control and create a more radiopaque root canal filling on the radiograph (possibly the beginning
Ideally, all sealers should be antimicrobial and biocompatible; some sealers or portions of substances within them may be absorbed when exposed to tissues and fluids. Substances used for radiopacity within the sealer are generally insoluble and may remain in the tissues either engulfed by macrophages or surrounded by fibrous capsules (Fig. 12-4). If large amounts are pushed beyond the canal confines, the patient may experience discomfort, especially if the sealer has a slow set, or chronic inflammation may persist and create problems at a later time. Sealer may be consolidated during the healing process and remain pushed up against the root of the tooth by the encapsulating tissue (Fig. 12-5), never really allowing the tissue to heal fully, although clinicians attempt to identify this as healing so long as the patient is symptom free.

Sealers are generally grouped based on their primary component or chemical makeup (e.g., zinc oxide eugenol, polyalkenoxy, epoxy, calcium hydroxide, silicone, glass ionomer, or resin based). Ideally, none of these sealers should be extruded beyond the end of the root canal, because chronic inflammation may persist (see Chapter 9). However, many clinicians attempt to extrude the sealer with their obturation technique and empirically claim that when they see sealer extruded beyond the confines of the canal, the canal is “perfectly sealed.” The fallacies in this position are that (1) a seal cannot be seen on a radiograph, (2) the radiograph only represents a two dimensions of a highly variable three-dimensional object, and (3) there is no evidence-based information to support this claim. As noted earlier, there is evidence to support the long-term presence of chronic inflammation.

Yet as we enter the second decade of the 21st century, gutta-percha still dominates. The gutta-percha cones that have been available for decades and gutta-percha on core carriers that have been used extensively over the past 20-plus years are still the filling material of choice globally—used, of course, with some type or root canal sealer or cement and compacted into the prepared root canal space.

When all the more recent developments in root canal obturation materials and techniques are considered, there appear to be recurring themes that beg Dr. Postman’s question: What is the problem to which this technology is the solution? The list includes developing ways to manage the intricacies of the root canal system, ensuring complete obturation, sealing the canal system, providing a radiographic appearance of the filled root that signifies to the clinician they have achieved their goal (and, of course, provided that needed signature of expertise), and strengthening the root canal to prevent potential fracture during function (see Chapter 20). A missing link in these themes only came into the clinician’s hands in the middle to late 1990s: new tools (nickel-titanium instruments; see Chapter 10) necessary to prepare the root canal system for proper obturation.

Root Canal Sealers: Their Role and Use

A root canal sealer or cement is essential with any gutta-percha technique, just as an etching agent and bonding material are required when using resin-filling techniques. These products serve many functions, such as being a lubricant to facilitate obturation and adhesiveness to enhance the seal and stability of the root canal filling. When mixed properly, they can be elevated from a mixing slab approximately 1 inch (2.54 cm) and held there for 5 to 10 seconds without flowing off the elevating instrument (Fig. 12-1). The sealer will flow into the dentinal tubules if the smear layer has been removed, depending on the obturation technique used (Fig. 12-2; also see Chapter 11) and may be expressed through lateral or accessory canals (Fig. 12-3).
FIGURE 12-2 Sealer penetration into the dentinal tubules (Rhodamine B dye). (Courtesy Ronald Ordinola-Zapata, São Paulo, Brazil.)

FIGURE 12-3 A, Sealer penetrating into dentinal tubules and accessory communications in a tooth that has been demineralized and cleared for visualization. B, Mandibular molar showing the movement of root canal sealer into accessory communication into the furcation.

FIGURE 12-4 Photomicrograph showing chronic inflammation surrounding the extrusion of root canal sealer beyond the root canal (H&E ×10).
Gutta-Percha Obturation Techniques

Popular methods of canal obturation are lateral compaction, vertical compaction, thermoplasticized gutta-percha injection techniques, and thermoplasticized core-filler techniques. Although other variations on these themes exist, such as thermatically executed lateral compaction and thermomechanical compaction, specific problems occur with these techniques, and their overall popularity at present is variable. Similarly, problem solving the standard techniques should aid in the execution of these alternative approaches to gutta-percha compaction. A brief synopsis of each technique is provided in the following text; however, the reader is encouraged to seek complete descriptions of each technique in the references cited and in other “how-to-do-it” endodontic textbooks. Each technique presumes proper canal preparation prior to commencing obturation. For the first two techniques and any technique that requires the use of a master cone, a gauge is available to assist in choosing a master cone with the proper diameter and length to match the canal preparation size and shape (Fig. 12-6).

Lateral Compaction

A spreader that reaches the working length or within 0.5 mm is chosen and fitted in the canal (Fig. 12-7, A). A standard or variably sized gutta-percha cone (master cone taper .02, .04, .06, .08) is chosen to correspond to the final size of the last K-file to the apex (master apical file; see Fig. 12-7, B). The cone is fitted to the working length with close adaptation in the apical 1 to 3 mm (snugness of fit, or tugback); A radiograph is obtained to verify the position of the master cone. Subsequently, the master cone is coated with a root canal sealer in the apical half and seated to the working length in the canal (see Fig. 12-7, B). A metal root canal spreader is placed beside the master cone, compacting the cone apically and laterally and at the same time creating space adjacent to the master cone (see Fig. 12-7, C). A smaller, nonstandardized accessory cone is placed in the void created by the spreader (see Fig. 12-7, D). The spreader is reinserted and the second cone is compacted (see Fig. 12-7, E). This procedure is continued until the spreader cannot penetrate into the apical two-thirds of the canal (see Fig. 12-7, F). The excess coronal gutta-percha is seared off at the orifice, and the coronally softened gutta-percha is compacted apically with a large plugger. The adaptation of the master cone apically should be noted when the spreader can be placed to the working length (see Fig. 12-7, G and H). Compaction performed in this manner results in well-filled root canals (see Fig. 12-7, I) even in long, narrow, or curved canals and the filling of accessory communications (Figs. 12-8 and 12-9). Variations on this approach include softening the master cone with solvents such as chloroform to achieve a better adaptation to the intricacies of the apical portion of the canal. If the shape of the canal is developed with a hand instrument, the taper usually closely corresponds to a cone that is .02 or slightly larger. Cleaning and shaping is often accomplished using the step-back technique or variation thereof. A .02 master cone is chosen for obturation that provides sufficient taper or space lateral to the master cone for root canal obturation. The cone is fitted to the working length with close adaptation in the apical 1 to 3 mm (snugness of fit, or tugback); A radiograph is obtained to verify the position of the master cone. Subsequently, the master cone is coated with a root canal sealer in the apical half and seated to the working length in the canal (see Fig. 12-7, B). A metal root canal spreader is placed beside the master cone, compacting the cone apically and laterally and at the same time creating space adjacent to the master cone (see Fig. 12-7, C). 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FIGURE 12-6  A and B, Measuring gauge is shown for both length and apical sizing. (Courtesy Dentsply Maillefer, www.maillefer.com.)

FIGURE 12-7  A, Fit of the spreader is visualized to the working length in a prepared canal. B, Fitting of the master cone to the working length. C, The spreader is placed alongside the master cone to length to compact the apical portion of the cone and seal the canal. D and E, Adding additional cones are followed by compaction apically and laterally. F, Finished compaction. G and H, Adapting the master cone to the root canal walls and apical preparation when the spreader is placed to the working length during lateral compaction. Failure results in a single uncompacted master cone in a sea of cement—an invitation to failure! I, Mandibular molar shows well-adapted and laterally compacted gutta-percha fillings.
• The cone must fit to the prepared length with snugness of fit or tugback.
• Space exists laterally to the cone for the fit of the spreader during compaction.
• Accessory cones must be slightly smaller or basically equal to the size of the spreader (Fig. 12-10, A).
• The spreader must reach to within 0.5 to 1 mm of the working length without binding in the canal (see Fig. 12-10, B-D). If binding should occur, there is a chance for tooth fracture with excessive pressures (Fig. 12-11).
• The sealer and core material (with the spreader) are adapted into the prepared apical third of the canal.

**CLINICAL PROBLEM**

**Problem:** At the point of cone selection, it appears that there is insufficient room for the spreader to extend to the proper depth as described in the preceding section.

**Solutions:** The interrelationship between the shape of the canal and the technique for obturation cannot be overemphasized. Furthermore, the understanding of the balance between preparation and obturation varies from person to person. It involves such subjective aspects as experience, the “feel” of the canal shape, the “feel” of the cone fit and the “fit” of the spreader. There are a number of objective remedies if there are problems with the fitting of master cone or the fitting of the spreader. For most clinicians, the majority of the problems seem to occur in the mid-root areas. Usually, there is insufficient enlargement of the canal space, but there may be other contributing factors.

To address this issue, there are a number of effective remedies:

• The orifice can be further enlarged with orifice wideners, Gates Glidden drills or Peeso reamers.
• The canal can be reshaped by hand with larger file sizes in a step-back manner principally in the middle and coronal thirds.
• If rotary instruments are in use, the canal can be reshaped with the same rotary instruments applying more lateral pressure to “plane” the canal walls.
• The canal can be reshaped with rotary instruments having a greater taper.
• If .06 tapered gutta-percha cones are being used, a .04 or .02 tapered gutta-percha cone of identical apical size could be used. It is generally unwise to choose a smaller apical size gutta-percha cone as it will not provide an adequate filling of the apical portion of the canal.
• Try different brands of gutta-percha products as the sizing varies somewhat among manufacturers.
• Choose a spreader of smaller diameter and taper. Spreaders are available in many sizes.

Some of these concepts will be revisited in greater detail later in this chapter in the discussion of obturation problem areas in general.

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FIGURE 12-8 Obturation of a mandibular molar with long, curved canals. (Courtesy Dr. David P. Rossiter III.)

FIGURE 12-9 Mandibular molar is obturated using the lateral compaction technique; note lateral canal in the distal root. (Courtesy Dr. David Stamos.)

sealer and placement of the spreader to within 1 mm or less of the working length.

If the shape is developed with a rotary instrument at larger taper sizes (.04, .06), the chosen master cone corresponds to the last instrument placed to the working length. The size of the cone may have a specific taper, or it may be a nonstandardized cone (e.g., fine-medium, medium) cut to fit the taper and length of the prepared canal. These cones can be cut to fit into the apically prepared space more accurately using a metallic standardized gauge (see Fig. 12-6). With ALL techniques of canal preparation and choice of lateral compaction:
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Vertical Compaction

A nonstandardized master gutta-percha cone (master cone taper .02, .04, .06, .08) is chosen to ensure that it has a slightly smaller taper than the prepared root canal space (Fig. 12-12, A)\(^{15,46}\). The cone is fitted snugly 1 to 2 mm from the prepared apical constriction. Root canal pluggers are also prefitted to ensure depth of penetration into the apical third of the canal without binding on the canal walls. A light coating of root canal sealer is placed on the apical half of the master cone, which is then seated in the canal short of the apical constriction. A heated instrument is used to sear off and remove coronal segments of gutta-percha and transfer heat to the remaining portion of the master cone (see Fig. 12-12, B). A cold vertical plugger is used to compact the softened portion of the cone apically and laterally (see Fig. 12-12, C). This process of heating, removing, and compacting (see Fig. 12-12, D and E) is continued until softened gutta-percha is delivered into the apical 1 to 2 mm of the prepared apex (see Fig. 12-12, F). Subsequently, softened segments are added and compacted to obturate the canal from the apical segment to the canal orifice (see Fig. 12-12, G). Figure 12-13 illustrates the clinical application of this technique.

With ALL techniques of canal preparation and choice of vertical compaction for obturation:

- Canal tapers should be .04 or larger. In these cases, selection of a corresponding master cone with the same taper and apical size is routine.
- If a nonstandardized cone (e.g., fine-medium, medium) is selected, it must be cut to the appropriate apical size and have a taper that allows it to penetrate to within 0.5 to 1 mm of the length of the prepared canal (see Fig. 12-6). The vertical compaction process will move the cone apically into the prepared canal.
- With canal preparation using NiTi rotary instruments, the taper will also be variable and may even be greater
A needle or applicator tip designed to deliver the softened gutta-percha is introduced into the canal to the junction of the middle and apical thirds, with care taken to ensure that the needle does not bind against the canal walls (Fig. 12-14, A). The gutta-percha is passively injected into the root canal system, avoiding apical pressure on the needle (see Fig. 12-14, B). In 5 to 10 seconds, the softened material will fill the apical segment and begin to lift the needle out of the tooth. During this lifting by the softened, flowing mass, the middle and coronal portions of the canal are continuously filled until the needle reaches the canal orifice. Compaction of the material follows to adapt the gutta-percha to the prepared canal walls (see Fig. 12-14, C). With some techniques, compaction is optional, depending on the type of gutta-percha used, because the softened material flows into the canal preparation. If necessary, additional amounts of gutta-percha can be easily injected into the canal to achieve complete obturation. Another option is to deposit a small amount apically, followed by compaction to ensure an apical seal (see Fig. 12-14, D). Additional material is then placed in the canal with the delivery device to complete the obturation (Fig. 12-15). With all techniques of canal preparation and choice of injection techniques and compaction:

than the size of the instrument. In these cases, selection of a nonstandardized cone may be indicated. Nonstandardized cones can be cut to fit more accurately into the apically prepared space using a metallic standardized gauge (see Fig. 12-6).

- The cone must fit to the appropriate length with snugness of fit or tugback.
- Pluggers (compactors) must be prefit to within 3 to 5 mm from the working length without binding.
- Sufficient space must exist for the plugger to move apically to the desired depth without binding between the dentin walls during compaction.

**Thermoplasticized Injection Techniques**

Gutta-percha may be softened and delivered to the prepared canal using a variety of instruments designed for injection that permits compaction (Calamus Flow, Calamus Dual 3D obturation system [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]; BeeFill 2in1 [VDW, Munich, Germany]; Elements Obturation Unit [SybronEndo, Orange, CA, USA]; E&Q Master [Meta Dental Co., Elmhurst, NY, USA]). A needle or applicator tip designed to deliver the softened gutta-percha is introduced into the canal to the junction of the middle and apical thirds, with care taken to ensure that the needle does not bind against the canal walls (Fig. 12-14, A). The gutta-percha is passively injected into the root canal system, avoiding apical pressure on the needle (see Fig. 12-14, B). In 5 to 10 seconds, the softened material will fill the apical segment and begin to lift the needle out of the tooth. During this lifting by the softened, flowing mass, the middle and coronal portions of the canal are continuously filled until the needle reaches the canal orifice. Compaction of the material follows to adapt the gutta-percha to the prepared canal walls (see Fig. 12-14, C). With some techniques, compaction is optional, depending on the type of gutta-percha used, because the softened material flows into the canal preparation. If necessary, additional amounts of gutta-percha can be easily injected into the canal to achieve complete obturation. Another option is to deposit a small amount apically, followed by compaction to ensure an apical seal (see Fig. 12-14, D). Additional material is then placed in the canal with the delivery device to complete the obturation (Fig. 12-15). With ALL techniques of canal preparation and choice of injection techniques and compaction:
• Tapers above a .04 using NiTi rotary instruments are recommended because the taper produced is essential for the flow and compaction of the softened material.
• Delivery needles or tips must reach to within 3 to 5 mm of the prepared apical terminus of the canal, depending on the canal shape and size. Needles are usually available in 20, 23, and 25 gauges, depending on the unit chosen.
• Delivery needles or tips must not bind in the canal. The tip is placed to the point of binding and retracted.
Intracanal vertical compaction of the softened material around the core is recommended. Once complete, the core is cut off with a bur at the orifice (see Fig. 12-16, D). Laboratory evaluations of these techniques demonstrate well-filled canals with three-dimensional adaptation of the gutta-percha to the intricacies of the canal (Fig. 12-17).

Modifications and combinations of these techniques yield numerous possible ways to obturate the prepared root canal space. For example, recent attempts to enhance the adaptation of the gutta-percha delivered in the thermoplasticized state to the intricacies of the canal walls have shown an intimate adaptation and penetration into the dentinal tubules when the smear layer is removed (Fig. 12-18, A-D). This technique has shown excellent adaptation, especially in complex canal systems (oval canals, C-shaped canals), but additional compaction may be a necessary part of the filling technique in demanding situations (see Fig. 12-18, E and F).

A concern on the part of many clinicians is the potential need for removal of this core material for post space or if there is a treatment failure (see Chapters 5 and 14). Fortunately, many techniques provide for simple, efficacious removal. To address this issue, Dentsply, the prime manufacturer of the core-carrier product and technique will introduce a new product with a complete gutta-percha core: Gutta-Core (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA). The availability of this new delivery device and its achievements will surpass those of previous core-carrier materials in ease of usage, adaptation to the properly prepared canal, and elimination of any concerns for post space preparation or canal revision, inasmuch as the material is easily removed (Fig. 12-19).

**Thermoplasticized Core-Carrier Techniques**

Gutta-percha that has been previously coated on a metallic or plastic core (carrier), corresponding to standardized instrument sizes, is heated in a preset system or oven. The vast majority of core carriers today are plastic: ThermaFil, GT, and ProTaper & Vortex gutta-percha carriers [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]; Soft Core [CMS Dental ApS, Copenhagen, Denmark].) After proper softening in a standardized heating oven, the coated gutta-percha core is placed to the working length, with the harder central core used as a compactor to carry the softened material apically and laterally (Fig. 12-16, A-C). Root canal sealer is an intimate and essential part of this system.

**FIGURE 12-15** A, Maxillary premolar obturated only with the injection method. The canal shape is essential for this achievement. B, Mandibular molar obturated with the injection technique.
FIGURE 12-17 A and B, Two examples of the mesial roots of mandibular molars are turned to view them proximally. The canals are filled using either lateral compaction with gutta-percha or the thermoplasticized core-carrier technique. Teeth are placed in India ink dye then demineralized and cleared to be able to see the canal anatomy and adaptation of the filling material with both techniques. Each specimen is labeled as to lateral compaction (LC) or core carrier (CC). The core-carrier technique provides better movement of both gutta-percha and sealer into the canal irregularities than does the lateral compaction technique. A, Distinguishing which canal is filled with which technique is difficult, emphasizing the importance of canal cleaning and shaping. C, Clinical case is filled with the core-carrier technique.
FIGURE 12-18  A, Fields of gutta-percha plugs penetrate the dentinal tubules after the smear layer is removed (see Chapter 11) (scanning electron micrograph [SEM] ×66). B, Gutta-percha plugs are placed in the tubules with sealer, giving them a carpeted or matted appearance (SEM ×720). C, Tips of the gutta-percha plugs display sealer particles (SEM ×2000). D, Cleared tooth specimen shows the penetration of both sealer and gutta-percha plugs into the tubules. E, After placing a core carrier, a lateral or vertical compacting instrument can be used to compact, followed by additional gutta-percha placement via cones and small gutta-percha segments or injection. F, After placement of a core carrier with gutta-percha, four additional cones are placed (arrows) and compacted. This technique works well in irregularly shaped canals (canals that are wide buccal lingually and C-shaped canals) when multiple core carriers cannot be used.

FIGURE 12-19  A, New Gutta-Core core carriers that do not contain plastic or metal. B, Example on extracted tooth of the appearance and quality of canals filled with this technique.
Resin-Bonded Obturation Techniques

The development of resin-bonded adhesive root canal filling materials naturally evolved from the need to more effectively seal the root canal apically and coronally. Successes with resin-bonded materials in the coronal portion of the tooth inspired this obturation innovation.42,44 Important in this respect were the needs for a material that (1) would be fully biocompatible, (2) would not deteriorate over time, (3) would seal all communications against the commonly found organisms in the root canal and oral cavity, and (4) could be easily placed into the canal and create a bond with the organic and inorganic components of dentin.

Multiple systems with this approach have appeared: Epiphany Soft Resin and Epiphany SE Self-Etching, in both cones and pellets for obturation (Pentron Technologies LLC, Wallingford, CT, USA); RealSeal, RealSeal 1 Bonded Obturator, and RealSeal Sealer (SybronEndo, Orange, CA, USA); Activ GP Monobloc Obturation and Activ GP Glass Ionomer Sealer (Brasseler USA, Savannah, GA).

These systems require the use of smear layer removal agents, such as 15% to 17% ethylenediamine tetraacetic acid (EDTA), to enable movement of the primer and sealer into the dentinal tubules (see Chapter 11). The materials are highly radiopaque and compact well into the prepared root canal, using cold lateral or warm vertical compaction. The availability of self-etching is claimed to enhance the product and process. Chemically, the main component is a polyester (polycaprolactone) that contains embedded bioactive glass and calcium hydroxide. The Activ points (which do not contain polycaprolactone) actually have the glass ionomer embedded on the points and in the sealer. If the polycaprolactone undergoes degradation, the manufacturer claims the bioactive glass component initiates an inductive response for bone or cementum formation.

This new technology’s major claims focus on its ability to produce a monoblock (and therefore a better seal of the root canal)35,42 and its ability to strengthen the root.43 In light of these claims, some very important observations must be made in a problem-solving format. First, for monoblock to be achievable, root dentin must be completely free of debris and bacteria.39 To date, this level of cleaning and disinfection is not achievable on a predictable basis, although technologic advances are reaching for this goal (see Chapter 11). Second, strengthening the root system has had serious challenges,8,11,18,47 because if monoblock is not achieved, strengthening cannot be achieved. Some have claimed greater strengthening compared to gutta-percha and sealer, but this may merely be a measure of the adherence of the sealer used with the gutta-percha.36 In fact, there are sealer/gutta-percha combinations that appear stronger than Resilon45 and positive long-term findings when it comes to leakage.48 Additional concerns center on the potential shrinkage polymerization that may occur in the root.7,24 Third, there are substantial claims as to the degradation of the materials being used.20,38-41 Fourth, while these same, previous concerns apply to the Activ GP monocone obturation, there are no evidenced-based data that support single-cone obturation,9,26,27 regardless of the sealer and manufacturer claims.

Even with the advent of these newer materials, the obturation process itself has not really changed, and any of the techniques of canal filling can be used. This is especially important when the canal anatomy prior to enlarging and shaping and subsequent to this process is taken into consideration. The technique must use methods or variations that will ensure movement of the filling materials into all aspects of the prepared root canal anatomy.30

Conceptually, however, a resin-bonded root canal filling material would be the ideal future of obturation in endodontics. Presently, many clinicians have adopted these new technologies with empirical claims of success being made globally (Fig. 12-20)4 (www.resilonresearch.com). However, great care must enter into the development and evaluation of these types of materials before and during widespread patient use.39 In this light, the operative term is evidence-based, that is, the need for long-term, prospective, randomized clinical trials to ensure that years from now, the dental clinician will be faced with tooth retention in symptom-free function and not with the ravages of periapical periodontitis and the need for treatment revision.

Guiding Principles for All Obturation Techniques

1. The success of any root canal obturation technique depends largely on the care exercised in canal preparation. Presently, with the newer NiTi rotary canal enlarging and shaping techniques, the final shape will enhance obturation no matter what technique is chosen.
2. Canals should be prepared with a definite apical matrix (seat, stop, or constriction in sound dentin) to retain...
the filling material within the canal space. This is key from both a biological and clinical perspective.14

3. Regardless of the type of gutta-percha filling or the nature of the resin material that is chosen, compaction to some degree is indicated. This enables the clinician to address the significant and widespread nature of root canal irregularities.

4. A complete and appropriate armamentarium to accomplish the chosen technique must be readily available. Clinicians must be prepared to learn the techniques well and have necessary instruments to manage the specific canal anatomy of each tooth (e.g., large canals, curved canals, C-shaped canals, canals with resorptive defects, etc.).

5. Obturation techniques may have to be modified to meet the needs of an individual case. Multiple techniques are often required to properly obturate a single canal because anatomic challenges dictate the need to practice problem solving during this phase of treatment. Most important may be the fact that no one technique can manage all cases.

**Problems Preparing to Obtain the Canal**

The main problems encountered when preparing to obturate are a blocked or ledged canal, debris present apically, or a separated instrument in the canal. When NiTi instruments are applied properly, along with the advocated irrigation techniques, these problems do not occur. Should they occur, this area of concern tends to show itself when trying to fit a master cone for any technique. When a master cone binds in the canal short of the full working length, three issues are potentially at work and must be considered:

- The shape of the canal is improper for the cone chosen.
- The wrong cone is chosen.
- Debris is packed in the canal.

To problem solve these issues, the following steps are recommended:

1. Cone size and shape should be checked and compared with the master apical file.
2. Recapitulation should be performed with the last K-file or size verified in the case of a core-carrier. All files should be curved as appropriate for the canal shape.
3. Radiographs should be obtained to verify that the working length is correct and that no ledges, blockages, or false canals have been created. However, these errors should have been seen much earlier by the cognizant, problem-solving clinician.
4. If necessary, the same-sized Hedström file as the master apical file or the final rotary NiTi should be used, and the canal walls should be carefully shaved in a step-back circumferential fashion. This step may permit selective shaping in specific canal areas. The goal is not to enlarge but shape.
5. Copious irrigation should be used to enhance instrumentation and dentin chip removal.
6. After reestablishing length with the file and drying the canal with paper points, recapitulation should be performed once more to remove any dry-packed chips from the apical dentin matrix (Fig. 12-21).

**FIGURE 12-21** A, Master cone fits short of working length on a model because of canal blockage with dentin chips. B and C, After recapitulation, chip removal, and confirmation of working length, the master cone is fitted to the correct length.
FIGURE 12-22  A, Gutta-percha is cut with a sharp scalpel to avoid irregularities. B, Gutta-percha master cones are cut with a scalpel (left) and scissors (right). Flanges are noted on right cone.

FIGURE 12-23  A, A gutta-percha solvent used for 1 to 3 seconds softens the surface of the cone without distorting the strength of the cone in its long axis, which is needed for firm placement into the canal. B, Upon placement, the cone will become adapted to the walls of the canal to enhance the fit (arrows). This process can be repeated until the cone reaches the desired depth and snugness of fit.

7. If the master cone does not snugly fit to the appropriate length, a different-sized cone can be chosen and adapted by cutting the cone based on the taper and the final instrument size. For example, enlarging with NiTi rotary instruments often produces a canal that is larger than the instrument. If the size were a No. 30, .06, the master cone would be a matching size. If it goes all the way to the working length, but is loose, by cutting off (Fig. 12-22) a half millimeter, the cone will be a No. 33. If the No. 33 does not go all the way, a 1- to 3-second apical chloroform dip (Fig. 12-23, A) will permit good adaptation to the apical portion of the canal. Another example: Presume the canal is prepared to an F3 ProTaper instrument (No. 30, .09), but the cone does not go all the way to the working length. Consider taking an F2 cone (No. 25, .08) and cutting off half a millimeter, which prepares a cone to an approximate size 29. Additional cutting or molding with chloroform in a creative and knowledgeable manner will enable custom preparation with any gutta-percha or resin-based cone. The gauge seen in Fig. 12-6 is most helpful for this process.

Problems During Canal Obturation

The main problems encountered during obturation focus on the inability to place the compacting instrument to the desired length, or pulling the material out of the canal with the compactor. Failure to place the compacting instrument occurs mainly because of lack of proper canal shape
and taper, use of inappropriate (too large) compacting instruments, or use of a straight, inflexible compacting instrument in a curved canal.

These problems can all be prevented by fitting the compacting instruments in the canal before obturation to determine their degree of adaptation. NiTi compacting instruments are also available for curved canals if necessary, although most compactors can be curved if carefully bent with a pair of hemostats.

Instruments that have a taper similar to that of the prepared canal should always be used. For example, not all D-11T spreaders have the same thickness and tapered shape because differences exist among the various manufacturers. In smaller-prepared canals, such as a size 25 to 35 at the apical extent, a D-11TS spreader is appropriate. In larger canals, a D-11T will work. In long canals (i.e., greater than 23 mm), these spreaders will not work. In these cases a GP-3 is used. Finger spreaders and hand spreaders are also available in NiTi alloy. Compared with stainless steel spreaders, these highly flexible compactors can more easily negotiate properly shaped curved canals; this negotiation is essential for adequate apical compaction. In addition, no precurving is necessary, and recent research suggests that decreased stress on root structure when compacting with NiTi finger spreaders exists, thus potentially decreasing the chance of vertical root fracture. Potential disadvantages of using these compactors include buckling the instrument during compaction and a limited accessibility to some canals because the spreader cannot be precurved. Present findings indicate that the flexible NiTi finger spreaders should be used to compact the gutta-percha in the apical third, followed by stiffer stainless steel finger spreaders to compact the gutta-percha in the remaining coronal two-thirds. Using stainless steel finger spreaders in the more flared portion of the canal may compensate for the buckling that would occur if NiTi compactors were used for the entire obturation procedure.

Compactors (pluggers) also vary in shape and taper, and they should be selected based on their adaptation within the tapered canal preparation. They are available to fit the specifically tapered root canal files. When a canal is obturated with the injectable thermoplasticized gutta-percha techniques, similar solutions as previously mentioned are recommended. However, vertical compactors do not have to fit to within 1 to 2 mm from the apical dentin matrix. Compactors are loosely fit only to within 3 to 5 mm from the apical dentin matrix or constriction. Similarly, the shape and flow of the canal in this area must be a smooth, continuously tapering funnel. With core-carrier techniques, seating the core to the depth of the prepared canal is very important.

If the compacting instrument, spreader, or plunger is pulling the master cone or accessory cones out of the canal, the following problem-solving questions should be considered.

- Is there too much canal wall divergence and lack of a snugly fitted master gutta-percha master cone?
- Has too much sealer been used? Is the sealer mix too thin?

• Is the compactor clean? Is there tacky sealer on the instrument before reinserting?
• Is the integrity of the compactor compromised by having bends, hooks, or irregularities at its tip?
• Is there moisture in the canal (blood, pus, or saliva)?
• Was the master cone too small?
• Was the compactor loosened before withdrawal from the canal?
• Was the compactor, if precurred, rotated in a curve canal?
• Was a separating medium, such as alcohol, used on the compactor?

Answers to these questions can only be provided when the clinician reassesses all aspects of a specific case. The following general guidelines may help in problem solving these queries. As previously discussed, a customized cone adapted to the apical 1 to 3 mm by means of a solvent or heat may be necessary if the walls are too divergent. This will create a better snugness of fit that will resist displacement during compaction. The moderate use of sealer is always recommended to provide a seal between the interface of gutta-percha and dentin. All compaction techniques when done properly in an ideally shaped canal will move the sealer laterally and apically into a thin layer along the dentin and into the dentinal tubules when the smear layer has been removed. To achieve good compaction with a spreader, it must be clean each time it is introduced into the canal. Often the clinician will have the assistant wipe the spreader, but if it is wiped in a straight motion, sealer will remain; wiping in a circular motion will remove the sealer thoroughly. Furthermore, there can be no irregularities in the shape of the spreader—that is, no flanges, hooks, or severe kinks in the instrument (Fig. 12-24). Too often these instruments are used for tasks for which they were not intended (e.g., searching for canals, trying to remove old filling materials), and they get these irregularities.

Root canals must always be dry before compaction. It may be necessary to dehydrate the root canal before obturation. Sterile paper points are the best devices for moisture removal. If necessary, the canal may be irrigated with 2 to 3 mL of either 70% or 95% isopropyl alcohol. The alcohol should be allowed

![FIGURE 12-24 Various spreaders are shown with less than ideal tips. Placement of these into canals is a recipe for problems.](image-url)
to remain in the canal for 3 to 4 minutes and then dried with sterile paper points. Rarely is this technique indicated.

In some cases, a larger or more appropriately tapered master cone must be selected before compaction. Properly fit master cones will penetrate to within 0.5 mm of the working length, and space is found on either side of the cone from the junction of the apical and middle thirds to the coronal orifice. When placing the compacting instrument, it should be rotated in a 180-degree curve until it becomes loose within the canal (Fig. 12-25). A retracting force can be gradually applied during this movement to allow the spreader to passively “walk” out of the canal without dislodging the compacted gutta-percha. However, if the canal is curved and the spreader is curved, then rotation will have to be limited to approximately 90 degrees while the clinician exerts a continuous coronal retracting force.

If the core-carrier technique is being used and a problem arises, the issue that may need to be addressed is:

- During the cutting of the core (metallic carrier with a bur or plastic carrier with a bur or a controlled heat source), was the handle of the core stabilized to prevent removal of the core (carrier)? (See Fig. 12-16, D). Even if not removed, failure to stabilize the top of the core may significantly disrupt the previously placed gutta-percha.

All the problems encountered during canal obturation can be prevented with careful attention to detail in canal preparation and during obturation. The operative word is prevention.

**Problems Identified After Obturation**

The major problems identified after obturation include overfilling, overextension, underfilling or lack of apical density, and voids in the filling. Overfilling implies that a root canal system has been filled in three dimensions, and a surplus of filling material extrudes beyond the confines of the canal (Fig. 12-26). However, an overextended root filling is solely limited to the vertical dimension of the root canal filling material, relative to the apical foramen. An overextended fill does not imply that the root canal has been three-dimensionally obturated. Rather, the implication is that the filling material has been placed beyond the confines of the canal but has not necessarily sealed the apical foramen (Fig. 12-27). Additionally, if placed in areas where vital structures are located, such as the inferior alveolar canal or mental foramen, there is a greater potential for serious complications.

An additional problem that may arise with core-carrier filling is the stripping of the gutta-percha from the core. This may be seen on a posttreatment radiograph and is usually due to improper canal shaping, as seen in Fig. 12-28. Note the core is exposed in the middle to apical third (arrows) because the shape of the canal narrows too rapidly, and there is no gradual and continuous funnel shape to the canal.

Major causes of placing the root canal filling material beyond the apical constriction in either overfilling or overextending when lateral or vertical compaction techniques are used are due to the following errors:

- Excessive instrumentation beyond the apical constriction, resulting in the lack of an apical dentin matrix
- Unanticipated communicating resorptive defects anywhere in the canal system
- Defects incorporated into the canal system during cleaning and shaping, such as zips, perforations, and strips (see Chapter 10)
- Excessive compaction force or excessive amounts of sealer; often occurs with the core-carrier technique when placed too rapidly and with too much pressure
- Use of a too-small master cone that allows for excessive penetration of the compacting instrument
- Any combination of these errors

The intentional placement of gutta-percha beyond the confines of the root canal system is not considered an acceptable technique because no long-term prospective or retrospective studies exist to justify this approach to canal obturation. Many techniques used in canal obturation are predisposed to this possibility, and their use should be modified to produce predictable control of the obturating material when possible. In fact, going beyond the apical foramen, other than to establish apical drainage, may not be warranted; pushing materials past may only hinder periapical healing and create problems for the patient that may not be immediately evident.

Although proper techniques have been followed, occasionally gutta-percha, resin-bonded filling materials, or root canal sealer may be unintentionally pushed beyond the confines of the root canal system. However, the periradicular tissues generally tolerate these materials. Although sealers may provoke an initial inflammatory response to a greater or lesser degree over a short period, the macrophage scavenger system eliminates the excessive material from the periradicular

**FIGURE 12-25** A, Rotating the spreader in a 180-degree arc will loosen the instrument in the canal without dislodging the filling material. B, During rotation, force is gradually exerted in a coronal direction to allow passive removal of the spreader.
FIGURE 12-26  
A, Maxillary lateral incisor with lesion many clinicians would claim is a cyst. Invariably, teeth with lesions have some degree of apical root resorption. B, Overfilled root canal. Material extends as much as 2 to 3 mm beyond the apical foramen, which is not at the end of the root (arrow indicates probable foramen, and red line indicates possible extent of overfill). C, Twelve-month reexamination shows excellent healing. (Case courtesy Dr. Paul Buxt.)

FIGURE 12-27  Significant filling material is pushed past the end of the root. In many such cases, a long-term chronic inflammatory problem occurs, so the case must be periodically reassessed.

FIGURE 12-28  Canals are filled with the core-carrier technique. Although obturation appears good, improper canal shaping has resulted in stripping of the gutta-percha from the core (arrows).
tissues. In any case, the mere placement of filling material outside the canal system is not a major cause for alarm if the canal space is three-dimensionally obturated. If excessive amounts of materials are extruded, the patient should be informed, and periodic reexaminations are indicated. In cases of overextension with the lateral compaction technique, the filling material can often be teased back through the foramen, provided the sealer has not hardened. If the sealer has hardened, it may still be possible to retrieve the gutta-percha, provided it is an intact cone. The gutta-percha is softened with one of the previously mentioned solvents in the apical third of the canal. While the gutta-percha is soft, a Hedström file is inserted into the softened mass, and excess solvent is flushed from the root canal. In a few minutes, the gutta-percha will harden around the Hedström file. The file is carefully teased out of the canal as parallel as possible to the long axis of the canal. In cases of overextension with the vertical compaction or an injectable thermoplasticized gutta-percha technique, retraction of the filling material through the apical foramen is impossible. Although some authors may cite this situation as an indication for periradicular surgery, the routine and immediate use of surgical intervention is neither indicated nor justified (see Fig. 12-26). In most cases, the periradicular tissues will heal, and the patient will be symptom free. If, however, the patient exhibits signs or symptoms of periradicular inflammation, surgery may be indicated. In cases of thermoplastic core-carrier overextension, removing the core from its overextended position is necessary. Concomitantly, retrieving small amounts of gutta-percha from beyond the confines of the apical matrix may be possible if they remain attached to the core.

Failure to achieve adequate apical density is a common problem in root canal obturation that only too often goes unnoticed by the undiscerning clinician (Fig. 12-29). In

![Figure 12-29](image-url)

**FIGURE 12-29** A, Apical half of these canals is insufficiently shaped to allow for thorough compaction of filling material. Excessive use of Gates-Glidden burs is noted in the coronal portion of the root canal. B, These canals are obturated with a single-cone filling in the apical half of the canal, whereas the coronal half is weakened by excessive removal of dentin with Gates-Glidden burs. C and D, Two cases of obviously less-than-ideal compaction are visualized as lack of apical density in root canal fillings. Each of these scenarios is preventable. In all four cases, apical lesions are present, and to be retained, teeth will require treatment revision.
essence, the apical third of the canal is filled with a sea of root canal cement and a single uncompacted master cone or a poorly condensed mass of previously softened gutta-percha. Radiographically, the apical third of the canal appears less radiodense (Fig. 12-30). An ill-defined outline to the canal wall is evident, along with obvious gaps or voids in the filling material or its adaptation to the confines of the canal. This problem is more evident when minimally radiodense sealers are used. Some clinicians avoid this perception by using highly radiodense sealers. Similarly, resin-bonded filling materials, both core and sealer, are highly radiodense; this problem may be evident with their use. Contributing factors to this problem include:

- Lack of canal patency inside the root and sufficient taper to allow for spreader penetration to the apical seat in the lateral-compaction technique, plugger penetration in the vertical compaction technique, and the flow of gutta-percha in thermoplasticized gutta-percha injection and core-carrier techniques

(In particular, this lack of proper shape and taper will accentuate the wiping or removal of the gutta-percha from the carriers in the thermoplasticized core-carrier techniques [see Fig. 12-28].)

- Failure to coat the accessory cones with a thin layer of root canal sealer (lateral compaction)
- Failure to insert accessory cones to the full length of spreader penetration (lateral compaction)
- Use of accessory cones with very fine tips that curl up or kink on placement during lateral compaction
- Use of a too-large spreader (lateral compaction) or plugger (vertical compaction, thermoplasticized gutta-percha injection techniques)
- Too much root canal sealer (all techniques)
- Use of a rapidly setting root canal sealer or an improperly mixed sealer that may set up too fast (all techniques)
- Failure to achieve depth of compaction and flow of softened gutta-percha (vertical compaction, all thermoplasticized gutta-percha techniques)
- Failure to soften the apical segment of the gutta-percha before compaction (vertical compaction)
• Excessive packing of dentin chips in the apical 1 to 3 mm (This should not occur when using NiTi rotary instruments and good irrigation, as these instruments are designed to bring debris out of the canal.)
• Failure to seat the core carrier to the apical seat or stripping of the core filler at its apical extent
• Inconsistent heating, too little or too much, with the core-carrier techniques (This inconsistency is easily prevented by using the manufacturer’s heating systems. The heating of the core filler over an open flame is subject to too many discrepancies and should be avoided.)

Each of these potential problems can be averted when using a cognizant, problem-solving approach—or better yet, a problem-preventing approach—to root canal obturation.

To obturate the prepared root canal system as densely as possible throughout its entire length, attention must be paid to canal preparation, proper fit of the master cone or injection needle, and proper fit of compacting instruments. In addition, effective use of not only the root canal sealer but also the accessory gutta-percha cones or material segments, gutta-percha, or resin-bonded materials is a must to fill the prepared canal space.

Radiographic voids in the root canal filling can be viewed in a number of ways:

“So what, and why should I worry? They never fail.”
“That doesn’t look good, but it will work.”
“That’s my signature, and I can’t let the patient or any other clinician see this radiographic film!”

**FIGURE 12-31** Tooth models that have been obturated and either sectioned (A) or cleared (B); voids are evident. C, Scanning electron micrograph of voids or gaps where the gutta-percha was not warmed sufficiently and compacted thoroughly. D, Obturation in the first molar is compared to that of the second molar. Compare the voids and lack of density in the second molar to the smooth contours and density of the canal shapes and fillings in the first molar.
voids are usually limited to the middle and coronal canal segments and obturation minimize the likelihood of voids affecting responses. Modern approaches to root canal cleaning, shaping, corrosion products initiated adverse periradicular tissue reactions. When gutta-percha cone fills or when silver cones were used, and contributed to many of the failures, especially in the single gutta-percha or silver cones. Occlusal leakage may have also tion was performed with little compaction, using single gutta-percha in the root canal filling25; see Chapters 5 and 21. In fact, rarely do we see all the voids we leave in the root canal obturation (Fig. 12-31).

Although classic studies have identified poor obturation as the major cause of failure of root canal treatment, these findings were based on cases in which cleaning and shaping were not performed as they are done today. Additionally, obturation was performed with little compaction, using single gutta-percha or silver cones. Occlusal leakage may have also contributed to many of the failures, especially in the single gutta-percha cone fills or when silver cones were used, and corrosion products initiated adverse periradicular tissue responses. Modern approaches to root canal cleaning, shaping, and obturation minimize the likelihood of voids affecting success. In addition, if proper apical compaction is performed, voids are usually limited to the middle and coronal canal segments and pose minimal to no threat to prognosis.

REFERENCES

RECOMMENDED ADDITIONAL READING

Chapter 13

Problem-Solving Challenges in Compromised Roots, Root Canal Systems, and Anatomic Deviations

“It is seldom that we see canals in buccal roots of superior molars, or in roots of lower molars, in which a drill can be used. . . . There are canals that are constricted just at the chamber, sometimes so much so that they can scarcely be found. . . . There are canals in curved roots and canals obstructed by osseous growths that, if not properly opened, would most likely cause trouble. It is with this difficult class of root-canals that I wish to deal at this time.”

J.R. Callahan, 1894

“I have seen resorption of apical cementum progressing with such attending conditions, while on the opposite surface of the same root there was a marked hyperplasia of cementum. In fact, it seems quite common to find these processes going on at the same time.”

J.R. Blayney, 1927

This chapter will focus exclusively on the total management of difficult or challenging root canal anatomies, such as immature root development and a necrotic pulp; teeth that have been altered due to caries (irritational dentin and calcification) or resorptive processes both internal and external; teeth with accentuated curvatures; and unusual root and pulp space development in C-shaped canals. The reader is encouraged to seek additional and supportive information from the other chapters in this text; however, the challenges addressed in this chapter seemed to warrant individual attention using the problem-solving format.

Problem-Solving List

Problem-solving challenges and dilemmas in the total management of compromised roots and root canal systems and anatomic deviations addressed in this chapter are:

- Problem-Solving Challenges in the Tooth With a Necrotic Pulp and Immature Apical Development: Apexification
- Problem-Solving Challenges in the Tooth With Fine and Calcified Canals
- Problem-Solving Challenges in the Tooth With Resorptive Defects
  - Internal resorption
  - External resorption
  - Cervical resorption
- Problem-Solving Challenges in the Tooth With a C-Shaped Canal
- Problem-Solving Challenges in the Tooth With Moderate-to-Severe Canal Curvature
- Problem-Solving Challenges in the Tooth With an S-Shaped Canal
- Problem-Solving Challenges in Anatomic Deviations

Historically, when a dental pulp had undergone demise before full root formation, an apexification procedure was indicated and still is the treatment of choice. However,
multiple directions in the management of this clinical challenge have emerged that differ from the traditional calcium hydroxide apexification procedure. The details of the traditional technique will be discussed briefly, as it has withstood the test of time. This will be followed by alternatives that are currently being advocated that include the use of mineral trioxide aggregate (ProRoot MTA [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]) and a technique that is referred to by some as revascularization and by others as regeneration within the pulpal space.

The traditional apexification procedure requires complete canal cleaning, shaping, removal of smear layer, and disinfection (see Chapters 10 and 11) before the placement of calcium hydroxide (Ca(OH)₂) to promote the formation of osteocementum or apical bridge formation. This technique is often referred to as the Frank technique. The calcium hydroxide kills bacteria, dissolves tissue, and creates an environment conducive to hard-tissue formation. The material is left in place or changed every 3 months, with intervals as long as 12 months in later stages to enhance the tissue response. The mean time to barrier formation in incisor teeth has been shown to be 34.2 weeks (range 13 to 67 weeks), but data on posterior teeth is unavailable. Recently this technique of changing the Ca(OH)₂ has been shown to be counterproductive to the formation of hard tissue, although it did seem to lessen inflammatory response. The hard tissue that ultimately forms is not dentin, because odontoblasts rarely if ever survive pulpal necrosis (Fig. 13-1). This important concept, while understood in the context of traditional apexification, has not necessarily been elucidated or addressed in the purported revascularization or regenerative techniques that will be discussed later. The tissue response in the traditional technique has been shown to be a gnarled osteocementum type of material (Fig. 13-2). It is often porous, and its formation, thickness, and location are often irregular in nature. It is a valid procedure for both anterior and posterior teeth. Figs. 13-3 and 13-4 offer detailed descriptions of traditional apexification using Ca(OH)₂ technique in anterior and posterior teeth.

From a contemporary standpoint, Ca(OH)₂ is still used for bacterial control, but its presence over a long period may weaken the dentin. A major problem inherent in the tooth with immature root formation is the structural weakness of root walls (root wall thickness). If the impact of Ca(OH)₂ is added to this weakness, the chance for long-term retention of these teeth would be doubtful. Often over time, these teeth—even with apical closure—may be unable to withstand not only the occlusal and functional stresses but also the impact of the wide range of restorative procedures that have been used to maintain these teeth. Furthermore, the use of preformed, intraradicular metallic posts in the tooth are not indicated; even if used, they would not likely strengthen the root structure (see Chapter 20). A bonded, carbon fiber post may be a...

**FIGURE 13-1**  
A, Developing root apex showing the Hertwig epithelial root sheath (arrows). B, Note how the sheath invaginates into the mesenchymal tissues (dental sac) on its way to root development. Once this sheath dies, the chance for normal root development ceases. C, View of tooth root that has not closed; perimeter of the opening represents the area of the root sheath.
The use of MTA in one-visit apexification treatment has received some significant attention, with outcomes favoring this approach as opposed to the use of Ca(OH)$_2$ followed by MTA (Fig. 13-7, A-E).* However, what is defined as a one-visit treatment may be ambiguous insofar as many clinicians access, enlarge, shape, and clean, then place Ca(OH)$_2$ for 7 to 14 days. Instead of waiting for a lengthy period, the canal is filled with MTA within 2 weeks or less (Fig. 13-8). If everything could be done in one visit, it would also negate the potential for leakage that has been identified when MTA has been placed following the use of Ca(OH)$_2$. In some cases, it may be wise to use MTA in a one-visit placement surgically to manage an open apex in light of other complications (Fig. 13-9).

Following placement of MTA in the canal, some options are available to the clinician for restoring the tooth, depending on whether only apical plugs were placed or the entire canal was filled. First, a glass ionomer can be placed on top of the MTA, followed by a bonded composite or bonded post. Second, bonded materials can be placed directly against the MTA after allowing the MTA to set for a minimum of 2 to 4 hours; some clinicians bring the patient back the following day for this procedure. Bonding the canal walls in these cases is a wise choice to prevent fracture. As mentioned, the use of metallic posts is contraindicated, but the newer resin-bonded obturation materials may be a choice because the strength of the root may be enhanced. Clinical evidence of this effect is unavailable, but what is known is that MTA itself may enhance the strength of the root structure by an interesting mechanism in which it induces the expression of tissue inhibitors of metalloproteinases (TIMPs), thereby preventing destruction of the collagen matrix. In adhesive restorations, one major problem is hybrid layer degradation. At present, this deterioration is explained by the activation of endogenous matrix metalloproteinases (MMPs) present in dentin owing to the acidic property of adhesive systems. Even mild self-etching adhesives activate latent MMPs without denaturing these enzymes and may adversely affect the longevity of bonded root canal fillings and posts. In this regard, the use of chlorhexidine (CHX) has been advocated to prevent the release of MMPs, and it is possible that CHX should also be advocated in place of Ca(OH)$_2$ for bacterial control in teeth with immature root development and a necrotic pulp. The concept of inducing TIMPs and preventing the release of MMPs is essential in achieving bonding in the root canal system with products such as Epiphany/Resilon (Pentron Technologies Inc., Wallingford, CT, USA).

The most contemporary approach to the management of teeth with immature root formation and either irreversible pulpitis and periapical periodontitis or necrotic infected pulps has been promulgated as revascularization, or even regeneration. In their infancy, these techniques claimed to be taking advantage of the pluripotent...
Preliminary technique: The technique to achieve this goal consists of an access to the canal, drainage as necessary, rinsing the canal with sodium hypochlorite (NaOCl) and CHX, drying the canal, and placement of a mixture of ciprofloxacin, metronidazole, and minocycline with a lentulo spiral. Placement to the working length or extent of the root apically does not appear to be important, and there is no compaction of the antibiotic paste. If successful, this is followed by the ingrowth of soft tissue (revascularization) and the presence of hard tissue building up along the internal walls of the root to varying degrees of thickness. In some cases this thickness is uniform, in others it may only occur in the apical portion of the root canal. In essence, what is being achieved is possibly a revitalization to some extent that encourages the apexogenesis process, as described in Chapter 7.

This initiative has even developed some of its own nomenclature in its claims, such as bioroot engineering, pulp revascularization, regenerative endodontic treatment or regenerative therapies, and stem cells from the apical papilla (SCAP). While only supported by diverse case reports at this moment, there is a significant research initiative to pursue this model, calling it "the hidden treasure in apical papilla." The treasure refers to the uniqueness of the SCAP relative to cellular types and their potential for differentiation and expression of their genetic potential—that is, cells with the phenotypic capability of becoming new odontoblasts. In combination with the genetic capabilities of cells from the periodontal ligament (periodontal ligament stem cells [PDLSCs]), they offer the promise of truly regenerating lost or damaged tissues.

It is not the intent of this text to espouse these theories or clinical innovations, but rather to raise some challenging problem-solving questions relative to the thought and direction behind them. The concept of stem cell identification and their potential applications is laudable, exciting, and should
A, This 10-year-old male has significant decay and delayed root development on the mandibular first molar. Apical and furcation bone loss is evident, and the tooth is scheduled for extraction. 

B, The pulp chamber and canals are cleaned and shaped, and calcium hydroxide is placed. The open apices and slight extrusion of the material is noted. 

C, Six-month assessment shows great healing and the beginning formation of apical bridging. The roots are filled with gutta-percha and sealer. Slight porosity of the apical bridge is noted, but the healing response is excellent. A space maintainer is placed on the tooth.

Figure 13-4

A, Maxillary central incisor that has undergone apexification and canal filling. B, Four months later, the patient had not had the tooth restored and complained of soreness in his gingival tissues. Radiograph shows a horizontal root fracture on the central incisor.

Figure 13-5
be pursued. However, there are issues that need distillation and clarification before these concepts and potential techniques can become meaningful and sought after by the clinician:

- If the pulp is necrotic, how can “regeneration” in the truest sense be achieved in a predictable manner? Where do the stem cells for “odontoblasts” come from in a necrotic environment, especially if there is a long-standing periapical lesion?
- The tissue, both soft and hard, that is claimed to grow into the root during “revascularization”: Is it pulp? Dentin? Cementum? Osteocementum? Bone?
- What purpose will it serve to have this tissue grow into the pulpal space if in time the tooth suffers from the ravages of caries or trauma?
- Is there any difference in tissue response when the pulp is necrotic or just irreversibly inflamed?
- How can the extent of tissue damage be determined clinically?
- How do we know the extent of the inflammation, and where do we stop our treatment procedures in the tooth?
- Will the use of antibiotics in the pulp canal have a systemic impact on the patient over time?
- Will bacterial species adapt and reengineer themselves around the capability of these antibiotic mixtures in time?
- How can we know that these procedures will provide predictable outcomes for the patient?
- If the procedure fails, how do we know we can revert to a traditional or MTA apexification process?

**FIGURE 13-6** A, Maxillary lateral incisor with an open apex, thin root walls, and a large periapical lesion. The tooth was opened by her general dentist 2 months subsequent to a coronal fracture in which the pulp was exposed. B, The root canal was cleaned and a plugger (compactor) fitted into the canal for both length and width assessment. C, Mineral trioxide aggregate (MTA) is placed and compacted using the plugger. D, Canal is completely filled and a 6-month evaluation shows good bony response. Healing is not complete but is progressing.
FIGURE 13-7  A, A 13-year-old male with a large periapical lesion on a mandibular second premolar. B, Calcium hydroxide was placed. C, Within 3 months, the apex appears to be closing. D, Entire canal filled with MTA. Note slight amount of material that is past the foramen, probably calcium hydroxide. E, Three months later, the tooth and periapical tissues are stable.

FIGURE 13-8  A, Mandibular molar with significant decay, periapical lesions, and open apices. B, Decay was excavated, and calcium hydroxide was placed. Four months later, the root apices appear to be closing. C, Mineral trioxide aggregate (MTA) was placed in the canal, and the tooth was restored.
Problem-Solving Challenges in the Tooth With Fine and Calcified Canals

The problem of calcification was introduced in Chapter 8 in reference to access preparation and location of the canal orifices. Calcification in the root canal system is also a frequently encountered problem in root canal treatment. Radiographs often indicate an apparent complete obliteration of the pulp chamber and the canal spaces (Fig. 13-10). The process of calcification appears to be a linear phenomenon beginning in the crown and progressing apically in most cases. Therefore, the failure to locate a canal orifice during a non-surgical access procedure, even if it is extended quite deep, does not rule out the possibility that canal space exists more apical than can be reached.

In these types of cases, the eventual development of periapical pathosis has been observed by the authors to be uncommon. It is also fortunate that only a small percentage of cases that radiographically exhibit fine or unidentifiable canals prove to be unmanageable using nonsurgical root canal techniques (Fig. 13-12). However, when patent canal space is present, successful negotiation of this type of canal to its apical extent is extremely difficult. Of the numerous

CLINICAL PROBLEM

Problem: A 71-year-old female sought dental consultation because the porcelain fused to metal crown on her left maxillary lateral incisor fractured off at the gingival margin. There were no symptoms and the tooth had no clinical or radiographic signs of pathosis. A root canal space is evident on the examination film (Fig. 13-11, A). Intraradicular root canal treatment was initiated with the object of providing space for a post. Following careful excavation with a No. 2 surgical length round bur deep into the root, no canal could be identified. A control radiograph was made with an endodontic explorer in the excavation to assess the direction of excavation (see Fig. 13-11, B). The direction of excavation appeared to be accurate in the mesial-distal orientation and clinically, the excavation appeared centered in the buccal-lingual orientation. Further excavation was no longer considered prudent due to the limited ability to assess the buccal-lingual orientation of the bur angulation. What is the best course of treatment at this point?

Solution: In the absence of symptoms or signs of pathosis, conversion of the excavation to a preparation for an intraradicular post is indicated. The tooth was subsequently restored with a resin-fiber type of post, followed by a new full crown. Two years later, the patient developed symptoms of periapical inflammation. A radiograph revealed an apical lesion (see Fig. 13-11, C). Periapical surgery was the appropriate remedial treatment. At surgery, an ultrasonically energized endodontic file was used for the root-end preparation (see chapter 16). The file followed the existing canal space to the point of calcified occlusion at which point the apical canal space was enlarged and filled with MTA (see Fig. 13-11, D).
Before file insertion, a small curve is placed in its apical 1 mm. This can also be done with the C+ file. The precurved instrument must be directed along the pathway the canal is most likely to follow (see Fig. 13-13, D). Consequently, knowing the direction in which the curve in the instrument is pointed is vitally important. Observing the rubber stop on the instrument shaft of the directional type makes this determination easy. Penetrate slowly, using a slight 90-degree back-and-forth rotation to assess for patency. If patent, proceed apically until resistance is met, but do not try to just push the file apically in a linear fashion. The operative word is tease; teasing the file will allow it to find its way through the milieu of tissue debris and calcified matter.

During penetration, the chamber must be filled with NaOCl. A chelating agent can be used, but this will not dissolve loose debris, and it will negate the action of NaOCl. The calcified canal should never be negotiated without irrigant. This approach only serves to pack debris or calcifications into the canal and risks complete blockage. As the file is teased into the canal, try to establish a “sense of the patency” as this will provide a guideline for subsequent instrument use. Obtaining radiographs to verify the file position is exceedingly important64 (Fig. 13-14). Once a few millimeters of penetration have been achieved, the file should be used in a circumferential manner, opening the orifice. This is followed by removing the file, irrigating, and replacing the file to the previous depth. The file should fit loosely; if not, the first step should be repeated with a No. 10 or possibly a No. 15 K-file, or C+ file. As the irrigant penetrates into this small opening, the instruments loosen debris and begin to create a coronal pathway to the middle portion of the canal.

techniques available to locate and negotiate these canals, those procedures known to be most effective in clinical practice and used by the authors are considered here. Success in negotiating small or calcified canals is predicated on a proper access opening and identifying the canal orifice or orifices as discussed in Chapter 8. Typically, the canal is ready for penetration with an endodontic file when the endodontic explorer firmly “sticks” when forcibly inserted into the orifice. If available, it is often helpful to use the ultrasonic instrument with a probe type of tip (see Fig. 14-4) to both enlarge the orifice and circumferentially remove some of the calcified material.

This discussion will assume that the orifices have been located. Each tooth group will be somewhat different, but the concept and technique of gaining access to these canals are the same.

A 21-mm No. 8 K-file can be used initially to negotiate the calcified canal (Fig. 13-13). This file is flexible enough to negotiate around curvatures and calcifications. If the flexibility is too great, then instruments such as the C+ file or ProFinder files (Dentsply Maillefer, Ballaigues, Switzerland) will serve. The C+ file is possibly better in some canals; the instrument shaft provides as much as a 300% increase in resistance to a buckling force during penetration. If chosen, a 21-mm No. 6 C+ file will work nicely for canal penetration, because even though it is smaller than the No. 8 file, it has a stiffer shaft. If the canal is longer than 21 mm, changing to a 25-mm instrument once 21 mm of penetration has been achieved is simple. A No. 10 K-file is usually too large and a No. 6 K-file is too weak to apply any firm apical pressure, particularly if precurved. Nickel-titanium (NiTi) files are contraindicated for this purpose because of their lack of torsional strength.

**FIGURE 13-10** A, Maxillary molar with significant calcification present. B Histologic variations that may be noted in these types of calcified canals (H&E stain ×40).
Once the file reaches the coronal to middle portion of the canal, a No. 10 or 8 K-file may be used to penetrate deeper into the middle third. If successful, the orifice should be irrigated and the file used to loosen debris. Excessive apical pressures should be avoided during all efforts at penetration; however, greater amounts of pressure can be applied with the C+ files. The last two steps may have to be repeated multiple times to gain access to the canal.

Once the middle portion of the canal is reached, a NiTi rotary instrument can be used to enhance the flare of the coronal portion of the canal if desired. This will establish a more patent pathway and will improve the tactile sensitivity as canal negotiation and enlargement continues. As an alternate, a small Hedström file may be used. Continue to use copious irrigation during this process.

FIGURE 13-11 A, Complete crown fracture on a maxillary lateral incisor with extensive calcification. B, Unsuccessful attempt to negotiate canal. C, Two-year reevaluation following restoration with resin-fiber post retained crown. Apical pathosis is evident. Note: Conversion of access excavation into post space. D, Post operative radiograph. Apical surgery was indicated to clean and seal remaining canal space at the apex.
**FIGURE 13-12**  
A, Mandibular premolar with apparent complete calcification of the entire root canal system.  
B, Successful negotiation of the canal with a .08 file in combination with a solution containing EDTA.

**FIGURE 13-13**  
A, 38-year-old male presented with a history of tooth trauma to his mandibular anterior teeth. His chief complaint was periodic pain to pressure in the left lateral incisor. The tooth was nonresponsive to sensibility tests, with a slightly abnormal response to palpation and percussion. A radiograph showed significant pulp chamber and coronal canal calcification.  
B, Initial penetration of the pulpal space shows a mesial deviation of the file in the root and how the dental dam clamp can block direct vision of the file penetration.  
C, After failing to penetrate the canal, a temporary filling was placed and a radiograph was exposed without the dental dam in place to determine the angle of the access relative to the residual canal position.  
D, Reorientation and penetration with a small apically curved file.  
E, the canal was located, and penetration was achieved to the apex.
When the middle portion of the canal is opened, the apical portion can be approached in a similar manner as described. The philosophy of this approach is based on two concepts: (1) using the crown-down canal technique and (2) limiting the application to only small segments of the canal instead of trying to gain full penetration immediately. This technique should be used to open all orifices and canals before determining working length (see Chapter 7).

During penetration into the apical portion of the canal, a stainless steel file (No. 10 or 15) with a slight apical curve should be used to penetrate beyond the middle third of the canal. A probing and very gentle stem-winding movement should advance the instrument another 1 to 2 mm into the canal. The middle portion and junction of the middle-to-apical portion of the canal can have highly variable anatomic challenges, such as rapid narrowings, canal deviations, and canal junctions.

The newly penetrated space is filed until the instrument freely slides to the next desired level in the canal. Remember that the entire canal does not have to be negotiated immediately. This technique continues with alternating irrigation and advancement in 1- to 2-mm increments. In extremely narrow or tight canals, a No. 8 K-file should be immediately exchanged for a No. 6 K-file or switched for a C+ file. However, forcing these small files too vigorously may lead to ledge formation or blockage.

Frequent inspection of the apical curvature of the files is performed to identify any defects. Any instrument that shows evidence of fatigue or irregularity of the spiral flutes should be replaced (Fig. 13-15, see Figs. 14-39 and 14-40).

Once the estimated working length of the tooth has been reached, the No. 8 K-file should be used in a filing-only motion until a No. 10 K-file can be passed freely to within 1 mm of the length. Retain the instrument in the canal at that point for radiographic verification of the working length.

In the attempted management of calcified canals, finding a total occlusion of the canal space at any level is common. Histologic studies reveal that these calcifications are seldom complete to the apex (Fig. 13-16, A). Consequently, the prognosis of the root canal treatment depends on the continued health of the pulp or the periradicular tissues on the apical side of the blockage. In the absence of symptoms or evidence of periapical pathosis, it is clinically reasonable and acceptable to instrument and fill the canal to the level negotiated and evaluate the tooth periodically (see Fig. 13-16, C).

The previous directives addressed canals that had calcifications but could ultimately be negotiated. In the case of canals with extensive calcifications, consider the following guidelines:
Irrigate copiously throughout the process; 3% to 6% NaOCl enhances dissolution of organic debris, lubricates the canal, and keeps dentin chips and pieces of calcified material in solution.

- Advance instruments slowly.
- Clean and inspect instruments upon withdrawal, and do not reinsert if the integrity of the instrument is questionable.
- Obtain a radiograph or use an electronic apex locator when a fine instrument has reached the approximate canal length; it should not be removed until this is done. The only difficulty may be when using digital radiography, as smaller files are difficult to see. When trying to remove this instrument after securing the length information, **tease** it out with slight rotational force. Do not try to pull it straight out, because separation can occur.
- Acids (hydrochloric acid) or alkalis (sodium hydroxide) should **not** be used to aid in canal penetration. Chelating pastes or solutions should be used to assist in canal penetration (see Chapter 11).
- Ultrasonic instruments should be used in the pulp chamber to loosen calcifications and debris in the

**FIGURE 13-15** All files should be inspected frequently for irregularities in the flutes that indicate weakness and potential fracture.

**FIGURE 13-16** A, Calcification in the dental pulp routinely occurs from the coronal to the apical root anatomy. B, Maxillary molar requiring revision due to severe pain and swelling. C, Revision is complete, but further length could not be obtained in the distal buccal root (arrows). Patient is to be observed for any signs or symptoms. Apical surgery would be indicated if pathosis were to develop.
Problem-Solving Challenges in Compromised Roots, Root Canal Systems, and Anatomic Deviations

Problem-Solving Challenges in the Tooth With Resorptive Defects

Resorption can occur in any tooth and has multiple etiologies, of which bacteria, inflammation, pressure, and trauma are probably the most common. Chemical and mechanical injury also are key factors. Treatment or management is usually related to the stimulating factors and their removal. For example, intrapulpal infection from bacteria is the stimulation factor for internal and external resorptive defects. This requires appropriate root canal procedures. This same stimulation factor via the gingival sulcus can cause cervical resorption, as can chemicals used in internal tooth bleaching. In these cases, management may include periodontal therapy, root canal procedures, restorative procedures, and surgical procedures. Orthodontic pressures during tooth movement can cause resorption both longitudinally, which usually undergoes some type of repair, and apically, which does not repair and results in loss of tooth length and sometimes tooth vitality. Two additional stimulation factors that affect tooth resorption are impacted teeth and ankylosis. Management of an impacted tooth usually implies a surgical extraction and subsequent treatment modalities on any retained resorbed teeth if possible. Ankylosis has no known factor and therefore the management thereof is unknown.

Most clinicians tend to place resorption into two broad categories of resorption: internal resorption (IR; Fig. 13-17, A) and external resorption (ER; see Fig. 13-21). However, from a diagnostic standpoint, the clinician should also be knowledgeable about the wide range of potential resorative processes that can occur. If necessary, management support can be secured from dental specialists with expertise in treating teeth with more specific types of resorative processes. In some situations, no treatment is indicated, whereas in others (especially when symptoms are present), rapid, thorough, expeditious management is required. From an endodontic standpoint, the resorative process, not the pulpal inflammation and need for root canal treatment, limits the long-term prognosis of the teeth to be treated and causes nonfunctionality and premature loss. For example, the maxillary lateral incisor seen in Fig. 13-18 appears to have an internal resorptive defect. However, a careful examination of the midroot radiolucency shows the canal is intact; the radiolucency must be due to external invasive or extracanal invasive resorption. The prognosis with this resorptive defect is much worse than if it were IR. For additional examples of resorptive lesions see Chapter 3.

Internal Resorption

Internal resorption is defined as a process by which a cell within the pulp can differentiate into a clastic type of cell (Fig. 13-19, A) that resorbs dentin in the pulp chamber (see Fig. 13-19, B), within the root canal system, or both. It can...
occur anywhere along the root canal wall (Fig. 13-20). Bacteria and chronic inflammation of pulpal tissue have also been implicated as causes of IR. Unfortunately, no adequate animal models have been discovered that allow researchers to study this phenomenon adequately. The IR process is not self-limiting; without expedient and appropriate treatment, the resorption will continue until communication occurs from the root canal system to the periodontium, at which time the prognosis for the tooth becomes guarded.

The simple placement of radiopaque Ca(OH)\textsubscript{2} in the canal, followed by a radiograph, will assist in the determination of a perforative defect. In addition, the IR can begin in the pulp chamber and spread aggressively so that the entire crown of the tooth becomes nothing but a shell of enamel, making it unable to withstand the normal forces of occlusion and thereby severely compromising the strength of the crown (Fig. 13-21). Fortunately, IR is rarely a sequela to traumatic injuries such as luxated or avulsed teeth because of the pathogenesis of pulpal necrosis. Luxated teeth either heal rapidly or quickly become necrotic, and chronic inflammation plays no role in the healing process. Avulsed teeth routinely become necrotic, which prevents chronic pulpal inflammation from occurring, thereby eliminating the possibility of IR.

When the clinician identifies what appears to be IR, chances are that root canal treatment will be the main

![Figure 13-20](image-url) A, Example of a severe internal resorptive defect in the middle third of the distal root. Chronic inflammation due to caries was the most likely etiology. B, Internal resorptive defect beginning at the orifice of the distal root canal.

![Figure 13-19](image-url) A, Scanning electron micrograph (×2000) of an isolated multinucleated odontoclast that is present on the root surface. Note the surface of the root and the numerous lacunae. B, Clastic cell resorbing hard tissue.

![Figure 13-21](image-url) Large internal resorptive defect that threatens the strength of the tooth subsequent to orthodontic tooth movement.
If IR is diagnosed and the pulp responds to vitality tests, the ideal treatment is to remove the pulpal tissue as soon as possible. A vital pulp will continue the resorption process until either the pulp becomes necrotic (which is not necessarily the typical sequela) or until the pulp is removed during root canal treatment. If, on the other hand, there is evidence of pulp necrosis or there is apical pathosis, the resorptive process may be presumed to be arrested. Prevention is the operative word from many standpoints: prevention of symptoms and prevention of further destruction of tooth structure, including root weakening and the possibility of a resorptive perforation. It is a particular challenge to clean and seal the irregularities in tooth structure caused by the resorption. Small defects such as the one seen in Fig. 13-22, A are treated with little variation from a routine endodontic case. Large defects require more generous coronal canal enlargement though the access cavity itself should not be excessive. Large Gates-Glidden drills (5 or 6) can be used to enlarge the lingual aspect of the coronal canal from the access opening to the enlarged defect. The defect itself is much too large for standard endodontic files to be effective for cleaning. Alternative and sometimes improvisational debridement techniques are indicated. Long endodontic curettes, periodontal curettes and the ultrasonic instrument have all been effective depending on the location of the defect. Generous rinses and soaks with sodium hypochlorite are always indicated. It is wise to leave the sodium hypochlorite and the solution should be left in the defect for a few minutes if possible.

Typically, the canal space apical to the defect is treated in a standard manner. It can be filled by either the lateral or vertical compaction techniques. If warm, vertical compaction is used, the defect can be filled at the same time. It is very difficult to achieve dense compaction with lateral compaction. Furthermore, the lateral pressures on such a weakened root invite vertical or horizontal fracture. An excellent alternative is to fill the defect with MTA after sealing the apical canal space with gutta-percha and sealer or a resin-based material (see Fig. 13-22, B and C).

External Resorption

External resorption is quite common in long-standing periapical lesions, abnormal pressures (e.g., tumors or impactions), avulsion injuries, and orthodontic tooth movement. It is also seen routinely in intrusive luxation cases (Fig. 13-23). Most concussion, subluxation, lateral, and extrusive luxation injuries do not demonstrate ER as a typical sequela; however, it is possible in these forms of trauma (see Chapter 19). The two external resorptive defects that must be discussed with the patient are inflammatory resorption (Fig. 13-24, A and B) and inflammatory replacement resorption (IRR; see Fig. 13-24, C). Occasionally a form of extracanal invasive resorption is identified, but it usually does not involve the dental pulp24 (Fig. 13-25, A). If it should penetrate the pulp and manifest as symptoms or signs of pulpal pathosis, extraction or root canal treatment can be anticipated (see Fig. 13-25, A-C).

Inflammatory resorption is rapid and extremely destructive, but for the most part it can be prevented or minimized by proper cleaning and shaping of the root canal system. This resorption is characterized radiographically by moderate to large “scooped out” radiolucent areas on the root of the traumatized tooth (Fig. 13-26). These areas cannot be treated, but removing the necrotic and bacteria-infested pulpal tissue within the root canal system can prevent additional damage.
Studies suggest the use of long-term Ca(OH)$_2$ (6 to 12 months) as a therapeutic agent to prevent resorption$^{13}$; however, recently this treatment has been shown to decrease the fracture resistance of dentin$^{2,3,12,15}$ and the ability of healing periodontal ligament cells to proliferate,$^{49}$ thereby causing an increase in replacement resorption.

Inflammatory resorption is also seen in intrusive luxation injuries and will eventually cause loss of the tooth. The process occurs over several months to years before it becomes critical and the tooth is subsequently lost. The patient should be made aware of this type of sequela, and its ramifications should be included in the long-term treatment plan. Avulsion injuries will also demonstrate replacement resorption, but this can take months to years before it becomes apparent. The process is not self-limiting, and no known treatment prevents its occurrence or its spread throughout the root.

When inflammatory resorption occurs apically, it creates a challenge in the cleaning, shaping, disinfection, and obturation of the root canal system. The natural apical foramen and general apical constriction of the canal is lost creating large irregular apical canal openings through which filling materials are easily displaced (Fig. 13-27).

**FIGURE 13-23** Clinical appearance of extensive destructive external resorption. The radiographic image of this lesion is Fig. 3-22, B.

**FIGURE 13-24** A, Mandibular molar that responded normally to sensibility testing (as did all the teeth in this arch), yet the patient was experiencing vague discomfort. B, Patient returned 4 weeks later with swelling and severe pain; note the extensive inflammatory resorption in just 4 weeks. C, Inflammatory replacement resorption on the distal of the second molar.
FIGURE 13-25  A, Extracanal resorption; tooth responds normally to sensibility testing. B, Extracanal resorption; tooth had symptoms. C, Pulp removed and calcium hydroxide placed. D, The canals were filled with mineral trioxide aggregate (MTA). Six-month reexamination; patient was symptom free. (Case courtesy Dr. Paul Buxt.)

FIGURE 13-26  Histologic appearance of inflammatory root resorption. Multinucleated giant cells are present in the resorption lacunae that are deep into the dentin. No tissue replacement is evident (H&E stain ×10).
During canal shaping, it is wise to choose a termination point that is 1 to 2 mm shorter than would be appropriate for a routine case in order to create an apical stop. Often the use of MTA, custom-fit gutta-percha cones (Fig. 13-28), or apical barriers are necessary. Inflammatory resorption will also have an impact on the working length of the tooth (see Chapter 9).

**Cervical Resorption**

When inflammatory resorption occurs at the cemental-enamel junction, it is referred to as **cervical resorption** (CR) or sometimes **idiopathic resorption**; the etiologies and process are sometimes vague and elusive. CR can result from a dental procedure or inappropriate technique causing destruction of the external surface of the root, usually (but not always) beginning at the cemental-enamel junction. The resorptive process can be self-limiting, but more often it is not; if left untreated, it can destroy significant amounts of tooth structure. Fig. 13-29 presents examples of idiopathic root resorption that began at the cementoenamel junction of the maxillary left central and lateral incisors. In this case, the defect was not adequately accessible from a surgical standpoint, and the patient and clinician elected to watch the progression of the resorption over a 10-year period.

Although systemic conditions may play a role in the cause of this form of resorption, most research fails to identify any relationship with systemic medical conditions. However, one recent finding has determined a mild association of idiopathic external resorption to calciuria and a history of nephrolithiasis.

Other authors suggest that the cause may be correlated with injury, irritation, or both to the periodontal ligament. Proposed etiologies are excessive pressure from tooth eruption, normal and abnormal orthodontic forces, nonvital bleaching, bacteria, and treatment of periodontal diseases. Treatment of idiopathic resorption is a function of its severity, the location, whether the defect has perforated into the root canal system, and the restorative integrity of the tooth. If the defect is accessible surgically, removal of granulation tissue and repair with a biocompatible restorative material is indicated. Smaller lesions are sometimes confused with cervical caries and an attempt is made to restore the defect. Lesions of this type do not often develop pulpal symptoms. Cervical
FIGURE 13-28  A, This 15-year-old male’s central incisor was traumatized and is now discolored. The apex of the left central shows evidence of resorption (arrow).  B, Three months after placement of calcium hydroxide, the patient is symptom free.  C, Custom-fit gutta-percha cone.  D, Radiograph showing the fit of the cone near the resorptive defect.  E, Sealer was placed, the cone was seated and then removed; note the contact on the walls of the gutta-percha cone when it is custom fitted prior to obturation.  F, Vertical compaction of the cone.
resorption is usually discovered on routine radiographic examinations or after the overlying gingival develops chronic inflammation. Despite the lack of a specific etiology or pathogenesis, smaller lesions are amenable to treatment with excellent long-term results (Fig. 13-30). See Chapter 17 for additional information on the treatment of cervical resorption defects.

In all cases, the clinician must initially assess the restorability of the tooth. The surgical accessibility of the defect and the depth of extension below crestal bone are important, since periodontal surgery is virtually always required. The effect of bone recontouring on the adjacent teeth must be weighed against the desire to place the bony crest 2 or more millimeters below the margin of the resorption defect. Finally, there is always the possibility of recurrence. Therefore the patient should be informed that the prognosis of managing any idiopathic resorption defect is guarded.

Root canal therapy is only indicated if the defect has perforated into the canal system or for restorative purposes. Root canal treatment in and of itself will not in any way minimize or inhibit the continued clastic activity of the granulation tissues within the defects created by the resorptive processes. Clearly, the management of this type of root resorption requires a multifaceted approach, oftentimes involving many procedures in dentistry ranging from the placement of simple restorative materials to complex surgical intervention. The root canal treatment is usually delayed until the resorption defect has been repaired. It is difficult to provide quality root canal treatment when the pulp is in contact with the hemorrhagic granulation tissue that is present with the resorptive process. The challenge in the repair process is to maintain the patency of the canal during the placement of the repair filling material. Calcium hydroxide is a good choice due to the ease of removal. See Chapter 17 for additional information. Because the teeth involved with this resorptive process are often anterior teeth, the clinician is urged to consider the additional esthetic complications of this treatment approach when planning treatment.
Problem-Solving Challenges in the Tooth With a C-Shaped Canal

Although the prevalence of C-shaped canals is low in many parts of the world, other countries have a high incidence of these diagnostic and treatment challenges (Fig. 13-31, A). Some C-shaped canals are difficult to interpret on radiographs and are not often identified until an endodontic access is made. These anatomic variations primarily occur in mandibular second molars and maxillary first molars. When roots in these teeth appear very close or fused, a C-shaped canal anatomy should be anticipated (see Fig. 13-31, B).

The key problems encountered during cleaning and shaping C-shaped canals include difficulty removing pulp tissue and necrotic debris, excessive hemorrhage, and persistent discomfort during instrumentation. Because of the large volumetric capacity of the C-shaped canal system housing transverse anastomoses and irregularities, continuous circumferential filing along the periphery of the C-shaped root walls with copious amounts of 3% to 6% NaOCl is often necessary to ensure maximum tissue removal and cessation of bleeding.
Problem-Solving Challenges in Compromised Roots, Root Canal Systems, and Anatomic Deviations

Hedström files are especially effective for efficient tissue removal. If bleeding persists, then ultrasonic removal of tissue or placement of Ca(OH)$_2$ may be used between appointments to enhance tissue dissolution and removal and control hemorrhage.$^8$ Further ultrasonic instrumentation should be considered to remove tissue and debris in inaccessible areas.

Overpreparation of C-shaped canals should be particularly avoided because only minimal amounts of dentin are between the external root surface and the canal system in these teeth. In some cases, even with adequate local anesthesia, pain persists during canal enlarging and cleaning. Frequent administration of intrapulpal anesthesia may be necessary to keep the patient comfortable until all remnants of pulp tissue have been removed. Ca(OH)$_2$ may be used as an intracanal medicament to both neutralize bacteria and dissolve remaining tissue remnants.

Before commencing management of a C-shaped canal, the nature of the challenges in treating these teeth should be foremost in the clinician’s mind:

- The three-dimensional nature of the C-shaped canal must be visualized (Fig. 13-32). It is usually ribbon-shaped, often includes the mesial buccal and distal canals, and may include the mesial lingual canal. Canal orifices may be found within the C-shaped trough, or the C shape may be continuous throughout the length of the canal (see Fig. 13-31, E and Fig. 13-35). In maxillary molars, the C-shaped canal can encompass the mesial buccal and palatal canals or the distal buccal and palatal canals.
- Multiple concavities along the external surfaces of the root should be anticipated to prevent a strip perforation.
- An unrestricted approach to the complex canal system should be created, and the canals should be initially soaked with NaOCl.

Once the canals have been properly cleaned and shaped, a cold or warm gutta-percha or a thermoplasticized gutta-percha obturation technique should be used to manage the complex three-dimensional nature of the C-shaped system (Figs. 13-33 and 13-34). Core-carrier obturations such as ThermaFil, ProTaper, and GT X series or Vortex™ (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) are especially effective in obturating the C-shaped canal system (Fig. 13-35).

FIGURE 13-31 A-C, Photographs of mandibular molars with C-shaped orifices. D, Apical view of one of these molars that verifies the C-shaped configuration. E, Root resection verifies the C-shaped configuration.
**FIGURE 13-32** A, Radiograph of mandibular molar with C-shaped canal. B, Microcomputed tomography scan of cross-section of A. C, Longitudinal section of A showing shape of the pulpal space within dentin. D, Shape of pulpal space only. (Sections and photo courtesy Dr. Fan Bing.)

**FIGURE 13-33** A, Mandibular molar in need of endodontic revision. B, Resin model of a C-shaped canal system similar to the tooth being treated. Note the flanges and wide canal configuration. C, Six-month reexamination of completed revision with tooth restored. Patient is symptom free. (Case courtesy Dr. Faisal Amir.)
Problem-Solving Challenges in the Tooth With Moderate-to-Severe Canal Curvature

Clinicians who perform root canal treatment deal with root canal curvatures on a regular basis. The level of case difficulty increases with increasing degrees of root curvature. The basic principle of canal shaping has already been discussed in Chapters 8, 9, and 10, with the ultimate shape of the canal at the point of obturation resulting in a continuum of access design, orifice enlargement, length determination, and intracanal mechanics. In this section, ideas to enhance the preparation of canals of increased curvature will be described. Essentially, there is no simple solution to this problem and the management of curved canals improves with experience. Even experienced endodontic specialists face a major challenge with severe canal curvature (Fig. 13-36). Fortunately, the incidence of teeth with severe root curvatures requiring root canal treatment is low.

This discussion will focus on canals with moderate curvature such as the one depicted in Fig. 13-37, A. The canal or canals of greatest difficulty will be in the mesial-buccal root. Management begins with the extension of the access cavity. It is not necessary or helpful to make the access cavity excessively large overall but it is very helpful to extend the mesial wall of the opening 1 to 2 mm closer to the mesial marginal ridge (see Fig. 13-37, B). The enlargement of the orifices begins with hand files and copious irrigation. Once patency has been established, the hand filing should be especially vigorous toward the mesial and mesial buccal. The intention is to straighten the curvature in the coronal third of the canal. Hand files are followed by Gates-Glidden drills or nickel-titanium orifice wideners. Pressure on the rotary instruments should be mainly to the mesial and mesial buccal. Penetration into the canal should be 2 to 4 mm at the beginning with Gates-Glidden drills and perhaps a bit more with tapered orifice wideners. A ledge is likely to be created or the instrument may fracture if it is extended deep into the canal. Recapitulate with hand files often and maintain patency around the curvature.

Once the orifice has been sufficiently enlarged and the coronal third of the canal has been straightened, the preparation of the apical canal space can be done. By eliminating some of the coronal curvature, the completion of treatment will be more or less routine for most canals. On mandibular molars the identical approach is effective (see Fig. 13-37, C). Many useful ideas for canal cleaning and shaping of these canals can be adapted from the next section.
A. Severe curvature on the mesial-buccal root of a maxillary first molar. B. Posttreatment radiograph indicating obturation 2 mm short of radiographic apex. Treatment was done by an experienced endodontist.

A. Posttreatment of maxillary molar with moderate curvature in the mesial-buccal root. B. Access cavity placed more mesially for roots with significant curvature. C. Mandibular molar treated in same manner as described for the maxillary molar.
Problem-Solving Challenges in the Tooth With an S-Shaped Canal

S-shaped, or bayonet-shaped, canals can be troublesome and challenging because they involve at least two curves, with the apical curve being the most vulnerable to deviations in anatomy, loss of working length, and potential for instrument separation (Fig. 13-38). These double-curved canals (in two dimensions) that often have an additional curve (three dimensions) are usually identified radiographically when they traverse in a mesial distal direction. If they also traverse in a buccal lingual direction, they may be identified with multiple-angled radiographs or when the initial apical file is removed from the canal and it simulates multiple curves. In these situations, the use of cone-beam computed tomography (CBCT) may be of assistance (see Chapter 2). S-shaped canals are found in maxillary lateral incisors, maxillary canines, maxillary premolars (primarily second premolars), and mandibular molars (primarily second molars) (Fig. 13-39).

To manage these canal systems, the clinician must approach them with knowledge of the anatomic challenges, experience in the use of both contemporary and traditional instruments, and a thorough assessment of the case at hand. Using a traditional approach with hand stainless steel instruments, the following guidelines are set forth. First, the three-dimensional nature of the S-shaped canal must be visualized mentally, using the radiographic evidence available (see Fig. 13-38, A). Second, multiple concavities along the external surfaces of the root and the approximate positions of both the curves and concavities must be anticipated to prevent a strip perforation. Third, the clinician must create an unrestricted approach to the first curve by skewing the access preparation if necessary. Fourth, shape the coronal curve passively, as the coronal curve is first to facilitate the cleaning and shaping of the apical curve. Irrigate frequently and recapitulate as necessary with small files. Fifth, it is usually necessary to overcurve the apical 3 mm of the stainless steel file to maintain the curvature of the apical portion of the canal (or use NiTi hand or rotary instruments). In this process, the master apical file should be in the smaller size range (20 to 25), and smaller file sizes are used in this mid-to-apical region with short-amplitude strokes to effectively manage the anatomic challenges and prevent stripping and ledging in the apical curve. Anticurvature or reverse filing in the coronal curve is used, with primary pressure placed away from the curve of the coronal curvature to prevent stripping. Each case will vary depending on the nature of the curvatures, position of the tooth, and skill/experience of the clinician.

If the loss of working length or deviations in anatomy are identified during enlarging and shaping, the same principles of error management apply as those with a straightforward canal system (see Chapter 10). However, focusing on a problem that has occurred in the apical curvature can easily produce an additional problem in the coronal curvature. The

**FIGURE 13-38** Diagram depicting key problem areas in S-shaped canal systems. Notice that stripping can occur in areas where external root concavities exist.

**FIGURE 13-39** A, Maxillary second premolar with S-shaped root canal system. B, Two mandibular second molars; the mesial roots have S-shaped root canal systems.
astute clinician must render careful clinical judgment when managing problems in the apical curve. Once enlarging, shaping, and cleaning have been completed, finger compactors are used with either a cold or warm gutta-percha technique to obturate these delicate canal systems. Here also, the core carriers would be ideal.

The use of hand or rotary NiTi instruments has enhanced the ability to manage S-shaped canals (Fig. 13-40). The attributes of these types of NiTi instruments have enabled the clinician to maintain the canal anatomy while cleaning and shaping with a minimum of errors. First, the three-dimensional nature of the S-shaped canal must be visualized mentally, using the radiographic evidence available. Second, multiple concavities along the external surfaces of the root must be anticipated to prevent a strip perforation. Third, the clinician must create an unrestricted approach to the first curve by skewing the access preparation if necessary. Rinse the canal extensively with NaOCl to begin tissue dissolution. Fourth, create a pathway or glidepath by using small K-files (No. 8, 10, and 15 minimum) in the canal to loosen debris and create an accessible shape in the multiple curves. PathFiles (Dentsply Maillefer, Ballaigues, Switzerland) can be used effectively for this purpose. Rinse often and use hand instruments circumferentially, but do not penetrate the apical segment during this initial cleaning and shaping. Apply all NiTi rotary instruments with minimal pressure, allowing the instruments to move through the pathway that has been created and providing a tapered shape to the coronal portion of the canal first. Fifth, develop the shape of the apical portion of the canal after the coronal portion is opened, tapered, and patent. Use irrigants frequently and recapitulate as necessary. In the process of enlarging and shaping, maintain a small apical preparation—approximately 20 to 25—with the progressively or continuously tapered instruments. Taper the canal from 4% to 8% in the apical portion, thereby creating both a clean canal and one that is sufficiently tapered for good obturation using any technique (Fig. 13-41).

**FIGURE 13-40** A, Attention is paid to skewing the access to minimize entry into the curvatures. B, Determination of the position of the curves and the approximate length over the entire canal from the orifice to the apex. C, Instruments are used around the first curve to open the pathway for deeper penetration. D, Use of various instruments at various depths to ensure a smooth transition in the canal's pathway.
Problem-Solving Challenges in Anatomic Deviations

Most anatomic deviations are the result of genetic alterations in tooth development, changes in development of the Hertwig epithelial root sheath as it penetrates into the cancellous bone during root development, or trauma to the developing tooth. These deviations may include extra canals, extra roots (such as the radix entomolaris), dilacerations, defalcations, twinning, concrescence, dens invaginatus, dens evaginatus, talon cusps, and combinations of any of the above* (Fig. 13-42). Most of these abnormalities or deviations are rare, with the exception of having multiple root canals or roots on mandibular incisors, premolars, and molars.74 The most important aspect of these deviations is the recognition of such by the general clinician and referral to a specialist for treatment planning and management.

REFERENCES


*References 4, 7, 19, 27, 45, 72, and 74.


44. Kogan RN, Holcomb JB, McVicker DW: Endodontic manage-


RECOMMEND ADDITIONAL READING
Chapter 14

Problem-Solving Techniques for Revision of Previous Root Canal Procedures

Whenever a pulp is removed and the canal treated and filled in a manner that is compatible with or favorable to a physiologic reaction, we may expect a satisfactory percentage of success. Also, whenever treatment is carried on in such a way as to antagonize biologic processes of repair, we will continue to have many failures. J.R. Blayney, 1928

If by accident, the instrument used should break—and this is an accident careful handling should make very rare—it will sometimes be found difficult, and it may be impossible, to remove. If not jammed in the fang so as to be immovable, it may, in many cases, be withdrawn by rendering a small instrument magnetic, and passing gently up till it comes into contact with the fragment to be removed. The use of a magnetized instrument was suggested some time ago by the late Dr. John Harris, for a similar purpose. Once or twice during my practice I have found it impossible to remove the broken fragment of the instrument from the fang, and was obliged to fill without regard to it. I have observed no unfavorable results in these cases which I could attribute to this cause. R. Arthur, 1852

Unfortunately, the need for revision of previous nonsurgical (and surgical) root canal procedures is quite common in today’s practice of endodontics. The number of these cases can be largely reduced, however, if adherence to the principles of technical excellence provided in this book is a priority during the initial treatment. Sadly, the origin of the majority of recurrent pathosis can be attributed to diagnostic and

Problem-Solving List

Problem-solving issues and challenges in the revision of previous root canal procedures addressed in this chapter are:

- Recommendations for Removal of Existing Restorations
- Removal of Restorative Materials from the Pulp Chamber
  - Techniques for removing intraradicular posts
- Removal of Soft Root Canal Filling Materials
  - Techniques for removing gutta-percha
  - Techniques for removing paste root canal filling materials
  - Techniques for removing plastic core carriers
- Removal of Metallic Objects from the Root Canal
  - The ultrasonic instrument
  - Hedström files
  - Specialized forceps
  - Masserann kit
  - Techniques for removing metallic core-carrier obturators
- Removal of Silver Cones from the Root Canal
- Prevention of Metallic Instrument Separation During Root Canal Procedures
- Removal of Separated Instruments from the Root Canal
  - Gates-Glidden bur heads, Peeso bur heads, and large metallic fragments
  - Separated endodontic instruments
Recommendations for Removal of Existing Restorations

Root canal treatment in general, whether initial treatment or revision, does not usually require the removal of existing crowns. It is in the best interests of the patient to preserve satisfactory restorations, but if by doing so, the ability to revise the previous root canal treatment is compromised, it behooves the clinician to treatment plan the dismantling of the restoration. Similarly, while it is wise to make access cavities as conservative as possible, the access cavity should not be so small as to compromise access to the root canal system and perhaps the quality of the revision. Excessively large access cavities, on the other hand, undermine the retention of existing and usually satisfactory fixed prostheses. In most cases, the size of the access cavity should be the same as one would make for initial treatment.

Revision of root canal treatment can sometimes be accomplished while preserving existing posts and cores as well. Knowledge of internal tooth anatomy will provide avenues of success without the necessity of post removal. Anatomically wide canals such as the distal canals of mandibular molars or the canals of maxillary second premolars typically have a morphology a preformed stainless steel post will not completely obliterate (Fig. 14-1, A). This fact leads to two clinically useful approaches to revision. The first approach concerns the root that has only one canal. If the post is round...
and the canal is ovoid, it is possible to negotiate past the post and revise the canal treatment without removing the post or restoration (see Figs. 14-1, B and C).

Second, in a multicanal tooth, the canal in which the post was placed may not need revision. Again, it may be possible to access a canal with recurrent pathosis or a canal that was previously uncleaned without removing the entire restoration. Fig. 14-2 illustrates a case in which a root canal treatment failure was encountered in a mandibular molar with four canals, a large cast post core, and satisfactory crown restoration. Fortunately the post was placed in the distal-buccal root, which had no radiographic signs of pathosis. Without removing the post and the coronal restoration, access was made through the crown and core, and revision was completed.

Crown or restoration removal becomes a necessity when recurrent caries is found to extend well under the crown margins and is often in fact the etiology of periapical pathosis. A simple method for removing a full crown is seen in Fig. 14-3, A to D. If the crown is metallic, a fissure bur, long carbide finishing bur or transmetal bur can be used to cut through the crown to the depth of the tooth.

**FIGURE 14-2** A, Inadequate root canal treatment and recurrent apical pathosis in mandibular first molar. Note the post is in the distal buccal root, which has no apical lesion. B, Completed revision of three canals without removal of the cast post-core.

**FIGURE 14-3** A, Crown indicated for removal due to recurrent caries under margin. B, Beginning at the buccal gingival margin, the crown is cut up the buccal surface and across the occlusal-lingual aspect. Note the underlying tooth structure is not cut. C, Large, flat instrument such as an operative chisel or surgical elevator is used to pry the crown away from the tooth. D, Crown removed.
structure (see Fig. 14-3, B) To preserve as much of the internal structure as possible, the cut should not extend into dentin but may extend into underlying buildup material. Cut completely from the gingival margin on the buccal vertically and across the occlusal surface onto the lingual surface. The crown is then expanded with any flat-bladed instrument and removed. If the crown is metalloceramic, a diamond bur used for crown preparation will remove the veneer prior to cutting the underlying metal coping with a carbide bur.

**Removal of Restorative Materials from the Pulp Chamber**

Although standard round and fissure burs are typically used for this procedure as the access preparation extends into the pulp chamber, there is an inherent risk of cutting excessive tooth structure and weakening the tooth. If the pulp chamber is restored with amalgam or composite resin, there is no alternative but to carefully dissect this material with high-speed burs. If, on the other hand, the pulp chamber is found to be filled with a cement such as Cavit (3M ESPE Cavit Temporary Filling Material, St. Paul, MN, USA), zinc oxyphosphate, or zinc oxide eugenol, an ultrasonic handpiece will efficiently remove the restorative material with little effect on the dentinal walls. The ultrasonic tip of choice is usually a prophylaxis tip or a probe shaped tip (Fig. 14-4) used on a moderate to maximum power setting with copious water irrigation. The ProUltra (Dentsply Tulsa Dental Specialties, Tulsa, OK) without water or Start-X (Dentsply Maillefer, Ballaigues, Switzerland) ultrasonic tips—with or without water—are effective alternatives. Gutta-percha is one of the easiest materials to remove by this technique.

The ultrasonic technique is especially useful if the root filling material has a core carrier or is composed of metal. A bur will cut these materials and eliminate the potential to retrieve them using a forceps-type instrument. The removal of zinc phosphate cement from the pulp chamber with the ultrasonic instrument is seen in Fig. 14-5. The entire pulp chamber was cleaned in 3 minutes.

**Techniques for Removing Intraradicular Posts**

Intraradicular posts are used routinely in restoring severely carious or fractured teeth (see Chapter 20). It is not unusual to find a post in a root in which root canal treatment has failed; to revise the treatment nonsurgically, the post must be removed.7 The presence of a post, the difficulty of removing it, and the possible adverse restorative consequences of removal are considered an accepted indication for surgical repair.7 Nevertheless, nonsurgical revision is the treatment of choice in most but not all instances.

**CLINICAL PROBLEM**

**Problem:** A 43-year-old male presented with symptoms that focused on the maxillary left second premolar area. He stated that the tooth had had root canal treatment and a post and crown, and he could not understand why he was now having a problem. The tissues were slightly swollen in the midroot region of this tooth. Radiographically, there was evidence of root canal treatment with a post and the presence of a large lateral lesion (Fig. 14-6, A). One of two possibilities might explain the cause of the lesion: a post perforation (which did not seem plausible) or a lateral canal. These aberrant canal structures cannot possibly be cleaned and obturated thoroughly.24 Failure was probably due to the internal exposure of the lateral canal during post preparation. The crown was aesthetic and worth preserving. Moreover, surgical revision would be extremely difficult, with the location of the lateral canal interproximally on the distal surface of the root.

**Solution:** Through a routine occlusal access opening, the composite resin surrounding the post was carefully removed, and the post was subjected to ultrasonic vibration with the probe type of tip described above. Revision was completed, and a 7-month reexamination of the patient indicated that the tooth was in full function; radiographically, healing of the lesion was apparent (see Fig. 14-6, B). This problem-solving case points to the importance of approaching each case based on its unique circumstances and assessing all factors before making a plan of treatment.

Although it is possible to remove almost any post with the current technology, the tooth may become so mutilated in the process, prognosis is questionable. For example, after post removal, a short root with thin walls has little hope for a long-term viable restoration (Fig. 14-7). The potential for
FIGURE 14-5 A, Demonstration case: silver cones embedded in zinc phosphate cement. B, Removal of zinc phosphate was done with the probe-type ultrasonic tip. The cement was removed completely in 3 minutes without damage to silver cones.

FIGURE 14-6 A, Lateral lesion on a maxillary premolar due to a lateral canal communicating with unsealed canal space prepared for the post. B, Reevaluation of revised root canal treatment after 7 months, showing complete resolution of the lesion.

FIGURE 14-7 A, Inadequate root canal treatment in a maxillary lateral incisor with a fractured post. B, Successful removal of the post, but a very weak tooth remains. Treatment planning may warrant the consideration of an implant.
retention of a new post is compromised, and the risk of vertical root fracture increases. The following case illustrates the problem of the fractured intraradicular post, which can occur with and without concomitant failure of the root canal treatment. Unfortunately, this occurrence is labeled incorrectly by many clinicians as an endodontic failure.

Fractures of intraradicular posts are typically observed to occur at or just below the cavosurface margin of the post preparation. They appear to be the result of metal fatigue, not unlike continuous bending of a piece of wire (like a coat hanger) that breaks eventually. In almost all cases of post fracture, it is also observed that there was minimal extension of the crown margin past the post/core buildup onto tooth structure. This is often referred to as lack of a ferrule. Several examples are illustrated in Chapter 20. Initially after placement, a crown restoration under function has support from the core cement bond to the surface of the tooth and the post. Eventually, the cement bond between the core and the tooth surface will fail, and the post becomes the sole support for the crown. This will be undetectable clinically until the post fatigues and breaks, and the crown falls out. Prevention of post failure focuses on preservation of as much tooth structure as possible in the initial carious excavation. If there is minimal tooth structure remaining, crown lengthening (see Chapter 17) is an excellent solution.

**CLINICAL PROBLEM**

**Problem:** A 55-year-old male presented with a fractured post in the maxillary right second premolar. In addition, the root canal treatment was less than acceptable, resulting in recurrent periapical pathosis (Fig. 14-8, A). The patient was having no pain but faced the dilemma of either having the tooth removed and an implant placed or trying to have the post removed and the entire treatment revised. Problem-solving considerations must include a full explanation of the treatment possibilities and outcomes, including the potential for implant failure. The clinician can give guidance to aid the patient in making the choice but should not make the choice of treatment for the patient.

**Solution:** Following a thorough discussion of the treatment options and potential outcomes, the patient opted to retain the tooth. The post was removed using ultrasonic techniques, and the root canal treatment was revised. The root canal was filled slightly short of the divergent apical canal walls using a custom-fit gutta-percha cone and a root canal sealer that included mineral trioxide aggregate (MTA) powder (see Fig. 14-8, B). The patient returned for reexamination at 12 months. He was symptom free, and the tooth was restored to function with a post and crown. At the 30-month reexamination, healing was almost complete, and the patient was still symptom free (see Fig. 14-8, C). This case illustrates that a conservative choice of treatment usually has a positive outcome and points to the importance of approaching each case based on its unique circumstances.


With the availability of ultrasonic devices, removal of intraradicular posts has become much easier, and there is less risk of physical damage to the root compared with levering types of post removers or pullers. In addition, specialized tips are available designed to apply energy to the post.

Posts can be removed successfully from the inside of full crowns in molar teeth, as illustrated in Fig. 14-9.
Through a traditional access opening, the coronal restorative material was dissected from the post circumferentially with surgical length half-round burs. It was necessary to remove the surrounding material to the level of the orifice at least on the mesial, buccal, and lingual surfaces. The post material extending into the pulp chamber was freed from the restorative material prior to use of the ultrasonic device. Sometimes it is advantageous to apply lateral pressure on the post with a hand instrument inside the access cavity to observe even slight movement. This will break the bond with any remaining restorative material. Using the ultrasonic tips previously mentioned, more often than not the post can be loosened using midrange to high energy levels, depending on the ultrasonic unit. A conventional heavy-gauge scaler tip will also suffice. If the cement luting the post has also degraded from coronal or apical leakage, ultrasonic vibration will often loosen the remaining portion of the post in a few seconds.

If the post cannot be removed with ultrasonic application only, a Masserann trephining bur (MicroMega SA, Besançon, France) is selected that has a diameter slightly larger than the post. The Masserann kit will be described later in the section on removal of metal fragments from the canal, but at this point, the trephine, which is a tubular drill, will effectively prepare a narrow space around a post sufficient to allow the ultrasonic instrument to vibrate it loose (Fig. 14-10). Since the trephines are made of stainless steel, they will not be effective if composite resins, amalgam, or glass ionomer cements remain around the base of the post. The ultrasonic device is useful for the removal of fragments of these materials if they have been reduced sufficiently with burs. After removing the restorative material in the center of the pulp chamber, often it is helpful to bend the post to remove additional restorative materials behind it. For example, if the post is in the distal root and surrounded by composite filling material, bend it to the anterior after removing the composite from the more accessible mesial side. This will enable further removal of composite on the distal side with surgical-length small round burs.

In the case of fractured posts, access is no problem, but the margins of the fractured end of the post must be troughed with a half-round bur or the ultrasonic instrument in advance of the trephine. With copious irrigation, frequent pauses to clean the bur, and slow penetration, a space is created around the post fragment to a depth of approximately half the post length. During use, it is important to inspect the bur for flaring and to resharpen it. Since the post is metal, there is no danger of cutting into it or of straying from it into the root. The drilling normally will take between 5 and 10 minutes.

Once the space has been created around the post, the ultrasonic device is used on the maximum setting with a vibrating tip against the exposed end of the post. Ultrasound vibration of the post may take from 30 seconds to 10

**FIGURE 14-9** A, Mandibular first molar bridge abutment with inadequate root canal treatment. Clinically, a drainage tract had been present for months. B, Following removal of two posts and renegotiation of the canals. C, Reevaluation after 1 year, indicating complete periapical healing.
minutes before mobility is detected. The post fragment can then be teased out of the canal. If there is no mobility after 10 minutes of continuous vibration, the Masserann bur should be used to deepen the space around the post another few millimeters, after which the ultrasonic probe is applied again in the same manner.

Occasionally the most difficult part of post removal is getting the loose post fragment out of the canal because of the very limited space around it and the lack of post material above the occlusal surface on which to grasp with an instrument. The usual approach is continued ultrasonic vibration. Other aids that have worked successfully are the ultrasonically energized endodontic file in the space alongside the post, or a tightly fitting Masserann extractor that can effect removal by friction. If available, any section of stainless steel tubing, such as a section of a very large-gauge hypodermic needle, can be attached with cyanoacrylate cement.

FIGURE 14-10 A, Masserann trephine bur. B, Fractured post in a maxillary lateral incisor. C, Use of the trephine to create space around the post prior to application of ultrasonic instrument. Approximately half the post length must be exposed for successful removal. D, Post removed.
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the maxillary central in Fig. 14-12, this is a very effective and rapid approach to gutta-percha removal.

- Establish access to the entire pulp chamber, eliminating dentinal overhangs or constrictions around the access opening.
- Enlarge the coronal 5 mm of the palatal or lingual aspect of the canal using a No. 5 or No. 6 Gates-Glidden (GG) drill to provide a more straight-line path of removal for the filling material. This operation is done even if this involves removal of some of the root filling material itself, which will present no difficulty for the bur.
- Screw a large-size Hedström or K-file (No. 45 or greater) into the gutta-percha material, and pull the file out (see Fig. 14-12, B). If the file proves too difficult to withdraw by hand, a surgical needle holder (preferably with carbide jaws to reduce slippage) can be used to lever the file against the occlusal or incisal edge of the tooth in the manner shown in Fig. 14-12, C. If the instrument pulls out leaving the gutta-percha filling material, a larger-sized instrument is then inserted, and the procedure is repeated. In most cases where removal is successful, the gutta-percha will come out in one piece after the first or second attempt (see Fig. 14-12, D).
- If this approach fails, the coronal canal space is already prepared for the use of rotary instruments (see Fig. 14-12, E). The technique will be the same as described later for small canals. This method will seldom completely remove the material in large canals, but it will quickly reduce the amount remaining in the canal, after which the remainder in the apical third can be removed with hand files.

Small Canals

The Hedström file technique is also viable for small canals but is unlikely to remove the entire filling in one piece, and the smaller-diameter files required are more prone to fracture if they are screwed into the gutta-percha. To devise a plan for removing gutta-percha from small canals, no one hand-instrument technique is effective or recommended to clear the entire canal. It is helpful to consider which techniques are more useful in the coronal half of the canal and which are more appropriate for the apical half, especially in the presence of curves.

Gutta-Percha Removal in the Coronal Half of Small Canals

Removal of Soft Root Canal Filling Materials

Techniques for Removing Gutta-Percha

Large Canals

Hedström File Technique

When the need for treatment revision is identified in the case of a poorly obturated, relatively large diameter canal, such as another option that can be used with fractured threaded posts is a combination of ultrasonic vibration and cutting a slot across the top of the post to serve as purchase for a small screwdriver. The slot can be made with a No. ½ to 1 round bur or 33½ inverted cone. A small jeweler’s screwdriver is placed in the groove, followed by application of ultrasonic vibration. Pressure is applied in a counterclockwise fashion on the screwdriver during vibration (Fig. 14-11, A and B). This approach is very useful when the fractured post has no place for lateral purchase and troughing would be dangerous owing to root configuration.

Small Canals

The Hedström file technique is also viable for small canals but is unlikely to remove the entire filling in one piece, and the smaller-diameter files required are more prone to fracture if they are screwed into the gutta-percha. To devise a plan for removing gutta-percha from small canals, no one hand-instrument technique is effective or recommended to clear the entire canal. It is helpful to consider which techniques are more useful in the coronal half of the canal and which are more appropriate for the apical half, especially in the presence of curves.

Gutta-Percha Removal in the Coronal Half of Small Canals

Removal of Soft Root Canal Filling Materials

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Large Canals

Hedström File Technique

When the need for treatment revision is identified in the case of a poorly obturated, relatively large diameter canal, such as
FIGURE 14-12  A, Inadequate root canal treatment in a maxillary right central incisor. B, Removal of gutta-percha in one piece with a large Hedström file. C, File retrieval assisted with a surgical needle holder. D, Hedström file with removed gutta-percha. Note the fluting of the file is ideally designed to engage the filling material on withdrawal. 

FIGURE 14-13  A, Rotary nickel-titanium file for removal of gutta-percha. B, Instrument is rotated at 500 to 700 rpm to soften the material. C, Gutta-percha adhering to the instrument.
Maillefer, Ballaigues, Switzerland) have been advocated for removal of gutta-percha in the coronal half of the canal. One of the newest and most consistent techniques uses NiTi rotary retreatment instruments. In particular, the D-series revision instruments have been designed with descending tapers (.09→.08→.07) to permit removal of the bulk of gutta-percha from the coronal portion of the canal, opening a pathway to the apical half of the canal (D-files [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]; see Fig. 14-12, E). These instruments rotate between 500 and 700 rpm and soften and remove the gutta-percha by creating frictional heat in addition to their mechanical activity in the canal. They are designed to be used in a crown-down manner, reaching depths up to 22 mm and moving around curves without deviation or destruction of root walls. The first instrument has a cutting tip and is limited to a depth of 16 mm, which is ideal to remove the coronal half to two-thirds of the material in most canals. The remaining two instruments have modified tips to prevent gouging into the root walls. Depending on the length of the canal, removal in the apical few millimeters may require the use of a hand instrument.²³,¹³

**Heat Technique** Heated instruments have been recommended to remove the gutta-percha from the orifices and coronal third to half of the canal space (Fig. 14-14).

- The instrument can be a plugger or spreader made of metal designed to be heated (if not, the instrument will be unusable for its intended purpose after just a few heatings) or a specific heat-transfer instrument. It is heated until it is cherry red and then plunged into the gutta-percha.
- The instrument is left in the softened gutta-percha for no more than 1 to 2 seconds. Usually the gutta-percha will have an ideal consistency for removal.
- The process is repeated, and gutta-percha is sequentially removed as the technique is continued into the canal.
- The disadvantage of this approach is that it is relatively ineffective for old gutta-percha that has lost its plasticity with age.

**Ultrasonic Technique** Currently available ultrasonic units designed for endodontic use possess enhanced energy to soften even old, hardened gutta-percha material (Fig. 14-15).

- Using a probe-type tip or even a standard prophylaxis tip, the machine is set on moderate to maximum power. If the ultrasonic instrument has been used to remove materials from the pulp chamber, it is easy and uncomplicated to extend the tip into the orifices of the canals at the same time. This will also help to locate the canals and clarify the internal anatomy.

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**FIGURE 14-14** A, Heated endodontic plugger used for gutta-percha removal. B, The heated instrument is plunged into the canal. C, Melted gutta-percha adhering to the plugger.

**FIGURE 14-15** A, Ultrasonic instrument used for gutta-percha removal. B, Probe tip is used on a high power setting. C, Gutta-percha material adhering to the ultrasonic tip.
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Problem-Solving Techniques for Revision of Previous Root Canal Procedures

Gutta-Percha Removal in the Apical Half of Small Canals

Rotary Nickel-Titanium Technique  Once again, with NiTi rotary instruments, thermal softening of the gutta-percha by frictional heat is the goal. This is the reason for higher speeds, but it is not the intention at this point to begin reshaping the canal. Therefore, the taper and the file diameter must always be smaller than the canal size to prevent binding and instrument fracture.

Possible techniques favored by the authors for removing the gutta-percha filling at this point include the following. (Note: all techniques must be tailored to the challenges of each case and are dependent on the clinician’s experience and expertise.)

Technique A

- Use a .06 No. 25 ProFile run at speeds of 500 to 700 rpm, depending on canal anatomy.
- Proceed carefully while the material is plasticized.
- Use a sequential plunge-and-withdrawal technique to go deeper into the canal.
- Use copious irrigation throughout the procedure.
- Use the solvent to remove the remainder of the gutta-percha along with the instrument segment, if an instrument should separate.

Caution:

When in contact with the walls of the access in the metallo-ceramic or full-ceramic crown, the ultrasonic probe may cause delamination or fracture of any porcelain veneer material around the access cavity opening.

Caution:

Do not use a Peeso bur in a curved canal.

Gates-Glidden or Peeso Bur Technique  These burs are in common use for orifice widening. They can be used in canals filled with gutta-percha as well (Fig. 14-16). The material will not alter the effectiveness of the burs to both enlarge the orifice and remove the gutta-percha simultaneously. If larger instruments are used, they may do some unwanted cutting on the dentin walls and must be used carefully in canals that anatomically deviate rapidly in the coronal third.

- The basic approach is “crown down” using a No. 4 GG bur or a No. 2 Peeso bur to open the orifice to a depth of 2 to 3 mm.
- A No. 3 GG bur is used to extend another 2 mm.
- Finally, a No. 2 GG bur extends the preparation and the gutta-percha removal another 2 to 3 mm to complete this first phase of removal.

may be uninstrumented or difficult to access. It is usually better to use this method after the bulk of material has been removed by other techniques. (Solvent may also cause movement of the old filling material into the dentinal tubules, thereby preventing access for medicaments to reach potentially embedded bacteria.)

- Removal of some root canal sealers may be enhanced through the use of EDTA (ethylenediamine tetraacetic acid) and NaOCl (sodium hypochlorite).17

Techniques for Removing Paste Root Canal Filling Materials

The presence of paste filling materials in the root canal is usually easy to detect on a radiograph. Paste materials typically have “bubbles” or air voids because a lentulo spiral instrument was used to augur the unset material into the canal during filling. The density of the material often varies radiographically within the same tooth. Sometimes the material will appear to be gutta-percha, and the paste is discovered only after access is made into the tooth. Visually it may appear as gray, white, or reddish.

On opening into a canal filled with a paste, the material usually looks and feels as though it had never set, or as though it had been dissolved by the action of the tissue fluid that has diffused through the unsealed apical foramen. It is usually soft, even mushy to the explorer. Any hand file or rotary file may be used to remove most of the remainder of the material, after which routine cleaning and shaping of the canal may begin.

**Technique B**
- Choose a ProTaper finishing instrument that is slightly smaller than the root canal filling as estimated from the radiograph. (Note: ProTaper finishing instruments have the same sizing as ProTaper D retreatment/revision instruments, only in reverse; that is, the D1 has a taper of .09, whereas the F3 has a taper of .09, and so on.)
- Place a small amount of solvent in the chamber.
- Using speeds of 300 to 500 rpm, allow the instrument to move gradually but steadily into the gutta-percha material to approximately two-thirds to three-fourths the length of the canal; further, safe penetration can be achieved using the ProTaper hand instrument of the same size.
- Withdraw the instrument frequently to wipe the material from the cutting edges and flutes of the file.
- Use copious irrigation throughout the procedure.
- ProTaper retreatment/revision instruments are also effective when applied at speeds of 500 to 700 rpm (see Fig. 14-12, E).

**Solvent Technique** A long-used method of removing gutta-percha and sealer from a root canal is softening the gutta-percha with a solvent such as methylchboroform, rectified white turpentine, or eucalyptol (Fig. 14-17).13 Solvent is especially useful in canals with ledges or other obstructions which limit the use of rotary files. This would also be the method of choice if during the use of the rotary technique, a section of NiTi file separated in the gutta-percha material.

- Once the orifice of the canal has been uncovered, fill the access cavity with solvent. The solvent must not be allowed to run onto the dental dam because it will denature both natural rubber and vinyl, and a large hole will quickly result.
- After 1 or 2 minutes, the solvent in the pulp chamber will dissolve the gutta-percha to the extent that a No. 15 or 20 K-file will easily negotiate the canal.
- Begin reshaping and cleaning of the canal.
- Solvents make thorough removal difficult; dissolved gutta-percha tends to flow into areas of the canal that

![FIGURE 14-17](image_url)

**FIGURE 14-17** A, Removal of gutta-percha with solvent. Solvent should fill the pulp chamber. B, After 2 or 3 minutes, the dissolved gutta-percha is removed with hand files. C, Dissolved material wiped on a cotton roll.
symptoms resolved shortly after the initial débridement, and the treatment was completed without complications (see Fig. 14-18, B).

The unsuccessful use of paste fills can be found in both posterior and anterior teeth. In Fig. 14-19, A the coronal restoration is aesthetic and worth preserving. The adjacent central incisor was diagnosed as having a necrotic pulp and also in need of a primary root canal procedure. Through a routine access opening, the post was retrieved by careful removal of the surrounding composite resin and ultrasonic vibration. The disintegrated paste filler was easily removed with a hand file and irrigation (see Fig. 14-19, B). Root canal treatment for the left central incisor was completed simultaneously with the revision of the right central (see Fig. 14-19, C).

Although most paste filling materials are largely zinc oxide eugenol in composition and are soluble in solvents, the ultrasonic instrument is much more effective in removing set material. Rotary NiTi instruments are equally effective for this procedure. If a case is encountered in which the material appears hard set deep into the canal orifice, solvents may help after removing as much of the paste as possible with the ultrasonic instrument. Usually the remaining material is soft enough to be penetrated with either hand or rotary instruments, but the exceptional case may benefit from the use of a solvent. In some cases, the paste will be impenetrable, or a calcified dentinal bridge will block further access into the uncleaned apical canal space. Periapical surgery may be the only recourse if pathosis exists in the periapical tissues (see Chapter 16).

**Techniques for Removing Plastic Core Carriers**

Unfortunately, identification of a plastic core carrier on the preoperative radiograph may be difficult insofar as it may not be distinct from the gutta-percha material that surrounds it.
It may be impossible to preoperatively associate the cause of failure with the problems of this filling technique (Fig. 14-20). To understand the problems encountered in removing the plastic core carriers, the major reasons for the need for revision when using this method of obturation must be discussed. First, the canal preparation must be a continuously tapered funnel (see Chapter 10). It is commonly observed that canals intended to be obturated with core carriers are underprepared. The lack of taper may allow the core carrier to reach the prepared apical seat, but the movement of the gutta-percha is impeded. The result is a stripping of the gutta-percha from the core due to frictional binding and a consequent lack of gutta-percha at the apex to provide the necessary seal. Conversely, if the canal is too large or too flared, gutta-percha adaptation to the walls may exhibit voids or gaps in the fill, especially in the proximal dimension. This gives the clinician a false sense of the quality of the obturation.

Proper access openings are also necessary when core-carrier techniques are used (Fig. 14-21, A). If the access is improperly shaped or insufficiently large, the softened gutta-percha will be stripped from the core carrier as it is placed into the canal. Because core carriers are flexible, they can lodge under ledges of the pulp chamber in anterior teeth or pulp chamber roofs or horns in posterior teeth. This creates significant problems when attempting to gain access to the chamber during revision while protecting the coronal extension of the core carrier.

**FIGURE 14-20** A, This diagnostic radiograph includes a sinus tract exploration with a gutta-percha point. B, One-year reevaluation after complete revision indicates excellent resolution of the apical pathosis. (Case courtesy Dr. Erick Menegazzo.)

**FIGURE 14-21** A, Access cavity for revision should be approximately the same as routine root canal treatment. B, Removal of filling materials in the pulp chamber should be done with care to avoid cutting core carriers. C, Gutta-percha can now be removed from the pulp chamber with the ultrasonic instrument.
The technique for removal of plastic core carriers must begin with the removal of all restorative materials, endodontic cements, and excess gutta-percha from the pulp chamber (see Fig. 14-21, B). If the pulp chamber contains only cement-based materials, Cavit, gutta-percha, or root canal sealers, an endodontic ultrasonic instrument with the probe tip on a high setting for débridement is used on the pulp chamber floor, in the same manner as described for gutta-percha and paste removal. The ultrasonic probe will not degrade the core material so long as contact is brief. As with removal of any root filling material, if the pulp chamber is restored with any of the permanent materials such as composite, glass ionomer, or amalgam, extreme care must be taken during their removal with the high-speed bur to avoid cutting the core-carrier material. Once the pulp chamber is prepared and the plastic core carriers are free from surrounding materials (see Fig. 14-21, C), the following techniques and considerations may be incorporated into the revision approach:

• Use a grasping instrument or small forceps if the plastic core carrier is long enough and reachable. The Stieglitz forceps or the Peet splinter forceps, among others, are suitable for this purpose (Fig. 14-22).

• Use the Hedström file technique without solvent.27 Screwing one or more Hedström files (No. 25 to 35) into the coronal canal space will engage the plastic core material in the flutes. It is often necessary to use a surgical needle holder for leverage because the Hedström file will be very resistant to retrieval. The plastic core will be retrieved completely in many cases without additional steps (Fig. 14-23). Most often the gutta-percha material will remain in the canal and must then be removed by one of the methods described earlier for gutta-percha.

• Flood the pulp chamber with chloroform. After a couple of minutes, the gutta-percha surrounding the plastic core carriers becomes softened, enabling a Hedström file to become easily engaged in its surface.14

• Solvents can be reintroduced into the canal if only a portion of the plastic core comes out. The remainder of the core is “instrumented” away slowly. Other solvents such as xylene, eucalyptol, and halothane do not soften the gutta-percha as readily as chloroform.

• Use a NiTi rotary file at high speed (1400 rpm), as with the removal of gutta-percha. The core material will become softened by friction and will either spin out of the canal space or will be removable by further filing. Alternatively, use a ProTaper retreatment file (D1-D3) or finishing file (F1-F3) that will macerate the plastic core as it cuts apically in the canal, or in some cases may result in removal in toto.

If extensive canal irregularities are present (e.g., fins, webs, culs-de-sac), the softened gutta-percha may lock the carrier into its position. Removal with a grasping instrument may be difficult, even after softening with a solvent. Likewise, if a file is being used with solvent to remove the gutta-percha
along the length of the carrier, the carrier may be severed, thinned, or pushed into the canal irregularities, especially with the smaller, more flexible carriers. If this occurs, it may give the impression that the canal is being cleaned, when in actuality the carrier is being slowly cut by the filing action. Radiographic checks during removal attempts will provide evidence that a portion of the carrier is still present, yet the canal may feel “smooth and clean” to the clinician. A curved or bent Hedström file can be used to engage the adherent section of the plastic carrier for removal. This approach also favors canal cleaning and shaping. Although the majority of plastic core carriers can be routinely retrieved—even those extending beyond the apical foramen—apical surgery cannot be excluded as a possibility for some of these cases.

Removal of Metallic Objects from the Root Canal

Various specialized strategies have been developed for instruments that can be used routinely for the revision of treatment, and some instruments are designed specifically for this purpose.

The Ultrasonic Instrument

The use of the ultrasonic instrument has already been discussed with respect to the removal of cements and debris from the pulp chamber surrounding plastic core carriers. This technique uses a prophylaxis or probe-type tip (see Fig. 14-4). The same technique will also apply to the removal of metallic carriers, with the added advantage that there is no effect from the ultrasonic tip on the stainless steel core, so the device can be used on a higher or even maximum power setting, depending on the unit without fear of weakening the carrier.

- Using the probe tip will often remove any calcified tooth structure in the orifice area that was not removed initially.
- The probe tip can apply ultrasonic energy directly to the metallic core with the object of loosening it. If corrosion and loss of sealer has occurred, the probe tip may loosen a failing silver cone and cause it to come out completely. This will rarely if ever happen with a metallic core carrier. If used directly on a segment of NiTi file, the file will usually break off.
- The probe tip will excavate dentinal tooth structure around an embedded fragment, similar to its use in exploring for a calcified canal. It will also excavate dentin circumferentially in the orifice area and longitudinally parallel to a metallic fragment in some roots (Fig. 14-24).
- An endodontic file can be attached to the ultrasonic instrument (Fig. 14-25), which can débride the canal of cements and paste filling materials.
- An ultrasonically energized endodontic file can enlarge root canal spaces alongside embedded metallic fragments.

In this application, it will usually be necessary to create a pathway by hand instrumentation prior to introducing the ultrasonic instrument. Occasionally, this strategy also may also loosen the object and remove it.

Hedström Files

- Hedström files are generally useful to enlarge a space in the canal adjacent to a silver cone, fractured instrument segment, or plastic core carrier. The use of rotary files against metal objects increases the risk of breakage,
which compounds the difficulty. Initial negotiation usually begins with Nos. 6, 8, and 10 K-type files. Once these files have opened a pathway, the Hedström file can rapidly enlarge the space for either bypassing an embedded file or using the ultrasonic instrument to dislodge it.

- If there is a space into which a No. 25 to 35 or larger Hedström file can be partially inserted, it can be further “screwed” into a deeper position, taking care not to stress it to the point of breakage. The metallic object may be dislodged and may come out as the file is withdrawn directly from the canal.

- In a larger canal with ample space surrounding the metallic object, multiple files can be placed alongside a silver cone (similar to the previous approach) and are withdrawn simultaneously. This is known as the file-braiding technique (Fig. 14-26).8

- Hedström files will not secure a purchase on other stainless steel files, and the technique will generally not work on metallic core carriers, broken files, lentulo spirals, or GG drills unless the canal shape permits an easy bypass.

- The one exception is the possibility of getting a purchase in the fluting of another file, metal-core gutta-percha carrier, or around the flutes when there is larger spacing in the fluting, such as a Peeso bur. Much time and effort can be spent trying to achieve retrieval without the desired result. This would rarely be the initial technique of choice in these cases.

**Specialized Forceps**

As mentioned earlier, several specialized forceps are available for removing metallic objects. All have narrow beaks that will extend into a reasonably conservative access opening (see Fig. 14-22, A). The Steiglitz (right) forceps is a grooved, needle-nosed pliers that is often too bulky to use in small access openings. The Peet splinter forceps (left) are generally more useful because the taper on the beaks is more gradual, allowing freedom for beak separation and grasping the metallic object in deep access openings. Equally useful alternatives are Perry gold foil pliers and Hartman 3/4-inch curved mosquito forceps (Miltex, Inc, York, PA, USA). Any of these instruments is useful for removing a loosened silver cone, a loose separated endodontic file fragment, or the shaft of a GG drill from the pulp chamber (see Fig. 14-24, B).

**Masserann Kit**

A useful and versatile system for retrieving metallic objects from canals is the Masserann kit (Fig. 14-27, A). This kit contains a series of tubular trephining drills, the largest of which were discussed earlier in the removal of endodontic posts. In addition, there are two sizes of tubular extractors (1.2 and 1.5 mm) (see Fig. 14-27, B). If a significant portion of the metallic object extends into the pulp chamber, only the extractor may be needed to remove it. The tubular extractor is placed over the object, and the plunger is screwed until tight. This will lock the object against a knurled ring in the
Nevertheless, it may become necessary to revise a case that was obturated in this manner, either because of treatment failure or the restorative need for an intraradicular post. Whereas plastic core carriers are difficult to distinguish radiographically, metal core carriers typically have the familiar spiral appearance of endodontic files (Fig. 14-29). Unlike the previous case (see Fig. 14-28) where the file shape is obvious, the metallic core carrier is surrounded by gutta-percha and can be somewhat disguised, especially with small-diameter carriers. A frequent clue to the presence of metal core carriers is the increased radiodensity of the filling material in canals that might appear to be underinstrumented.

In addition to the mesial buccal root canal in Fig. 14-29, the gutta-percha was stripped from the carrier during placement in the palatal canal, leaving the apical 3 mm of the core carrier denuded.

Revision will begin with access through the existing restoration. If the pulp chamber is filled with Cavit or other softer cements, the ultrasonic instrument will suffice. If the pulp chamber is filled with composite resin or glass ionomer cement, it will be necessary to dissect these materials with the high-speed bur or ultrasonic. Upon removing the restorative material from the pulp chamber, it is especially important to avoid contact between the bur and the metal carrier, as even a small cut or notch will be a weak point at which the metal may break off during the attempt to loosen or remove it. The ultrasonic instrument is highly effective for both removing the surrounding endodontic filling materials in the coronal canal space and loosening the metal core carrier, at least in the coronal third to half of the canal. Since the stainless steel is unaffected by ultrasonic vibration, the device can be used at maximum power, which will help loosen the carrier and remove tube wall. This mechanism provides adequate retention for removal of most silver cones, metallic core carriers, and some separated endodontic instruments.

If the metallic instrument is cut off at a level preventing use of the extractor, the smaller tubular trephining drills can create enough space in both length and width for eventual placement of the extractor. Once the extractor device is secured to the end of the metallic object, the technique for removal is a gentle pull combined with a slight counterclockwise rotation. The general idea is to “unscrew” a separated instrument rather than attempt to pull it out directly.

Techniques for Removing Metallic Core-Carrier Obturators

Although never advocated in formal institutions of dental education, some practitioners once embraced the use of endodontic files for permanent obturation of the canals (Fig. 14-28, A). This is a perfect example of “clinician failure” through the use of inappropriate materials and techniques for root canal treatment. Due to the inherently inadequate seal, the treatment failed and revision was indicated. Following removal of the zinc phosphate cement surrounding the ends of the files protruding into the pulp chamber, the Masserann extractor was used to remove the instruments (see Fig. 14-28, B). Routine root canal procedures were used to complete the revision (see Fig. 14-28).

This case illustrates a removal technique that applies directly to metal core-carrier obturators, since the concept of the core carrier for gutta-percha obturation is derived from a K-type endodontic file coated with gutta-percha. Metallic core carriers have mostly been replaced with plastic.

surrounding gutta-percha. It is rarely possible to loosen a metal core carrier to the point of removal with ultrasonic vibration alone.

Once ultrasonic vibration is done and the coronal extension of the core is mobile, there are a number of useful ways to proceed to removal:

- As described with removal of plastic cores, additional gutta-percha in the midroot area can be removed by flooding the pulp chamber with solvent and using a small instrument to attempt to bypass the core as far as possible both vertically and circumferentially.
- Heat applied directly to the metallic core, using a Touch ’N Heat or System B (both from SybronEndo, Orange, CA, USA) BeeFill 2in1 (VDW, Munich, Germany); or Calamus® Dual (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), can be helpful to soften the gutta-percha that surrounds the metal carrier deeper in the canal space. In lieu of this, a heated large instrument (e.g., amalgam compactor) can be applied to the carrier two or three times for 5 to 10 seconds each (Fig. 14-30).
- In canals that are wide buccal lingually, a hand or rotary instruments can be used to soften and remove gutta-percha filling material around the core. Sometimes the canal size may allow removal as far as the apical third. This will allow the core greater mobility in the canal space. Ultrasonic vibration may complete the retrieval.
- The specialized forceps technique is very fast and works well if the metal core is fairly loose and long enough to be accessible. Fig. 14-31 documents the revision of a mandibular molar in which the metal core carriers were removed with a Peet forceps. The file-braiding technique might work if the core is very loose but too short to grasp with the forceps.
- A Masserann extractor is especially effective if the metal core has great retention. In the same manner as shown in
Fig. 14-28, B, the extractor is secured tightly over the end of the metal core, which is virtually the same as an endodontic file. Simultaneously the extractor is both pulled and rotated counterclockwise, thereby “unscrewing” it from the canal space. Pulling directly on the metal core does not usually result in retrieval; friction of the metal against the canal wall or adhesion to the gutta-percha in which it is embedded inhibit withdrawal. The Masserann extractors can be used to expose more of the length of the core to affix the extractor. When the core extends into the pulp chamber, the trephine will easily follow its long axis.

- Carriers that are surrounded by amalgam in the pulp chamber are difficult to distinguish and could be cut off at or below the canal orifice. Some cases present for revision with the obturators already cut off at the level of pulp chamber floor. These circumstances pose a different set of problems in revision because it is impossible to grasp the core remaining in the canal space. Furthermore, passage of a small instrument alongside the metal core may be a technical challenge even with the aid of a solvent. The trephining technique is indicated.

- The technique for loosening would begin with an ultrasonic tip followed by the Masserann trephining burs that would cut a widened space around the metal carrier in the canal orifice. Initially, it is usually more difficult to center the trephine over the metal core owing to the lack of core material in the pulp chamber to follow. This is where the ultrasonic comes in by helping to not only loosen but expose more of the coronal end of the object. Ultimately the goal is to attach the Masserann extractor or instrument retrieval system (IRS) extractor in a stable position and remove in the manner described earlier. This may prove to be difficult and time consuming.

An interesting clinical finding with metal core gutta-percha carriers sometimes occurs if the metal core extends through the coronal buildup and is in contact with a metallic restoration or a full crown, either all metal or porcelain with a metal coping. The metal core carrier will often act as a thermistor in the conduction of temperature changes to the vital periapical tissues. In these cases, patients report significant discomfort to heat in a root canal–treated tooth. This problem is especially acute when the core carrier is beyond the root apex or has been stripped of its gutta-percha in the apical third of the canal. A positive response to a heat test on such a tooth would be convincing evidence for revision.

**FIGURE 14-31** A, Recurrent apical pathosis on a mandibular molar treated with metal core carrier endodontic obturators. B, Retrieval of the metal cores with a Peet splinter forceps after removal of coronal gutta-percha by ultrasonic instrumentation.

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**CLINICAL PROBLEM**

**Problem:** A 26-year-old male with symptoms of acute prolonged sensitivity to cold and spontaneous pain in the mandibular right quadrant was seen for emergency consultation. He could not bite on the first molar without excruciating pain. Root canal treatment had been completed 3 days earlier using a metallic core-carrier obturation technique (Fig. 14-32). When cold was applied to the teeth in question, the main source of the discomfort was the second molar. However, pain to percussion was most intense on the first molar.

**Solution:** A diagnosis of irreversible pulpitis and normal periapical tissues was made for the second molar and acute apical periodontitis for the first molar. Root canal treatment was initiated on the second molar, and the occlusion was adjusted on the first molar. Percussion pain continued on the first molar for 1 week after occlusal adjustment. After completion of the root canal treatment on the second molar, using gutta-percha and sealer, treatment on the first molar was revised (see Fig. 14-32, B). All symptoms subsided within 2 weeks, and the first molar was obturated with gutta-percha and sealer using lateral compaction (see Fig. 14-32, C).
irrigation and drying will allow the earliest detection of the silver cone in the surrounding filling material (Fig. 14-34). Once again, if the material filling the pulp chamber is relatively soft, it can be removed entirely with the ultrasonic unit, as was shown in Fig. 14-5. If the filling material is hard and requires removal with a high-speed bur, avoidance of contact between the bur
Masserann extractor is an effective device for silver cone retrieval. Like the retrieval of a metal-core gutta-percha carrier or an endodontic file, the extractor is attached to the silver cone and withdrawn (Fig. 14-36). Caution: No rotational force should be used with silver cone removal. Significant force can be applied, although the surgical needle holder strategy is not recommended because it will collapse and ruin the extractor (even though the removal may be successful!).

- If a silver cone is loose and accessible, the simplest method of removal is the specialized forceps (Fig. 14-35).
- Single Hedström file: Assuming all filling material has been removed from the pulp chamber, use the ultrasonic probe tip to vibrate in the orifice areas of all canals. This will remove some of the coronal sealer and loosen the coronal extension of the silver cones. If a space can be negotiated alongside the silver cone with small K-type files, the goal would be to enlarge this space by hand instrumentation until a No. 25 to 35 or larger Hedström file can be inserted and “screwed” to a deeper position. Silver is relatively soft, and the Hedström file will gain a purchase in the side of the cone. The file is then withdrawn directly as described previously for the removal of plastic core carriers. Once again, a surgical needle holder may be of use to increase the leverage to effect withdrawal.

- Multiple Hedström files: If one Hedström file does not provide removal and there is sufficient space to accommodate additional files, the file-braiding technique may be applied. The technique is illustrated in Fig. 14-26. In this variation, two or three smaller files (in the No. 20 to 35 range) are placed beside the silver cone as far apically as possible and screwed into position until tight. The Hedström files are then twisted together and are simultaneously pulled out by hand, or again, clamped together with a surgical needle holder and levered out against the incisal or occlusal edge. This technique is especially useful when access is limited or the silver cone does not extend out of the orifice. Even “twist-off” or sectional silver cones can be removed.

- Occasionally the silver cone will have too much retention for either of the methods described. Once again, the
• Very large-diameter silver cones can be very resistant to removal. There may be no lateral space to negotiate and insufficient silver cone extension into the pulp chamber to engage with instruments (Fig. 14-38, A). Some silver cone cases were treated with a sectional silver cone called the twist-off technique to leave post space. Retrieval of the apical section is sometimes impossible. The only recourse in either case may be apical surgery (see Fig. 14-38, B and C). The surgical procedure is also complicated by the presence of metallic filling material in the apical canal space. Preparation for a retrograde seal can be a technical challenge.

**Prevention of Metallic Instrument Separation During Root Canal Procedures**

Prior to a discussion of the removal of fractured or separated instruments, from a problem-solving standpoint, it is appropriate to consider how this complication might be prevented. Most breakages of metallic instruments in the root canal system can be prevented by knowing how the instruments are manufactured, how they are to be used, and what limitations should be placed upon them. In general, all types of
root canal instruments are too often used beyond their usefulness, in a manner for which they were not designed, or with excessive amounts of force (see Chapter 10).

To avoid problems, basic guidelines for using and evaluating intracanal instruments are:

1. Inspect all instruments for irregular windings or evidence of fatigue on stainless steel hand files, NiTi files, and NiTi rotary files.
2. Pass the instrument through a bright light and check for irregularities in the symmetry of the fluting (Fig. 14-39), or shiny spots that indicate unwinding of the instrument. Small stainless steel files will become fatigued but often without visual evidence, so it is wise to test each file by intentionally placing a small curve in the apical 2 to 3 mm before use and recurving it during use.
3. Even good stainless steel instruments separate with only gentle curving. Smaller-sized instruments (Nos. 8 to 20) should be used minimally and replaced automatically if bent or kinked during use.
4. NiTi instruments should never be precurved and should be discarded if one should appear slightly curved after use.
5. Inspect NiTi instruments for irregularities in the fluting, and discard any file that shows even slight deformation (Fig. 14-40).
6. There is a worldwide movement to encourage or even mandate the single use of all root canal instruments, particularly in light of the transmission of diseases. In some countries, single use is mandatory, and the future of endodontics may very well be one that embraces this concept.

The advent of Ni-Ti hand instruments has had both a positive and a negative effect on the delivery of quality root canal treatment (see Chapter 10). The ability to negotiate and maintain canal curvatures has been most beneficial. However, these instruments require a different tactile sensation during working motions. Movements such as aggressive, rapid penetration of the canal, forcing an instrument to an arbitrary length, or forcing an instrument around a curve have led to numerous fractures of these instruments without warning. This also occurs with both rotary and hand instruments of all manufacturers. Most of these instruments do not have the standard tapers found in traditional hand instruments and therefore lack the same tactile sensations an experienced operator may expect. The best way to deal with the increased possibility of breakage is to practice extensively with these instruments, learning their nuances and developing an acute tactile sensation. Prevention is the operative word in their successful usage. If they should fracture, the techniques for removal identified in this chapter will apply.

Before GG drills or orifice shapers/openers are used to countersink the coronal portion of the canal (some refer to this as preflearing),21,25 a pathway should be established with a hand instrument first. With some systems like the ProTaper, the pathway then allows for an immediate application of the first shaping instrument that in essence eliminates the need for GGs. In fact it is the pathway or glidepath that is developed initially that makes the use of NiTi instruments both effective and safe in their applications in the root canal system. If the GGs are used, short advances of the rotary instrument followed by complete withdrawal will allow the shavings to escape and prevent binding of the bur head in the canal orifice. Copious irrigation is also necessary. The smaller-size burs will almost invariably bind and break if forced. When GGs are used to flare the canal after the use of files, all cutting should be done passively as the drill is withdrawn from the canal. If the orifice-shaping instruments that come with the new NiTi systems are used in sequence during cleaning and shaping root canals, the use of GGs is unnecessary.

**FIGURE 14-39** Deformity in the fluting of a file indicates metal fatigue. Instrument separation is imminent.

**FIGURE 14-40** Deformities in nickel-titanium files. These instruments should be discarded.
Removal of Separated Instruments from the Root Canal

For these procedures, the operating microscope has proven to be indispensable. In the absence of a microscope, high-power loupes with a good light source are strongly recommended.

Gates-Glidden Bur Heads, Peeso Bur Heads, and Large Metallic Fragments

For instruments fractured at the midroot level, including GG bur heads, Peeso reamer heads, explorer tips, and files, the best approach is ultrasonic instrumentation. The first step is to enlarge the canal space coronal to the fractured segment with a series of GG burs or Peeso reamers in a step-back manner. The purpose of this approach is to remove any dentinal barrier to the coronal passage of the fragment after it is loosened. Next, it is absolutely essential that if possible, the fractured segment be bypassed using small hand instrumentation. This space must be carefully enlarged so that a No. 20 Hedström file will pass easily by the obstruction. At this point, a new No. 15 file in the standard ultrasonic endodontic tip is placed in the canal and energized at normal settings (usually a low setting) for instrumentation.

- Fig. 14-41 illustrates successful bypass and removal of a separated Peeso bur head at the midroot level of a maxillary lateral incisor, using a Hedström file.
- Fig. 14-42 demonstrates the case of a fractured-off endodontic explorer tip that prevented completion of the root canal treatment in the mesial buccal root of the maxillary first molar. The treatment was done 8 years prior to the onset of symptoms. The ultrasonic technique was used to remove the fragment, and the revision was completed.
- Fig. 14-43 documents the unusual case of two sewing-needle tips fractured by the patient in the root canal of the maxillary canine in the effort to relieve an acute abscess months after the tooth had been opened for routine root canal treatment. The patient had neglected to have the treatment completed. The ultrasonic technique was used to remove the needle fragments, and the root treatment was completed.

Separated Endodontic Instruments

The least difficult challenges in removing endodontic instrument fragments are when the fragments are long, located near the access openings, and are in large canal spaces. Unfortunately, these factors tend to be found in the minority of failed treatments. Fig. 14-44 shows a case of failure in which a small-sized Hedström file separated in the coronal third of the canal. The file fragment extends approximately 2 mm through the apical foramen. The remainder of the canal was obturated with gutta-percha. Removal of the instrument fragment was accomplished with an IRS extractor after removal of as much gutta-percha as possible with the ultrasonic probe tip.

For the removal of instrument fragments in the coronal third to midroot level, the available techniques are reasonably reliable and successful. As previously noted, the NiTi instruments now commonly in use are more prone to fracture in the canal than conventional stainless steel instruments. Unfortunately, their susceptibility to fracture is often a function of incorrect and inappropriate application, not necessarily a shortcoming of the instruments themselves. However, the techniques for removal are quite different, due mainly to the limited effectiveness of ultrasonic instrumentation on nickel-titanium metal. With stainless steel, ultrasonic vibration can be used for trenching surrounding tooth structure and vibrating directly against the metal. In contrast, prolonged vibration against a NiTi file will usually result in fracture of the exposed length of instrument. If ultrasonic vibration is considered, it should be used mainly for precise excavation around or parallel to the fragment, avoiding continuous contact. If the ultrasonic device is used with the intention of vibrating the fragment loose, the fragment should be well dissected from the surrounding dentin to increase the chance of removal. At the same time, the device should be used on a low power setting and only for short time frames.
If a stainless steel instrument fragment is in the coronal half of the canal, use of the Masserann or IRS extractor has no limitations other than it is expensive and does not have the versatility an ultrasonic unit may have. Therefore most clinicians will have access to an ultrasonic unit of some type. What is of benefit with the extractor devices is the locking mechanism. The grip is effective, and on stainless steel, the device can be tightened with considerable force. However, care must be exercised when locking onto a segment of NiTi file because breakage of the exposed portion of the file is possible. Note the locking mechanism shown in Fig. 14-44, B.

On the positive side, NiTi hand files (see Chapter 10) often separate in shorter segments than stainless steel files and owing to the difference in flute design are not as tightly locked into the tooth structure. Light vibrations from an ultrasonic or a light rotation with a Masserann extractor will often “pop” a NiTi file loose. If the end of a broken endodontic instrument is near the orifice of the canal, ultrasonic application will remove it rapidly; or a small trephining drill may be used to create space for the extractor or choice of forceps. If the instrument is stainless steel, there is no danger of cutting or weakening it with the trephining drill. The procedure would be the same as that for the retrieval of a metal-core gutta-percha carrier or silver cone cut off at this level. Typically the trephining drill will follow the instrument very easily whether it is stainless steel or NiTi. Once the shaft of the instrument is exposed at least 2 mm, the extractor is used with the appropriate caution. The 1.2-mm extractor will be adequate for instruments up to size 40. Because of the spiral shape of endodontic instruments, a gentle counterclockwise rotational pressure is exerted during instrument withdrawal.

Previous authors have diagrammatically described the removal of instrument fragments deep in the canal by penetration with the Masserann trephines. In clinical practice, however, trephining into the apical third of the root can be extremely hazardous and is not recommended even in large,
Problem-Solving Techniques for Revision of Previous Root Canal Procedures

When removing fractured instruments in multirooted teeth, there is the potential problem of the fractured segment floating out of one canal and finding its way into one of the other orifices. To prevent this, it is wise to place cotton into the other orifices or complete the straight roots with generous use of large GG burs to enlarge the coronal access. In most attempts, the trephining drill will approach a lateral perforation as the root tapers anatomically toward the apex. Fig. 14-45 documents an unsuccessful retrieval of an instrument fragment located in the apical third. Although generous coronal canal widening with GG drills was done prior to the use of the Masserann technique, the trephines failed to reach the fragment. In addition, the smallest trephine nearly caused a lateral perforation.

The removal of very deep instrument fragments is possible with the ultrasonic technique if the fragment can be bypassed. Fig. 14-46 shows routine removal of a deep instrument fragment in the buccal canal of a maxillary premolar. Fortunately, the canal shape permitted small files to bypass the instrument fragment. It was ultimately removed by the ultrasonic handpiece with an endodontic file. Subsequently, the canal treatment was successfully revised. Unfortunately, if an instrument fractures in a canal smaller in diameter than the instrument, it will rarely be bypassed. Excessive rotational pressure is more likely a cause of instrument fracture than manufacturing defects (see Chapter 10).

- File separation can be a significant problem with ultrasonic instrumentation itself, especially in the smaller file sizes. It is important to stay within the recommended power settings. Usually the fragment will loosen and flow out of the access cavity undetected, along with the irrigant. The same result is achievable when using specifically designed abrasive ultrasonic tips. There would be no difference in technique for the NiTi file fragment if it can be bypassed. This frequently occurs in the first minute of ultrasonic usage.

- When removing fractured instruments in multirooted teeth, there is the potential problem of the fractured segment floating out of one canal and finding its way into one of the other orifices. To prevent this, it is wise to place cotton into the other orifices or complete the
obturation on the other canals, so long as there is no communication with the canal containing the obstruction.

The application of techniques to remove small fragments in the apical third or around significant canal curvature is not only difficult but fraught with risks of severe thinning of the root wall if not outright perforation. Removal of instrument fragments that cannot be bypassed is problematic. New techniques using ultrasonic excavation under magnification and without irrigation have shown success in exposing a portion of the buried file fragment without breaking it off.

Excavation deep into the root parallel to an instrument fragment requires consideration of the root anatomy. To avoid potential perforation, it is safest to excavate in the thickest area of the root. For the mesial buccal root of a maxillary molar, the safest area to excavate would be palatal to the mesial buccal canal in which the fractured instrument is located; however, very small-diameter ultrasonic tips are required (Fig. 14-47).

Fig. 14-48 illustrates a technical procedure to remove a fractured instrument. The strategy is to excavate a space parallel to the instrument fragment. The fragment is then loosened laterally into the space sufficiently to negotiate past it with a small file. Once this is accomplished, the space is gradually enlarged until a No.15 file in the ultrasonic instrument can vibrate the fragment loose. In some cases, the Masserann extractor or the smaller-sized extractor, the IRS, would have application as well if the instrument fragment is exposed sufficiently.

Many file fragments cannot be removed. Attempts to do so usually are both unproductive and destructive. If there is no apical pathosis and the tooth is asymptomatic, cleaning, shaping, and obturation of the coronal portion are indicated. The prognosis is generally favorable. Reevaluation is indicated at various time intervals. Surgical revision would be the treatment of choice in the event of failure.

When choosing nonsurgical revision of previous root canal procedures, careful assessment and treatment planning with each case are the cornerstones to success. Keen awareness of the options, skill in the techniques advocated for revision, appreciation for the support provided by adjunctive technologies, and understanding the potential hazards encountered in revision will allow the astute practitioner to enjoy a significant level of success in this approach to the prevention, identification, and management of these endodontic challenges.
REFERENCES


FIGURE 14-48 A, Demonstration case showing fractured nickel-titanium file in the mesial buccal canal of a maxillary first molar. B, Excavation with small ultrasonic tip. Prolonged contact with the separated instrument should be avoided. C, View through the operating microscope showing exposure of the end of the instrument. Excavation is primarily in the thick dentin just palatal to the canal. Additional dentin can be excavated from the instrument with an endodontic explorer. D, Bypassing the instrument with a No. 6 file. E and F, The instrument is ultimately dislodged after progressive enlargement of the bypass space.

RECOMMENDED ADDITIONAL READING
Chapter 15
Problem Solving in the Management of Painful Tooth Emergencies

Problem-Solving List
Problem-solving challenges and dilemmas in the management of painful tooth emergencies addressed in this chapter are:
- Patients Presenting With Complaints of Hypersensitive Teeth
- Patients Presenting With Signs/Symptoms of Reversible Pulpitis
- Patients Presenting With Signs/Symptoms of Irreversible Pulpitis
- Procedures to Manage Teeth With Irreversible Pulpitis
  - Single-rooted and single-canal teeth
  - Multicanal teeth
- Procedures to Manage Teeth With Necrotic Pulp
  - Incision and drainage
- Apical and Surgical Trephination
- Analgesics and Antibiotics
- Anesthesia for Painful Teeth

To cure the Tooth-ache, Take a new Nail, and make the Gum bleed with it, then drive it into an Oak. This did Cure William Neal, Sir William Neal’s Son, a very stout Gentleman. When he was almost Mad with the Pain, and had a mind to have Pistoll’d himself.1

J. Aubrey, 1972

The most important aspects of treating the endodontic emergency patient are accurate and expedient diagnosis of the problem and the ability to relieve the patient’s pain. Diagnoses must be based on the patient’s signs and symptoms, and because pain is always variable and subjective at times, filtering appropriate information during the subjective assessment is essential for all clinicians. Chief complaints are extremely valuable and offer a wide range of potential diagnoses, from mere hypersensitivity to irreversible pulpitis to potential periapical abscess:

“I get an occasional short shooting sensation in my tooth when I drink my morning tea.”
“My teeth are really sensitive when I brush at night.”

“This one tooth will not let me eat ice cream unless I move it to the other side of my mouth.”
“I had to take some pain medicine, but the pain went away in 20 minutes, and that’s the only time it hurt.”
“The pain has kept me up all night.”
“I cannot chew on my tooth because it feels as though it’s sticking up in my mouth, and it’s the first tooth I hit even when I just try to close my teeth together.”

Chief complaints also give the clinician clues as to the level of tissue damage if any in the pulp or periapical areas.

Many patients also believe they know which tooth is causing the problem, and here the clinician must be able to selectively filter useful information from information so subjective it should be discarded, such as “The pain hurts me in these three teeth.” It is highly unlikely that there are three problem teeth causing the patient’s symptoms, but in the case of hypersensitivity due to gingival recession, it is possible. The same is true when the patient indicates that a tooth hurts terribly when they drink something cold, and the clinician’s records and radiographs indicate there is a well-done root canal procedure on that particular tooth. The operative words in dealing with a patient’s painful situations are listening, understanding, integrating, analyzing, and synthesizing. Without this problem-solving approach, the clinician may very often jump to invalid conclusions and miss the real diagnosis.
The clinician must decipher from the patient’s own words approximately where the problem is located and how severe the problem has become (see Chapter 1). The final diagnosis is a combination of the patient’s description of the problem, which represents the subjective data, and the objective data elicited from the various sensibility and manipulative tests. As a rule of good clinical judgment, no tooth should ever be destined for root canal treatment unless the clinician is approximately 90% or better assured that the correct diagnosis has been made and the correct tooth has been identified. At times, from the history and description of the symptoms, the clinician will sometimes know root canal treatment is indicated but not be able to identify the offending tooth upon clinical examination. This is especially common in quadrants of teeth in which all have had extensive coronal restorations and sensibility testing is limited. For example, all the data may point to an irreversible pulpitis, but identification of the tooth is elusive. Although contrary to the desire to provide pain relief for the patient, it may often be better to send the patient home with palliative support rather than risk treatment of the wrong tooth. It is entirely inappropriate to initiate a root canal procedure until the symptoms will localize in time to a specific tooth. It will then be possible to diagnose the problem accurately and provide definitive treatment. The solution to difficult diagnostic problems in endodontics is never found by guesswork. The clinician fears that the patient will lose confidence in his or her diagnostic ability.

In reality, however, if the clinician has conducted a thorough examination and has presented the diagnostic dilemma in a compassionate manner, the patient will understand that the symptoms will localize in time to a specific tooth. It will then be possible to diagnose the problem accurately and provide definitive treatment. The solution to difficult diagnostic problems in endodontics is never found by guesswork. It is entirely inappropriate to initiate a root canal procedure with the attitude of “Let’s try this and see if it works.” This is especially true when one considers the many possible sources of nonodontogenic pain (see Chapter 6). Whereas Chapter 1 dealt in depth with diagnosing odontogenic pain, this chapter’s focus will be on problem solving painful tooth emergencies.

Patients Presenting With Complaints of Hypersensitive Teeth

A perceived reason to see the dentist for a painful tooth can be anything from an occasional shooting sensation to a tingling or sensitivity when ingesting certain foods or drink to discomfort during tooth brushing or flossing. If the clinician is seen immediately upon the onset of the symptoms, more often than not there is no pulpal pathosis that requires significant intervention. However, if the patient does not seek help immediately and the problem continues or accentuates, often they are referred to a specialist for an in-depth evaluation or even root canal treatment. It is in these scenarios that a true differential diagnosis must be made—especially to determine whether this is an actual “painful” tooth emergency or merely an accentuated hypersensitivity that was not dealt with previously in a timely manner. The reader is referred to Chapter 7 for a more in-depth discussion of tooth hypersensitivity; this diagnosis and its treatment parameters fall within the realm of vital pulp therapy. Needless to say, some prolonged cases of hypersensitivity will fall in the diagnostic range of either a reversible pulpitis or an irreversible pulpitis. Invariably the patient will comment, “I should have come to see you months ago when this first started bothering me, but it was only slight, and I thought it would go away, and I’ve been very busy and could not come in, but now it has my attention.”

In this pulpal condition, patients will have transient pain of mild to occasionally moderate nature (see Chapter 1). There is often a history of recent restorative dental procedures, periodontal therapy, or possibly a history of minor dental trauma, such as a concussion or subluxation injury (see Chapter 19). Rarely do these patients complain about the pain keeping them up at night or being awakened by the pain in the middle of the night.

The symptoms of thermal sensitivity do not prevent the patient from eating or drinking normally, although in more severe cases, there may be a history of avoidance of temperature extremes in specific areas of the mouth. In these situations, and in particular when thermal sensitivity is the patient’s chief complaint, the clinician must be able to distinguish between sensitivity and true pain. The interpretation of either by the patient and clinician may vary considerably. Too many cases of root canal treatment are done in the presence of an annoying sensitivity as opposed to a true pain that indicates the need for pulp removal, and too many patients are being overtreated for a minor inflammatory situation that may be handled in a much less aggressive way. The only way to manage these situations properly is to attempt to identify the etiology and remove it. If successful, the transient sensitivity will subside, and the patient will not only be comfortable but grateful to the clinician for the professional expertise in managing the problem.

If an etiology such as caries, exposed cervical margins of dentin, a fractured cusp, or a fractured restoration is discovered, the majority of cases will resolve by appropriate restorative treatment (Fig. 15-1). Tincture of time will also improve some patients’ symptoms. In most cases, the reversible pulpitis was the result of some restorative procedure that caused transient inflammation within the pulpal tissues (Fig. 15-2). In no case does the inflammation spread into the periapical tissues, and therefore no periapical changes are seen as one might find when an irreversible pulpitis is diagnosed.
Patients in pain should be made aware that any type of restorative procedure, whether the removal of an existing amalgam, the removal of caries, or preparation of a crown prep or class II inlay, has the potential to cause pulpal inflammation that may linger for various time periods. In most cases, the inflammation of the pulp is “reversible,” but the pulp is only able to withstand a given amount of insults or irritations before the inflammatory state becomes irreversible. This is a concept not always considered by the restorative dentist prior to extensive restorative procedures. Obvious changes may have occurred in the tooth: a narrowed pulp chamber, the presence of pulp stones or linear calcification in the root canal, hidden caries beneath an old restoration, the presence of various degrees of condensing osteitis, the presence of minor areas of root resorption, obvious crack lines on the margin ridges, and so forth (Fig. 15-3). Such
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Tissue cannot respond favorably to any type of palliative treatment and must be removed, or the tooth must be removed (see Chapter 1). If the patient or clinician can localize the source of the pain to a particular tooth, the diagnosis can usually be made within a few minutes of taking the patient history and performing a few clinical tests as necessary (see Chapter 1). If the patient complains about any of the following symptoms, the likelihood of an irreversible pulpitis is high. These symptoms include (but are not limited to) pain that lasts several minutes to hours, pain that throbs or is sufficiently intense to awaken the patient at night, pain that is spontaneous throughout the day or evening hours, pain that is severe when hot or cold foods come into contact with a specific tooth, pain to biting on the tooth, or pain so severe the patient completely avoids eating on that side of the mouth.

These findings are all valid indicators of an irreversible pulpitis and in some cases will indicate that the inflammatory response has already progressed through the apical changes may not bode well for a tooth that is treatment planned for extensive restorative procedures. The tooth may exhibit no symptoms, and sensibility tests may give the impression that the pulp is vital or a subtle reversible pulpitis is identified, but this does not mean the pulp is healthy and can withstand further insult without succumbing to an irreversible pulpitis. These issues are key for the restorative dentist to understand to prevent problems for the patient, and these considerations in treatment planning must be communicated fully to the patient.

Patients Presenting With Signs/Symptoms of Irreversible Pulpitis

The diagnosis of irreversible pulpitis implies that there are sufficient signs and symptoms to indicate that the pulp tissue cannot respond favorably to any type of palliative treatment and must be removed, or the tooth must be removed (see Chapter 1). If the patient or clinician can localize the source of the pain to a particular tooth, the diagnosis can usually be made within a few minutes of taking the patient history and performing a few clinical tests as necessary (see Chapter 1). If the patient complains about any of the following symptoms, the likelihood of an irreversible pulpitis is high. These symptoms include (but are not limited to) pain that lasts several minutes to hours, pain that throbs or is sufficiently intense to awaken the patient at night, pain that is spontaneous throughout the day or evening hours, pain that is severe when hot or cold foods come into contact with a specific tooth, pain to biting on the tooth, or pain so severe the patient completely avoids eating on that side of the mouth.

These findings are all valid indicators of an irreversible pulpitis and in some cases will indicate that the inflammatory response has already progressed through the apical

**FIGURE 15-3**

**A.** Mandibular first molar with significantly reduced pulp chamber, pulp stones, and condensing osteitis. Changes reflect degenerative pulpitis. No symptoms. **B.** Mandibular first molar showing a pulp chamber that is almost occluded with calcification and canals that also show the same. While teeth like this may register as “vital,” the pulps are not healthy, and this is where the diagnostic dilemma lies when it is difficult to determine the source of the patient’s distress. **C.** Occlusal surface that depicts questionable restorative margins and the presence of significant fractures on the distal margin (arrows). Patient was suffering from vague pain in the maxillary left quadrant. **D.** Crack in tooth dentin showing invasion of bacteria even into the dentinal tubules. In the presence of long-term defects of this nature, dental pulps can easily undergo degeneration and be symptomatic.
foramen and affected the periradical tissues. This information can be obtained from a thorough history of the patient’s symptoms, and a definitive diagnosis can usually be made regarding the patient’s need for a root canal procedure. However, the true histopathologic status of the tissues cannot be ascertained at this point, so clinical tests must be performed to obtain a pulpal and periradicular diagnosis. The patient’s responses have only informed the clinician of an “irreversible situation” that is occurring but not whether the pulp is inflamed or necrotic. The use of thermal tests may provide a definitive but not entirely accurate diagnosis of the pulpal status.

**Procedures to Manage Teeth With Irreversible Pulpitis**

Once the diagnosis of irreversible pulpitis has been established, concise treatment will usually provide the patient with immediate relief. However, there are specific treatment modalities with respect to irreversible pulpitis that minimize the patient’s postoperative discomfort and enhance confidence in the treating clinician. The approach to treatment will depend upon two factors. The first is whether the irreversible inflammation is in a single-rooted/single-canal tooth or a multicanal tooth. The second factor is whether the tooth demonstrates sensitivity or pain to percussion. Once these two factors are known, the treatment can be rendered expeditiously and accurately with a high degree of success and minimal postoperative sequelae. While these two determinants for treatment are not “cast in concrete,” they will guide the clinician in the rapid problem-solving management of these painful situations.

**Single-Rooted and Single-Canal Teeth**

When a single-rooted or single-canal tooth has been diagnosed with irreversible pulpitis, the ideal treatment is to remove the pulp in its entirety (pulpectomy; Fig. 15-4). A pulpectomy means complete removal of the pulp from its root canal. To be effective, however, this implies more than just placing a file or broach into the root canal at some undetermined level for a few seconds. Once profound anesthesia is obtained, it takes but a few minutes to access the tooth, obtain a working length (see Chapter 9), and clean and shape the canal sufficiently to remove the dental pulp and any residual remnants. While a properly sized broach or two may work to remove the pulp on occasion, this process is most effective when using rotary nickel-titanium (NiTi) instruments and 6% sodium hypochlorite (NaOCl) to perform a pulpectomy (Fig. 15-5). If the problem is to be solved expeditiously in the patient’s best interest, the procedures used must favor the complete removal of the inflamed tissue. Hand instruments (K-files and broaches) will often just shred the tissue, leaving remnants that may still be connected to the apical neural elements. **Thoroughness** is the operative word in managing this emergency situation. Upon completion of the emergency procedure, a medicament such as calcium hydroxide can be placed (see Chapter 11).

Some clinicians choose to do a pulpotomy because the procedure is virtually the same with respect to the amount of time required. It is more appropriate to perform a
Fortunately, in most emergency situations, symptomatic relief can be achieved without removal of all of the pulp to the apices even though this would be preferable. It is important to note the approximate length of the roots and penetrate at least into the apical third in each canal.

On the other hand, it is extremely important to remove pulp tissue from all canals. Patients who seek relief of acute thermal sensitivity can sometimes experience the same symptoms after emergency treatment if vital, acutely inflamed pulp remains intact in one of the canals. Persistent signs and symptoms of an acute apical abscess can also be due to failure to clean a root canal of its inflamed tissue (see Fig. 15-6). If time permits, the approach is similar to that discussed for anterior teeth, with access, working length, cleaning, and shaping to a size sufficient to remove the tissue to the desired length (usually a minimum of No. 25 K-file and larger if possible). This procedure is indicated because it is difficult to ascertain which root or roots may be causing the periapical inflammation. In many cases, the root canal systems are narrowed or quite small in diameter, but if there is sufficient time to manage the emergency, the original dictate applies. If there is insufficient time to manage this problem ideally, then a pulpotomy should be performed and the occlusion reduced, or it may be possible to perform a pulpectomy on the largest root canal (distal root in mandibular molars, palatal root in maxillary molars and premolars). Upon completion of the emergency procedure, a medicament such as calcium hydroxide can be placed (see Chapter 11).

Patients with irreversible pulpitis usually present with a history of severe pain, either spontaneous in nature or stimulated by cold foods or liquids. At times the patient may identify a particular tooth they feel is causing the problem, but the clinician is unable to reproduce the symptoms, even with extensive and rigorous testing. Likewise, the

**Multicanal Teeth**

Most posterior teeth with irreversible pulpitis will require either a pulpotomy or pulpectomy for immediate pain relief\(^3\) (Fig. 15-6). If no mastication sensitivity is reported, a pulpotomy is usually sufficient as an emergency treatment. When the tooth demonstrates percussion sensitivity or pain, it is important to adjust the occlusion or remove the tooth from occlusion, or the patient may not have adequate relief from their symptoms.

The treatment of posterior teeth is not much different than that of anterior teeth. The canals of posterior teeth are significantly smaller than those of anterior teeth, and emergency procedures may require modification. Only the largest of canals in posterior teeth permit the use of broaches and one seldom sees the pulp as an intact tissue after removal. The removal of the pulp in typical small canals is virtually a by-product of the mechanical enlargement of the canal with rotary or hand files. Patients who are seeking treatment for acute problems on an emergency basis are often seen by dentists who do not have full appointment times immediately available. An emergency visit may be scheduled after normal hours or “squeezed” into an improvised time period during the day. For single canal teeth described above, thorough canal débridement is possible even in an abbreviated time period. For multi-canal teeth, the time commitment for complete preparation to the apices may not be available.

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**FIGURE 15-6** A, Mandibular molar with vague symptoms. The radiograph shows chronic focal sclerosing osteitis on the distal root end, indicative of a chronic degenerating pulp. When testing with cold, the tooth exhibited no response at first then gave a throbbing ache that lingered. B, Mandibular molars with probable carious exposures. Both were painful to percussion and varying degrees of thermal stimulation.
radiographic presentation is often completely normal or at least thought to be normal. There are no signs of abnormal periapical changes, the lamina dura and periodontal ligament space all seem to be within normal limits, several teeth have large restorations or crowns present, but the clinician cannot elicit any pain to percussion or abnormal response to cold from the tooth the patient is convinced is the source of pain. Unfortunately, there is often a disparity between the symptomatic status of a tooth and the histologic picture of its pulp, which may explain the difficulties of diagnosis (Fig. 15-7).

**Figure 15-7** A, Mandibular molar that exhibits narrowed chamber and canals and the presence of condensing osteitis, indicative of a degenerating pulp. Symptoms are minimal, and tests could not reproduce the patient’s discomfort and chief complaint. B and C may very well provide an explanation of the changes and why it is difficult at times to make a diagnosis. B, Mandibular molar that was symptom free, and the patient had no recollection of any pain or discomfort to function. All tests were normal but because of the depth of the caries, she was advised that root canal treatment was likely to be needed along with a crown to maintain the tooth. Because of cost factors, she opted to have the tooth extracted. C, Histologic section of the coronal pulp. Note the wide variety of histologic findings in a tooth that was symptom free and had normal responses to cold, percussion, palpation, and electric pulp testing. (NP, Normal pulp; Al, acute inflammation; CI, chronic inflammation; PN, partial necrosis; LN, liquefaction necrosis (B&B stain x4; no bacteria evident).

First, single-root/single-canal teeth will be much easier to manage than multicanal teeth. Second, if a sinus tract is present, treatment will be much easier because more often than not the patient’s symptoms are minimal. Third, if a swelling is present, the type of swelling, such as a localized swelling or nonlocalized (cellulitis) must be determined. There are appropriate treatment approaches for each situation, and these will be dealt with separately.

The tooth with a necrotic pulp will usually give no response to cold or other thermal tests and will not respond to an electric pulp test (EPT) (Fig. 15-8). The tooth may be sensitive to mastication or percussion, but this is not relevant to the diagnosis and only becomes significant when considering the need for occlusal reduction.

When the diagnosis of a necrotic pulp has been established in an single-rooted or single-canaled tooth and no swelling is present, the tissue must be removed completely from the canal system in order to alleviate the symptoms (Fig. 15-9). The clinician may use the same technique as in the anterior teeth with an irreversible pulpitis to remove the necrotic
The use of NiTi rotary instruments in a crown-down fashion favors a thorough cleaning. The nature of the instruments and their application result in auguring debris out of the canal in addition to developing ideal canal shapes for rinsing residual materials from the canal. A significant amount of NaOCl (see Chapter 11) should be used, especially because of the need to remove the necrotic tissue from the canal system. The use of NiTi rotary instruments in a crown-down fashion favors a thorough cleaning, and the clinician must not act based upon the patient's insistence that a particular tooth is painful and the source of their problems, but rather must rely on the objective findings produced at the time of the emergency visit. If clinical findings are confusing and do not lend themselves to a rapid or logical diagnosis, it may be wise to not act upon meaningless data but wait until valid data can be obtained and an accurate diagnosis is established.

In most cases, the symptoms will recur within a short time and the patient can be reexamined. It is always inappropriate for the clinician to begin root canal treatment without having a reasonable diagnosis. Patients have sometimes been subjected to treatment on multiple teeth in the hope of relieving pain only to discover, ultimately, that the pain was of non-dental origin. See Chapter 6.

Clinical Challenge #2: It may be necessary to examine clinical findings more comprehensively: How extensive are the restorations that are present? How long have they been there? Are there marginal discrepancies that may be contributing to bacterial leakage? Are there fracture or significant craze lines? Are there changes in the size of the pulp canal spaces and chamber compared to other teeth? Are there pulp stones present? Is condensing osteitis present? Are there subtle changes in the root apex compared to others that may indicate some evidence of a low-grade resorptive process? These questions may or may not be helpful, but they provide a better assessment of the data available and help the clinician make interpretive judgments (see Fig. 15-7). One result could easily be that the patient is sent immediately to a specialist for an in-depth evaluation.

Clinical Challenge #3: In securing the subjective data, important questions must be asked, and these are detailed in Chapter 1: “Listen to the patient, they are giving you the diagnosis!”—Sir William Osler, 1867. Often, thermal tests do not lend themselves to a diagnosis and are in fact within normal limits, as is frequently the case when an acute irreversible pulpitis becomes chronic and pulp responses become identical to noninflamed teeth (see Fig. 15-7). Radiographic signs are the only definitive method for obtaining a diagnosis. However, it is common for the radiographic presentation to be normal; or is it truly normal? This is especially true in cases of early irreversible pulpitis or in posterior mandibular teeth in which the cortical plate is extremely dense and changes in the bone may not become obvious until significant destruction has taken place, usually in the last stages of irreversible pulpitis.

single canals should be treated identically. If a working length cannot be established (the ideal method before instrumenting the canal in an emergency visit), an estimated working length should be obtained based on the initial radiographic film. This can also be achieved with an electronic apex locator (see Chapter 9). The operative word in this clinical situation is débridement, which includes the effective use of NaOCl. Upon completion of the emergency procedure, a medicament can be placed (e.g., calcium hydroxide mixed with 2% chlorhexidine [see Chapter 11]).

If the necrotic pulp is in a multicanaled tooth, the treatment is similar to that of a single-rooted/single-canaled tooth, but there are different approaches. The purpose of any technique is to establish the most rapid method to remove a majority of the necrotic tissue within the root canal system. In molars, this can be challenging because of the difficulty in removing the necrotic tissue from very small, curved, and narrow canals.

The first approach can be similar to that used for posterior teeth with irreversible pulpitis. When possible, a hand or rotary instrument can be used to remove the pulpal debris. This may not be accomplished routinely in the canals of posterior teeth (buccal canals of maxillary teeth and mesial canals of mandibular teeth) inasmuch as these canals require smaller files initially for easy penetration. A pathway for the larger instruments must be made, and at the same time, débridement is achieved. Here again the crown-down technique must be used. Initially a small K-file, such as a No. 08 or 10, is used to establish coronal patency. Next, a rotary PathFile (Taper .02 at diameters of 0.13, 0.16, and 0.19 [Dentsply Maillefer, Ballaigues, Switzerland]) can be used to enhance access to the apical portion of the canal. Once the canal is opened coronally, it can be débrided gradually and safely, increasing to a size No. 25 or comparable rotary file.
FIGURE 15-9  
A, Débridement of the canal system reveals complete putrefaction of the dental pulp. B, In some cases, the necrotic pulp will come out intact.

FIGURE 15-10  

to the estimated working length. Copious amounts of irrigant (NaOCl 3% to 6%) must be used during the débridement process. Care must be exercised with this technique to prevent necrotic debris from being forced out the apical foramen and into the periradicular tissues, thereby causing additional discomfort for the patient. Here again, the use of crown-down instrument techniques will be beneficial to prevent this potential postoperative sequela.

In the second approach, the first step is to establish a working length for all canals. This is easily accomplished in canals that are patent (Fig. 15-10, B). After obtaining a working length, the canals are instrumented to a size No. 25 or comparable rotary file using copious amounts of NaOCl. The larger distal or palatal canals are instrumented routinely to a larger size (approximately Nos. 30 to 40) during this procedure. An intracanal medicament of calcium hydroxide is placed, and a cotton pellet is placed over the exposed canal orifices, followed by an appropriate temporary with adequate depth (a minimum of 3 to 4 mm) to prevent occlusal leakage. The patient who presents with a necrotic pulp and a draining sinus tract usually has little to no symptoms. There is often a history of pain associated with a specific tooth or a history of a bad taste in the patient’s mouth, but rarely does the patient recall severe pain associated with a tooth. It does, however, occur on occasion and this is usually a result of the abscess within the cortical bony plates eroding the last couple of millimeters of cortical bone, causing pressure on the periosteum. This pressure, immediately before the sinus tract is established, is the cause of the severe pain the patient may have experienced. Clinically, the patient is diagnosed with a necrotic tooth, and a soft-tissue lesion is present in the form of a small orifice or “pimple-like” lesion on the attached gingiva or in the mucosa. It may have many different appearances from a swelling to being pedunculated to merely a reddish area on the gingiva. A sinus tract should always be traced to verify the diagnosis that is made based upon clinical
tests and patient symptoms (Fig. 15-11). This is accomplished by using a size 25 to 40 gutta-percha point that is placed into the sinus tract and slowly traced to the source of the problem. By threading the gutta-percha slowly into the sinus tract, the clinician can determine more accurately which tooth is the source of the problem. If the gutta-percha is introduced into the sinus tract slowly, it will warm up to body temperature and not cause any undue pain or discomfort while it is being inserted. Using too small a gutta-percha point will sometimes prevent the point from reaching its true endpoint because it will bend prematurely. Too large a point will be prevented from tracing the tract the entire distance because of the morphology of the sinus tract and its lack of flexibility. In a majority of cases, gutta-percha points between sizes 25 and 40 should achieve the objective.

Because of the lack of true “emergency-type” symptoms in these cases, routine root canal procedures are indicated. Should the patient be in that rare instance when they are experiencing acute pain, the most appropriate emergency procedure would be complete débridement of the root canal system.

Postoperative instructions should indicate that the probability of any painful sequelae is rare, and only over-the-counter analgesics are indicated. There are no indications for antibiotic therapy in these cases; however, appropriate follow-up care is essential.

Patients with necrotic pulps will present periodically with a localized swelling. Often these patients are symptomatic and sensitive to palpation over and around the soft-tissue swelling. The lesion is generally directly over the apices of the offending root, but it must be recognized that penetration through the bone and periosteum of an inflammatory process usually occurs at the site of least resistance. Therefore in some cases, the soft-tissue swelling will not be directly over the root or necrotic tooth causing the lesion but manifest adjacent to the offending tooth, and one or two teeth will appear to be contributing to this swelling (Fig. 15-12).

The treatment of a necrotic pulp with localized swelling is not an indication for antibiotic therapy. However, it is imperative that the necrotic tissue be completely removed from the pulp chamber and root canal system. The patient should always be made aware before treatment is rendered that regardless of the clinical diagnosis, most root canal treatment results in additional periapical inflammation with subsequent symptoms. In all probability, the patient will experience additional discomfort and in some cases, an increase in localized swelling. Most interventions such as instrumentation, obturation with sealer, and pulpectomy/
pulpotomy procedures result in additional periapical irritation and inflammation. This results in tissue changes that manifest as pain in the periapical area, which the patient perceives as pain in the tooth or discomfort in the mandible or maxilla when the tooth is moved or palpated.

In no cases should a tooth with an inflamed, vital, or necrotic pulp be left open to drain, either if drainage has been established from within the tooth or if no drainage was obtained.\(^{36}\) Leaving a tooth open for drainage will only lead to additional bacteria and salivary contaminants being introduced into the root canal system the clinician is attempting to “sterilize” as well as possible, although some studies refute this impact clinically.\(^{37}\) There is clinical evidence that the longer a tooth is left open for drainage, the longer it will take (additional postop appointments required to close the tooth) to manage the closure of the tooth. This can be attributed to colonization of the root canal spaces with bacterial species that are able to protect themselves through mechanisms of biofilm formation.\(^{38,44}\)

**Incision and Drainage**

If a swelling is present adjacent to a tooth or teeth, the clinician must determine whether the swelling is fluctuant or nonfluctuant. This determination must be made so the appropriate treatment can be provided for the patient. Should an incorrect assessment be made, inappropriate treatment may result in additional discomfort for the patient, and a longer period of healing will be required.

There are four scenarios to consider, each requiring proper management to alleviate patient symptoms and provide the appropriate periapical environment for healing to ensue. In all these cases, the pulp has been diagnosed as necrotic, and periapical symptoms range from mild to severe.\(^{26}\)

**Fluctuancy: Drainage Through the Tooth**

Once the tooth is opened for treatment, drainage is obtained from the canal(s) through the access opening. The drainage can be minimal (Fig. 15-13, A) or profuse and in some cases may continue for minutes, exhibiting a pulsating type of flow. This usually starts as purulent only (see Fig. 15-13, B) and culminates with both purulence and blood (seropurulent; see Fig. 15-13, C). The canal is cleaned and shaped, and a medicament and temporary filling is placed. If the tissue is fluctuant, an incision and drainage can be performed, especially if the tissue is still turgid (Fig. 15-14), but since drainage was obtained through the tooth, most of the time this procedure is optional. Additional anesthetic solution should be introduced around but not into the area of the localized swelling. If a small gauge needle is available, the tip can be inserted into (not through) the thin mucosa in the area of intended incision and a couple of drops can be deposited to blanch the tissue.

**Fluctuancy: No Drainage Through the Tooth**

In these cases, the pulp chamber is opened, but no drainage is obtained from the canal or canals. Cleaning and shaping are completed, calcium hydroxide is inserted along with a cotton pellet, and a temporary filling is placed. Anesthetic solutions are delivered on either or both sides of the swelling, providing the patient with sufficient time for anesthesia to become profound. *Do not inject directly into the swollen tissue.* It will only cause the patient significant pain and potentially disseminate undesired inflammatory products and bacteria deeper into the tissues. A No. 12 or 15 scalpel blade is placed into the fluctuant mass and pressed firmly down onto the bony plate through the swelling (Fig. 15-15). This incision can be made horizontally at the base of the swelling or vertically but preferably between the roots of the teeth. In posterior teeth, the purulence in the tissues may not be as localized and can spread laterally both buccally and lingually/palatally (Fig. 15-16). In these cases, drainage may not occur immediately and must be encouraged if necessary by opening and closing a hemostat within the incised fluctuant area. The abscess “pocket” must be opened, releasing the purulence and achieving additional drainage (Fig. 15-17). Drains are not indicated in most instances; the incision will remain open long enough to achieve the desired result. Warm saline rinses are suggested for approximately 24 to 48 hours after the incision and drainage procedure.

**No Fluctuancy: Drainage Through the Tooth**

After the access opening is established, cleaning and shaping of the canals are completed. During this procedure, drainage is obtained through the canal(s). Because the tissues are nonfluctuant, meaning they are usually quite firm, there is no indication to incise and drain the soft tissue inasmuch as this procedure would be nonproductive. Warm saline “holds” as opposed to rinses may be suggested in an attempt to pool the purulence into a localized area for later incision and drainage. Although the amount of purulence and necrotic debris that exits though the root canals of teeth is nominal, it usually is adequate to provide relief for the patient in acute discomfort.
Seropurulent drainage from a small canal in a mandibular molar. B, Initial purulent drainage from a maxillary lateral incisor with a necrotic pulp and localized swelling. C, As the drainage continues, it becomes more seropurulent. Drainage of these types occurs often just upon access to the pulp chamber. In some other cases, apical trephination may be warranted.

Incision and effective drainage from the swelling above a maxillary lateral incisor.

No Fluctuance: No Drainage Through the Tooth

If an access opening is made but no drainage is obtained, the canals are cleaned, shaped, medicated, and closed. Because the tissue is nonfluctuant, incision and drainage is contraindicated. The patient should be placed on hot saline rinses that will soothe the tissues and may promote either a reduction in overall symptoms or encourage more rapid movement of the inflammatory response through the bone into the soft tissues; at this point the incision and drainage can be attempted. These clinical scenarios present difficult challenges. The patient must be treated expeditiously and appropriately, but cleaning and shaping of the canal system is the only treatment that can be performed in an attempt to alleviate the symptoms. Although some clinicians advocate the routine use of patency filing in all cases, this may not be the time to consider a technique that has no clinical or scientific basis (see Chapter 9). If used aggressively, especially without cleaning the canal thoroughly prior to going past the apical constriction, it may inoculate the periapical tissues with undesirable bacterial species, thereby creating an even worse clinical situation.38 Likewise, while studies have shown that drainage may not achieve the level of desired pain relief,32 a systematic review of the literature (done to identify evidence-based directives) found that drainage is indicated to lessen the patient’s problem.26 However, if there is a reasonable possibility drainage could not be obtained by going past the apex, apical trephination can be considered.
Figure 15-15  A, Incision and drainage of a localized swelling. The area has been anesthetized, but the anesthetic solution is not placed directly into the swelling. Placement of a No. 11 scalpel blade for the incision. B, Deep incision releases the contents of the tissue swelling.

Figure 15-16  A, Drainage could not be obtained through the tooth in a maxillary molar. Note the swelling. B, Incision with drainage readily achieved. (Case courtesy Dr. Rob Roda.)

Figure 15-17  Opening the incision with a hemostat to enhance drainage.

Apical and Surgical Trephination

A trephination procedure can be of tremendous help when indicated for relieving a patient’s excruciating pain. Apical trephination is indicated when a diagnosis of acute alveolar abscess can be made with reasonable assuredness, there is no swelling, and there is every reason to believe that going beyond the apical foramen with a small file will result in drainage. The procedure is accomplished by aggressively placing a No. 15 to 25 K-file 2 to 3 mm beyond the confines.
of the apex. In most cases, this will establish drainage. Each case should have radiographic verification of the file position beyond the apex. This procedure can introduce some treatment problems, such as destruction of the natural apical constriction or zipping of the canal at the apex in curved canals if the clinician is too aggressive. Remember also that in cases of acute pain and acute infection, obtaining profound anesthesia for surgical intervention can be difficult. However, the benefits of the procedure far outweigh the potential problems.

Surgical trephination is rarely needed to manage pain if good principles of diagnosis and treatment are followed. Although studies have not supported its efficacy,\(^{21,28}\) when chosen selectively it is a reliable procedure to manage intractable pain when all other methods have failed. In all likelihood, the severe pain is caused by a significant increase in intracortical pressure in the periradicular tissues, which can only be relieved through a surgical opening when apical trephination has failed or cannot be performed, as in the case of a previous root canal procedure in which the canal cannot be accessed at that moment or the canal is blocked apically. Surgical trephination involves a soft-tissue incision, cortical penetration with a rotary instrument, and creation of a pathway for drainage from the periradicular tissues.\(^1^2\) Three approaches may be considered:

**Treatment Option 1:**

1. Proper anesthesia is obtained.
2. A No. 15 scalpel blade is used to make a small (5 mm) horizontal or vertical incision in the mucosa apical and usually superior or lateral to the root apex. This positioning is critical to avoid penetration into tooth structures.
3. Retract the mucosa with a tissue retractor, periosteal elevator, or the wide end of a sterile No. 7 wax spatula (Fig. 15-18, A).
4. A No. 6 or 8 round bur is used to penetrate the cortical plate at an angle designed to reach the periradicular tissues or lesioning, avoiding contact with the root (see Fig. 15-18, B). This approach works well when a large periradicular lesion is present.
5. Immediate drainage for relief of intracortical pressure is usually obtained.
6. The patient is advised to use warm to hot saline rinses for at least 24 hr; longer is desirable.

**Treatment Option 2:**

1. Proper anesthesia is obtained.
2. A No. 15 scalpel is used to make a small (5 mm) vertical incision adjacent to the root of the tooth in question.
3. Retract the mucosa with a tissue retractor or wide end of a sterile No. 7 wax spatula (see Fig. 15-18, A).
4. A No. 6 or 8 round bur is used to penetrate the cortical plate only (see Fig. 15-18, B).
5. A large K-file (No. 40 minimum) (see Fig. 15-18, C) or spoon curette is used to bore a path through the cancellous bone to the periradicular tissues or lesion, avoiding contact with the root apex (Fig. 15-19).
6. Immediate drainage or relief of intracortical pressure is usually obtained.
7. The patient is advised to use warm to hot saline rinses for at least 24 hr; longer is desirable.

More often, option 2 is a safer approach, especially if vital structures are adjacent to the tooth in question, if roots are closely approximated, or if the vestibule is shallow (Fig. 15-20). Failure to adhere to these principles can result in destruction of the root structure and periodontal ligament, with the potential for subsequent external root resorption. An alternative to either of the previous options is to use a large endodontic spreader to penetrate the cortical plate:\(^6\)

**Treatment Option 3:**

1. After the penetration site has been anesthetized, a No. 3 spreader is placed parallel to the root surface, with a silicon stop as a reference point.
2. The spreader is then rotated to a point nearly perpendicular to the root apex.
3. Apical pressure is applied as the spreader pierces the alveolar mucosa, periosteum, and cortical bone into the periradicular lesion.

The value in this approach is that no incision or surgical flap is necessary, and the chance of damage to the root structure is minimized. However, entry to the lesion may be very difficult in the presence of thick cortical bone.

If a patient presents with a necrotic pulp and an extensive extraoral swelling or cellulitis, accurate and aggressive treatment is essential. In these cases, the patient should be placed on antibiotics immediately upon completion of the root canal treatment—or before if the clinician is unable to treat the patient in a timely fashion (Fig. 15-21). Antibiotics of choice are penicillin or amoxicillin 500 mg every 6 hours for 5 to 7 days. Clindamycin has become very popular as a substitute for penicillin and cephalosporin, but there is little evidence-based support for other antibiotics over penicillin at this point in time. Because of the potential for this condition to worsen quickly without any indications of its rapidly deteriorating state, removal of all necrotic tissue within the root canal system is recommended. This type of root canal infection requires immediate and aggressive action on the part of the clinician. Mistakes are costly and can result in serious sequelae.

If the patient is febrile and has lymphadenopathy in combination with a cellulitis, it is advisable to prescribe a loading dose of antibiotic. Usually, in the case of penicillin, a loading dose of 2 g is indicated and adequate to control a fulminating infection. Unless the patient is allergic to penicillin, antibiotics should not be substituted without adequate clinical judgment. One-appointment root canal treatment in these cases is not contraindicated based on any physiologic or biological
Problem Solving in the Management of Painful Tooth Emergencies

FIGURE 15-18  

A, Preparation for a surgical trephination; a small vertical incision was made and the tissue was retracted slightly with a small periosteal retractor.  

B, While the tissue is retracted, a bur is used to begin cortical penetration.  

C, Once most if not all of the cortical bone is penetrated, a large file can be used to create a drainage pathway from the desire site.

FIGURE 15-19  

A, This 27-year-old female was referred for treatment; maxillary lateral incisor was opened and left open for drainage, but no drainage occurred.  

B, After an incision was made, a curette was used to establish a pathway for drainage, which was profuse. However, the patient became swollen and was sent to an oral surgeon, who opened the area and did a biopsy; report indicated rhabdomyosarcoma.
basis. However, most clinicians would agree that because the patient is in a potentially labile state that could become unstable and serious very rapidly, one-appointment treatment is unadvisable. The patient should be reassessed every few days. Because cleaning, shaping, and obturation can cause additional irritation to periapical tissues, the clinician should wait for signs and symptoms to subside before treatment completion. If lymphadenopathy is present, the enlarged nodes should be responding to the antibiotic treatment before additional root canal procedures. Once resolved, treatment can be completed.

**Analgesics and Antibiotics**

With the advent of nonsteroidal antiinflammatory drugs (NSAIDs), many patients present to the dental office already taking antiinflammatories, but they may not be taking sufficient doses to have an impact on the problem at hand. Because most pain of tooth origin is inflammatory in nature, there are few medications the clinician can prescribe that are superior to over-the-counter (OTC) NSAIDs. The OTC market is redundant with aspirin and acetaminophen substitutes that are both analgesics and antiinflammatories. In fact, recent data support the combined used of ibuprofen (600 mg) and acetaminophen (1000 mg) to achieve analgesia and pain relief equivalent to that of a narcotic without the side effects.14,27 Despite such findings, no correlating decrease in purchases of prescription analgesics has been documented.

If analgesics and/or antibiotics are being prescribed on a regular basis to manage endodontic emergencies, there is likely a problem with accurate diagnosis and treatment techniques. Pain is not an indication for antibiotic treatment.19

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*FIGURE 15-20* A, This patient was in severe pain, and the referring dentist could not find the root canal to begin revision. For pain relief, trephination was indicated on the mandibular first premolar. The mental foramen did not appear to preclude this approach to pain relief. B, Use of a curette to establish direct and immediate drainage.

*FIGURE 15-21* A, Buccal cellulitis in the right mandible. Place the patient on antibiotics, and wait for a reduction in the swelling or if fluctuant, incise and drain. B, Facial cellulitis in the canine space; arrows indicate extent of swelling.
Pain before or after an emergency appointment does not necessarily indicate an infection or the need for antibiotic coverage. Mild pain and occasionally moderate pain are normal consequences of treatment intervention. Not every patient will be completely pain free immediately afterward, but the majority will be improved significantly or completely within 1 to 3 days following any type of emergency management. If this is not the case, reevaluation of clinical procedures and diagnostic techniques is in order. When endodontic treatment procedures are managed properly, the incidence of a painful response requiring emergency treatment is documented at only 3% to 5%.\(^{42}\)

Overuse of antibiotics became a significant problem in the late 20th century.\(^{15,16}\) Clinicians prescribed antibiotics for everything from routine problems such as pain after instrumentation to “covering” a potential infection when a diagnosis could not be determined and the practitioner felt obligated to “do something” for the patient. This blatant misuse of antibiotics resulted in the development of antibiotic-resistant bacteria, but increasing awareness of such harmful consequences has fortunately led to more judicious prescribing practices.

When antibiotics are prescribed because a patient is febrile, the effect of this medicament will not manifest for several days. The fact that the patient’s temperature is not continuing to rise is usually indicative that the antibiotic is working appropriately and that additional antibiotics or switching antibiotics is not indicated (Fig. 15-22). Patients often need education in this regard if they expect antibiotic treatment to have immediate results.

The same is true for a patient who presents with a cellulitis. If placed on an antibiotic, there will be minimal improvement in the first 24 to 48 hours, and the fact that the cellulitis has not increased during this latency period should be ample support for the clinician that the antibiotic is working appropriately. Switching antibiotics within the 24- to 48-hour time frame at the behest of a patient who has not seen improvement occurs too often via a phone call. The clinician should see the patient and make a proper objective evaluation of the patient’s condition.

For the benefit of the patient, first and foremost the clinician should be cognizant of the following considerations:

- The reduction or disappearance of pain is an excellent indicator of the effectiveness of the treatment, even if some residual swelling remains.
- When a patient presents with a definite indication for antibiotic use, the clinician should not consider the patient’s remaining status quo for the first 2 to 3 days of therapy indicative of antibiotic failure if prescribed properly.
- A loading dose is recommended when the patient presents with a fever, lymphadenopathy, or moderate cellulitis.
- Most antibiotics will not produce significant clinical changes or effects within the first 24 to 48 hours.
- The clinician should not consider switching antibiotics within the first 24 to 72 hours after the initial dose unless the patient is demonstrating rapid and significant clinical signs/symptoms of deterioration. At this point, referral to a specialist is probably indicated.

Anesthesia for Painful Teeth

One of the greatest problems in managing pain of tooth origin is inability to provide adequate anesthesia for the patient in distress.\(^{13}\) With the advent of newer anesthetic devices, much if not all of the discomfort can be eliminated. Problem solving painful tooth emergencies mandates an understanding of the inflammatory processes involved,\(^{3}\) a knowledge of the osseous and neural variations of the area to be anesthetized, knowledge of the action of anesthetic solutions, skill in administering solution to the target area, and an appreciation for the psychologic makeup of the patient.

The normal pulp has a relatively high blood flow that is minimally influenced by vasodilator substances (irritational products). This results in only minor increases in localized blood flow during irritation and inflammation.\(^{20}\) In this inflamed environment, capillary permeability appears then to be more significant than blood flow with regard to the inflammatory response of the pulp. This rules out the concept of generalized pulpal edema, despite the low-compliance environment within the tooth. The localized inflamed tissues experience an increase in tissue pressure that results in a focal vascular stasis, ischemia, and tissue necrosis. These focal areas of necrosis serve as additional insults within the pulp, and the subsequent cyclic episodes of inflammation and cellular death result in the incremental circumferential spread of tissue destruction.\(^{40}\)

**FIGURE 15-22** In febrile patients, periodic assessment is necessary to monitor the situation, and referral is often indicated for possible extraoral incision and drainage.
The periodic irregular inflammation and destruction of localized tissue components coupled with bacterial invasion can only partially explain the clinical experience of episodic pain. Further explanation may include neural fluctuations, with cycles of increased nerve-fiber and peptide cytochemical alteration followed by decreases, perhaps associated with cycles of intrapulpal abscess expansion and pulpal attempts at repair. Interestingly in this respect, the sprouting of new cycles of intrapulpal abscess expansion and pulpal attempts at alteration followed by decreases, perhaps associated with cycles of increased nerve-fiber and peptide cytochemical changes that can only partially explain the clinical experience of episodic localized tissue components coupled with bacterial invasion.

The inflammatory process of pulpal disease and degeneration is basically the same as elsewhere in the body’s connective tissue. When coupled with endodontic procedures, coronal leakage of bacteria and their products from inferior dental restorations, or toxic root canal filling materials, the periradicular tissues will appear variable with regard to inflammation and repair. Histologically, the lesion consists predominantly of granulation tissue, exhibiting significant angioblastic activity, many fibroblasts, connective-tissue fibers, an inflammatory infiltrate, and often connective-tissue encapsulation. The inflammatory infiltrate consists of plasma cells, lymphocytes, mononuclear phagocytes, and neutrophils. Occasionally cholesterol clefting is seen along with foreign-body giant cells. If, in addition, adjacent strands of epithelium or rests of Malassez have been stimulated by the inflammatory response to form a stratified squamous epithelium–lined cavity filled with fluid or semisolid material, a cyst will be present.

As long as there is an egress of tissue irritants and bacteria from the root canal system, or there is a failure of the phagocytic macrophage system to control this irritation, the histologic pattern of the periradicular lesion will be one of concomitant repair and destruction. Often this variable tissue response is subjected to superimposed inflammatory, infectious, or immunologic processes, and patient signs and symptoms will reflect these changes, moving from a chronic clinical state of minimal to no symptoms to an acute state with the complete litany of painful characteristics.

The inflammation that accompanies pulpal and periapical degenerative/infective changes results in a reduced tissue pH over variable areas, depending on the extent and acuteness of the process. This has been suggested as the explanation for the difficulty in achieving quality anesthesia, because the ability of the weak anesthetic base (pKa 7.5 to 9) to dissociate is significantly affected. Others have suggested that inflammation alters peripheral sensory nerve activity, possibly because of neurodegenerative changes along the inflamed neural element distal from the inflammatory site. Research data suggests that nerves located in inflamed tissue have altered resting potentials and excitability thresholds and that these changes are not restricted to the inflamed pulp itself but affect the entire neuron cell membrane in every involved fiber. The nature of these changes is such that the reduction in ion flow and in action potential created by local anesthetic agents is not sufficient to prevent impulse transmission for the reason that the lowered excitability threshold allows transmission even under conditions of anesthesia. As suggested by some investigators, an increase in anesthetic concentration (not necessarily volume) is required to lower the neural action potential when attempting to achieve complete anesthesia in the presence of inflamed tissues. An alternative approach would be to administer the local anesthetic remote from the area of inflammation, such as the use of a regional nerve block whenever possible, especially in the case of extensive cellulitis.

Variations in the osseous anatomy surrounding tooth roots and aberrant neural structures have received renewed attention as potential impediments to administering successful anesthesia. The common variations encountered are discussed relative to the maxilla and mandible, along with the suggested sequence for achieving profound anesthesia in each jaw.

Generally the outer cortical plate of the maxillary bone is thin and sufficiently porous in the adult to make infiltration anesthesia effective. However, in facial or buccal areas of the zygomatic alveolar crest, penetration of the anesthetic solution to the middle superior alveolar nerve may be restricted, especially in children. Likewise, the absence of this neural branch has been reported, requiring more extensive placement of the anesthetic solution to manage the first molar and premolars.

Anteriorly, the prominence of the anterior nasal spine and prominent floor of the piriform aperture may preclude approximation of the root apices of the incisor teeth. In the premolar and molar region, the position of the palatal roots relative to the buccal cortical plate may by necessity require placement of palatal infiltration anesthesia.

Providing adequate anesthesia in the maxillary arch is not difficult. Most often the inability to do so cannot be attributed to the presence of infection but rather to error in technique and placement of the anesthetic solution. For the patient in pain, maxillary infiltration in the buccal or labial vestibule of one carpule (1.8 mL) is usually sufficient for anterior teeth; however, some maxillary anterior teeth are palatally inclined (lateral incisors, some central incisors, canines), whereas others have palatal roots that must also be anesthetized. These roots are often overlooked after the buccal infiltration, and the patient experiences needless discomfort.

Infiltration on the facial or buccal side should vary from the standard approach of depositing the solution near the apex with the needle parallel to the long axis of the root. Rather, an angulated approach directed at the root apex will usually provide a more rapid and accurate diffusion through the bone.

Palatal infiltration should be used routinely, especially when the patient is already somewhat hypersensitive. Knowledge of the exact location of the palatal apex with
accessory innervation has received the most attention. These range from the presence of well-defined foramina in the retromolar fossa (Fig. 15-24), to extension to and innervation of both posterior and anterior teeth by branches of the mylohyoid nerve, to the presence of median symphyseal crossover from branches of the incisive nerve. Finally, the existence of a transverse cervical cutaneous nerve that may intermingle with fibers of the mental nerve has been suggested to enter the mental foramen and course posteriorly, innervating the premolars or molar teeth.

The mandibular posterior teeth are perhaps the most difficult to anesthetize adequately. The reasons are multiple and include accessory nerve innervation, inadequately administered mandibular blocks, and lower pain thresholds for inflamed teeth. However, a few basic principles can aid in achieving profound anesthesia:

- Do not infiltrate for the purpose of anesthetizing accessory innervation until the mandibular block has been given and lip signs indicate profound anesthesia.
- Infiltrate one-third carpool of anesthetic solution around the affected tooth.
- Use a mental block and/or mylohyoid infiltration with mandibular molars.
- Do not attempt root canal treatment until the tooth can undergo percussion (if originally sensitive) or until the stimulus of pain (cold, heat) can be placed on the tooth without discomfort.

Too often the clinician fails to wait an adequate amount of time before initiating emergency treatment, and the cold water or air from the turbine causes severe pain for the patient. This lessens the patient's confidence in the practitioner and decreases the patient's pain threshold. If after these basic principles have been followed, adequate anesthesia still has not been achieved, intraligamental injection (Fig. 15-25) or intraosseous injections (Stabident [Fairfax Dental Inc., Miami, FL, USA]; X-tip [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]) may be considered. However, with multirooted teeth, intraligamental and intraosseous injections should be placed beside or near each root for complete anesthesia. This is especially true in molar teeth, where in some respects to the palatal vault is critical for proper placement of the anesthetic solution and elimination of any painful response. Block anesthesia, such as an infraorbital block, posterior superior alveolar block, or injection into the greater palatine foramen, is considered very good for achieving maximum anesthesia, especially in cases where the patient has minimal discomfort.

The mandibular foramen is the primary target for deposition of anesthetic solution for profound anesthesia of the mandibular teeth. Although the position of the foramen is variable, it is usually found anterior to the midpoint of the ramus of the mandible when the anterior border of the mandible is defined as the internal oblique ridge (Fig. 15-23). Studies have identified this position as slightly above the occlusal level of the molar teeth. The importance in this variability cannot be overemphasized for the clinician, because the angle and level of needle penetration will have to be reassessed and altered accordingly in many cases in which profound anesthesia is not readily achieved with a standard approach. Although rare, the potential for extreme variability in the coursing of the mandibular canal has been identified, even to the extent of bifidity. Conventional attempts at mandibular blocks in these cases may lead to failure. Examination of panoramic views of the mandible is extremely helpful to anticipate variations of this nature, at least two-dimensionally.

Of all the variables that create controversy in achieving profound anesthesia in the mandible, the presence of accessory innervation has received the most attention. These range from the presence of well-defined foramina in the retromolar fossa (Fig. 15-24), to extension to and innervation of both posterior and anterior teeth by branches of the mylohyoid nerve, to the presence of median symphyseal crossover from branches of the incisive nerve. Finally, the existence of a transverse cervical cutaneous nerve that may intermingle with fibers of the mental nerve has been suggested to enter the mental foramen and course posteriorly, innervating the premolars or molar teeth.

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chapter 15 | Problem Solving in the Management of Painful Tooth Emergencies

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chamber, with the anesthetic agent injected during penetration. Often only a few drops of solution are necessary to anesthetize the pulp tissue. The intrapulpal technique may anesthetize only the coronal pulpal tissue. Often the vital tissue in the canals has not been properly anesthetized, and a pulpectomy should not be attempted. In some cases, total pulpal anesthesia can be achieved, and the pulp can be removed in its entirety. After complicated crown fractures (see Chapter 19), especially in the presence of soft-tissue swelling, injections can be given directly into the site of the pulp exposure. Rapid anesthesia is achieved with minimal patient discomfort.

REFERENCES


RECOMMENDED ADDITIONAL READING


Chapter 16

Problem-Solving Challenges in Periapical Surgery

Probably the first requisite for a successful operation is that the operator should be thoroughly familiar with the anatomy of the region.²

J.R. Blayney, 1932

Pulpless teeth, no matter how well filled, with the slightest previous history of functional or periodontal disturbance which showed any evidence of apical denudation (as indicated by variation in the lamina dura and trabeculae and periodontal width, when compared with adjacent normal teeth) should be root resected.¹²

C.F. Fawn, 1927

Rationale for Surgical Endodontic Treatment

There are multiple treatment planning options for root-treated teeth that develop recurrent periapical pathosis or have periapical lesions that fail to heal following adequate root canal treatment. While nonsurgical revision is usually the clinical treatment of choice,³ many teeth are unsuitable for revision owing to irreversible changes in the tooth or to the nature of the periapical pathosis.³ Furthermore, there are very few studies that reflect high levels of evidence relative to the success or failure of nonsurgical revision.⁴ Periapical surgery is not only appropriate for these cases¹⁰ but also for the occasional case in which nonsurgical revision is possible but may result in excessive destruction of either the tooth or restoration. In fact, data show that the success rate for surgical intervention may be higher than that for nonsurgical revision* and should be considered in the treatment-planning process when teeth are compromised with failure of previous root treatment.¹ The choice of periapical surgery is a valid alternative to tooth extraction¹⁷ and should always be considered. At the same time, there may be unique circumstances that indicate extraction would be the treatment

Problem-Solving List

Problem-solving challenges encountered in periapical surgical considerations addressed in this chapter are:

Rationale for Surgical Endodontic Treatment

Indications for Apical Surgery

Failure of nonsurgical root canal treatment or persistent apical radiolucencies

Reaction to Foreign Bodies in the Periapical Tissues

Root Canal Anatomy That Is Impossible to Manage Nonsurgically

Anatomic obstructions

Iatrogenic obstructions

Failure of previous periapical surgery

Surgical Access and Manipulative Techniques: In Vitro Directives

Surgical Access and Manipulative Techniques: In Vivo Directives

Surgical anatomy

Anesthesia and hemostasis

Soft-tissue considerations: flap design

Curettage and enucleation of the soft-tissue lesion when the lesion penetrates the bone

Root apex exposure in the absence of a periapical lesion

Root-end resection and identifying the root canal space

Root-end cavity preparation

Root-end fillings: materials and placement

Tissue repositioning and stabilization

Postsurgical Care and Potential Complications

Complications

*References 10, 11, 32, 43, 56, and 60.
of choice. Even in these situations, the option for intentional replantation \(^{73}\) may exist, and an informed clinician will usually take into account all options before condemning a tooth to removal.

It may appear that no treatment and a watchful waiting period is an additional option, but in reality, this approach only delays the decision to choose one of the other viable treatment plans. Furthermore, a significant delay in treatment may result in irreversible bone loss and limit the ultimate choice of treatment to extraction.

The theory and treatment planning behind the choice of periapical surgery has not varied much from the earliest citations in the endodontic literature.\(^{24}\) The objectives are to eliminate any periapical reactive tissues when present and to clean and seal all communications from the root canal space through a surgical approach to the apex. Historically, however, it was not uncommon to perform a surgical curettage with the belief that the patient's problem resided in the inflamed/infected tissue around the end of the root.\(^{24}\) More often than not, the source of the problem was failure to clean, disinfect, and fill the root canal space, or to seal the canal space coronally, permitting leakage into a poorly managed root canal system. Ironically, both of these issues would ultimately doom the tooth to extraction following the surgical procedure because of the recurrence of pathosis. Substantial changes in understanding the causes of the disease processes, improvements in surgical techniques, and enhanced choices for root-end materials, supported by a wealth of excellent research,\(^{21}\) have made surgical endodontics a reasonable and predictable choice in tooth retention.\(^{13,38,58,77}\)

### Indications for Apical Surgery

**Failure of Nonsurgical Root Canal Treatment or Persistent Apical Radiolucencies**

Several etiologies have been identified for persistent periapical pathosis following nonsurgical root canal treatment.\(^*\) Of all factors identified, the only one for which nonsurgical revision would have a predictably high chance for success is the case of inadequate initial root canal treatment in which there are no iatrogenic alterations of the canal morphology\(^{8,19}\) (Fig. 16-1). If the apical 2 to 3 mm of canal space was cleaned and shaped minimally in the original treatment or left completely uncleaned, the procedures of revision would not differ significantly from routine root canal treatment of any similar tooth.\(^3\) The prognosis for healing would be correspondingly very good (Fig. 16-2).

Inadequate nonsurgical root canal treatment in teeth with significant alteration of the root canal morphology is not unusual in cases with recurrent or persistent apical pathosis (Fig. 16-3). A poor healing response would be expected after nonsurgical revision owing to the increased difficulty or impossibility of cleaning, disinfecting, and obturating the altered apical canal anatomy. While the level of success with nonsurgical revision is below that of initial treatment,\(^{32,74,75}\) nonsurgical revision is still indicated in most cases as the

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*References 4, 41, 42, 47-49, 74, and 75.*
primary approach, since healing may be possible despite the diminished prognosis (Fig. 16-4). After a suitable period of healing time, usually 6 to 12 months, apical surgery would become the treatment of choice for those that fail to heal. In all cases of nonsurgical revision, the patient should be informed that healing may be delayed and surgical revision may yet be necessary.

Four causes of persistent periapical pathosis that are unlikely to be identified or differentiated by clinical or radiographic means\textsuperscript{41,42,74,75} are infection located in inaccessible spaces in the root canal system\textsuperscript{16,30,47-49,71} (Figs. 16-5 and 16-6), infection located outside the root canal in the apical lesion itself\textsuperscript{47,49} (Fig. 16-7), true cysts or tumors (Fig. 16-8), and vertical root fracture (see Fig. 4-12, B). The chief clinical presentation is a nonhealing periapical lesion after acceptable root canal treatment. The specific etiology is usually not identifiable preoperatively and is confirmed either at the time of surgery by direct observation or later by histologic examination.\textsuperscript{41,42}

Residual bacteria located in inaccessible parts of the root canal system have been the subject of considerable research.
Histologic studies of resected root tips and microbiologic studies of bacteria sampled from root canals have identified that the majority of root canal treated teeth with asymptomatic periapical periodontitis harbored persistent bacteria in the apical portion of the complex root canal system. From a clinical standpoint, there is no available method to detect such spaces, but knowledge of their possible presence should serve to increase the thoroughness of canal preparation during routine treatment (Fig. 16-9).

Cases of persistent periapical infection caused by bacteria that persist after adequate root canal treatment are not common. In some cases, these pathogens have established a
**FIGURE 16-6** A, 6-month reevaluation after root canal treatment of a mandibular left central incisor indicating the lesion had failed to heal. B, Postsurgical treatment radiograph. During surgery, multiple accessory canals were observed as the apical bevel was prepared. The canal had been well filled.

**FIGURE 16-7** A, Large radiolucency around maxillary right incisors. Root canal treatment had no impact on the course of the acute infection. Infection gradually involved the bone of adjacent vital teeth. B, Surgical exposure and curettage 1 week after root canal treatment. The infection continued. The central and lateral incisors were ultimately extracted, after which healing progressed uneventfully.

**FIGURE 16-8** A, Large radiolucency associated with a failed root canal with silver cones. B, Reevaluation after 6 months indicating radiographic resolution of the lesion. Histologic examination confirmed a true cyst.
Problem-Solving Challenges in Periapical Surgery

During periapical surgery, a fracture line is observed to originate at the apex and extend coronally. If there is no extension through the attachment, the fracture line may be repaired as part of the root-end filling (Fig. 16-10).

**Reaction to Foreign Bodies in the Periapical Tissues**

At times gutta-percha filling material may be inadvertently extruded through the apical foramen or lateral foramina during obturation.7,54,76 The appearance of a small amount of filling material at the apex or at a lateral canal site is not
unusual and is even considered desirable or “esthetic” by some practitioners. Rarely do these materials present a prognostic problem (Fig. 16-11).

Occasionally, excessive material may be extruded, which clearly does not look “esthetic” on the postoperative radiograph. Nevertheless, if the apical foramen is clean and well sealed, lesions will heal around the extruded material. Assuming the patient is comfortable, the best postoperative course is reevaluation in 6 to 12 months (Fig. 16-12). If symptoms or signs of pathosis either persist or recur, surgery might be indicated before a 6-month reevaluation. Even if the patient has been comfortable, apical surgery would also be indicated if the lesion showed no radiographic signs of resolution at the time of reevaluation.

Paste-type root filling materials are largely uncontrollable when placed with a lentulo spiral. If the apical foramen is naturally large or has been enlarged during canal cleaning and shaping, the paste material can be forced through the apex into apical bone, the sinus, or the mandibular canal. Excessive extrusion of these materials can result in persistent periapical pathosis. Surgery is indicated to both remove the

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**CLINICAL PROBLEM**

**Problem:** Root canal treatment was completed 1 month previously on the maxillary right first molar. The postoperative radiograph indicated an acceptable and unremarkable result. The patient continued to complain that since the day of treatment, there has been a small lump over the apex in the vestibule that remains tender to touch. Clinical examination confirms the small nodule that is locally inflamed and sore to palpation.

**Solution:** The apices of many maxillary premolar and molar buccal roots are very superficial relative to the surface of the bone (fenestration) (Fig. 16-13). If gutta-percha filling material/sealer are extruded through such a root, it will sometimes extend laterally into the periosteal tissues. The radiograph may not look unusual, since the extruded material is often angled toward the x-ray beam. Periapical surgery will be necessary to remove the extruded material and resect the root end into the bony housing. This will usually resolve the problem (Fig. 16-14). Rarely, a bone graft and membrane may need to be considered.

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**FIGURE 16-11** A, Obturated mandibular molar with extrusion of filling materials out of a large lateral canal in the mesial root and the apical foramen of the distal root. Note the extent bone destruction in the furcation. B, Healing in progress 6 months later.

**FIGURE 16-12** A, Inadvertent extrusion of gutta percha through the apical foramen during routine obturation. B, Six-month reevaluation indicating normal healing despite the presence of the extruded material.
FIGURE 16-13 Cadaver specimen of the right maxilla illustrating the superficial relationship of the buccal roots to the surface of bone.

FIGURE 16-14 Clinical photograph of gutta-percha that had been extruded into the submucosal tissues. Periapical surgery was required for removal.

FIGURE 16-15 A, Radiograph illustrating extrusion of paste filling material into the maxillary sinus. B, Radiograph demonstrating gross extrusion of paste filling material into the periapical bone of the maxillary right lateral incisor, causing acute periapical periodontitis. C, Clinical photograph depicting removal of the extruded material during periapical surgery.
excess and ensure the canal is filled properly at its terminus (Fig. 16-15).

**Root Canal Anatomy That Is Impossible to Manage Nonsurgically**

Some teeth have root shapes that prove impossible to treat nonsurgically. Severe curvature combined with calcifications can prevent negotiation to the terminus of the root canal (Fig. 16-16).

**Anatomic Obstructions**

The standard of care for treatment of teeth with open apices centers around techniques and materials that result in the formation of a calcified apical barrier. Apical surgery would be indicated in cases that fail to develop the barrier or in which the canal anatomy prevents using the technique. Fig. 16-17 illustrates a case in which an early radiograph indicated the formation of a dens in dente in a maxillary lateral incisor.

Five years later, the patient developed an acute apical abscess, and the periapical film at the time of emergency treatment confirmed that the apex had not developed. It was judged that nonsurgical access through the dens in dente would be destructive and would in itself diminish the long-term prognosis of the tooth. Apical surgery in this case was the most effective and least invasive option.

One of the most common complications in routine root canal treatment is the presence of calcified material in the root canal space. Chapters 8 and 13 discussed the various techniques for successfully locating and penetrating canals that appear radiographically to be partially or completely closed. Nevertheless, some of these teeth are in reality calcified to the extent that penetration to the apex is not possible.

**FIGURE 16-16** Radiograph of a mandibular premolar with severe apical curvature in the canal that proved to be nonnegotiable to the apex. Surgery was indicated to resolve the persistent apical periodontitis.

**FIGURE 16-17** A, Dens in dente formation in developing lateral incisor. B, Five-year reevaluation indicating an apical lesion and incomplete apex formation. The patient presented on emergency with an acute apical abscess. C, A 19-month postsurgical reevaluation indicating excellent healing.
Problem-Solving Challenges in Periapical Surgery

in the canal space that prevent the use of nonsurgical revision techniques (see Chapter 14). The placement of these materials could have been intentional, as in the case of posts, or accidental, as in the case of instrument separation. Chapter 14 describes the usual techniques for removing these materials or obstacles, but at times this is impossible, especially when the blockage is in the apical third or located in a curved canal. Periapical surgery is the only effective method to resolve the periapical pathosis and retain the tooth.

One technique which is particularly difficult to revise nonsurgically is the sectional silver cone that was placed to allow space for an intraradicular post. Fortunately, the use of silver cones is obsolete, but a legacy of cases remain. In the event the silver cone section is not removable nonsurgically, apical surgery is indicated. Fortunately in many cases, it is possible to remove the entire piece of silver cone from the apical direction because many will be found to be loose in

Iatrogenic Obstructions

The term *iatrogenic* refers to adverse complications caused by previous treatment. In the case of obstructions, it would be the presence of irretrievable dental materials or instruments in the canal space that prevent the use of nonsurgical revision techniques (see Chapter 14). The placement of these materials could have been intentional, as in the case of posts, or accidental, as in the case of instrument separation. Chapter 14 describes the usual techniques for removing these materials or obstacles, but at times this is impossible, especially when the blockage is in the apical third or located in a curved canal. Periapical surgery is the only effective method to resolve the periapical pathosis and retain the tooth.

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the canal following resection. If the silver cone can be removed, apical preparation can proceed in the usual manner without complication.

If the silver cone cannot be removed, the apical preparation (described later in this chapter) becomes much more complicated. The metal will have to be cut back with a very small bur or diamond-coated ultrasonic tip to create a cavity preparation for the root-end filling material (Fig. 16-21). The same problem may be encountered with some paste filling materials that set to a hard consistency.

When separated instrument fragments cannot be removed, surgery is indicated to clean and fill the apical portion of the root canal. If the instrument fragment does not extend to the apex, it is not necessary to remove it. In fact, the attempt to remove it may excessively destroy root structure. Instrument fragments at the apex or protruding through the apex can frequently be removed during surgery, which greatly facilitates apical preparation and placement of a root-end filling (Fig. 16-22).

Intraradicular posts can be problematic in three ways relative to periapical surgery. Like other iatrogenic obstructions, they impede the use of nonsurgical revision techniques. Fortunately, modern technology makes it possible to remove most posts, but it is not always advantageous to do so. On occasion, the remaining tooth structure may be severely weakened, which will diminish the prognosis of the restored tooth even if the revision is successful (Fig. 16-23). Often, periapical surgery is the more conservative approach.

Secondly, although removal of the post is usually the treatment of choice, it is seldom possible to determine the extent

**Figure 16-21** A, Root canal completed with a sectional silver cone. A symptomatic lesion is present. B, After an unsuccessful attempt at removal, surgery was completed.

**Figure 16-22** A, Root-treated mandibular first molar with periapical pathosis. Note the separated instrument extending through the apex of the distal root. B, Immediate postsurgical radiograph indicating removal of the instrument fragment before placing the root-end filling. (Courtesy Dr. Ryan Wynne.)
to which a post may be essential to the retention of a restoration. Treatment planning for periapical surgery is sometimes based on the conservation of satisfactory functional or esthetic restorations even if the post could be removed (Fig. 16-24).

A third consideration concerns post placement within the canal. If the post preparation is overextended, or if a post is placed in a short root, the apical portion of the root fill may be compromised, resulting in the development of a periapical lesion. During surgery, insufficient canal space may remain for ideal surgical filling of the apical portion of the canal (Fig. 16-25). Occasionally the apical portion of the canal can be prepared by cutting the post itself. This procedure is more difficult than that described for silver cones. Contemporary metal post materials such as stainless steel and titanium are extremely difficult to cut with small burs, and the burs tend to be difficult to control.


**FIGURE 16-24** A, Mandibular canine with inadequate root canal and recurrent apical pathosis. The tooth is an abutment for a functional and esthetic fixed prosthesis. B, Although the post appears easily removable, periapical surgery was elected to avoid possible loosening of the crown.
Resin and ceramic post materials cannot be cut with burs and must be prepared with diamond-coated ultrasonic tips, a technique that is very slow if effective at all. The resulting preparations can become excessively large and shallow, and the prognosis for healing may be compromised. Successful surgical management of cases requiring preparation into post materials requires a high level of skill and experience. Nevertheless, the result can be satisfactory (Fig. 16-26).

Prevention of potential surgical complications due to post placement involves excellence of both endodontic and restorative treatment. The restoration of root canal treated teeth with posts is discussed further in Chapter 21.

**Failure of Previous Periapical Surgery**

The causes of failure of previous periapical surgery have been identified by many authors. Often indicted is failure to properly clean and shape the root canal system, which implies that either the apical portion of the root canal was not filled during surgery, not filled properly, or filled with an unacceptable material. Second, a major factor identified for failure following surgery is advancing marginal periodontitis. One of three possibilities will support this claim: (1) periodontal disease was present at the time of periapical surgery and ignored by the clinician; (2) periodontal disease has developed since the surgical procedure; or (3) the reflected tissue at the time of surgery was not repositioned and stabilized properly, which resulted in a downgrowth of epithelium and communication with the periapical surgical site. Additional causes of failure cited include coronal leakage through faulty restorations of teeth that have had surgery, anatomic aberrations that were not addressed during surgery, iatrogenic damage to the tooth, and iatrogenic damage to the supporting periodontium.

Amalgam was in common use as a root-end filling material for the first 90 years of the 20th century. At the time, there appeared to be no viable alternatives, even though amalgam was not considered biocompatible and failures occurred. Eventually, studies confirmed that the long-term prognosis for amalgam retrofills was poor, despite the observation that many cases remained functional for decades. Although amalgam is considered obsolete in this application, the legacy of cases completed in this manner is significant and represents possibly the most common type of surgical failure. Unfortunately its use continues today in many parts of the world.

Nonsurgical revision alone is never an option in cases of surgical failure unless the previous surgery has completely missed the apex, which is rare (Fig. 16-27). In virtually all cases, there is the need to remove the existing root-end filling material. Secondly, previous apical surgery has irreversibly altered the apical canal shape that cannot be corrected by nonsurgical revision. Third, bacteria in the preparation surrounding the existing root-end filling will be impossible to eliminate. And fourth, when amalgam is present as the root-end filling, the apical preparation is usually contaminated with corrosion products. Fortunately, surgical revision of previous apical surgery is a reasonable and effective treatment if the causative factors can be eliminated (Fig. 16-28).

There are a few differences in surgical techniques used with surgical revision as compared to cases without previous surgery. First is the necessity of removing previously placed root-end fillings. Fortunately, the techniques for apical preparation prior to the advent of ultrasonic instruments were not...
bur can penetrate. Often the only solution is to create more extensive apical bevel than would typically be desired. Another solution is to use ultrasonic diamond-coated tips, but they may not possess the necessary length to remove the entire filling, and their aggressive ability to cut dentin relative to the amalgam can create excessive enlargement. The operator must avoid high power levels with the use of ultrasonic tips, especially in a narrow, fragile root tip. Cracks in the root can result.46,55

If the root-end filling extends well into the canal space, removal can be a challenge if the material is hard, like amalgam. Amalgam can only be removed with a high-speed bur. Similar to the problems with silver cones described earlier, access and angulation limit the depth to which the bur can penetrate. Often the only solution is to create more extensive apical bevel than would typically be desired. Another solution is to use ultrasonic diamond-coated tips, but they may not possess the necessary length to remove the entire filling, and their aggressive ability to cut dentin relative to the amalgam can create excessive enlargement. The operator must avoid high power levels with the use of ultrasonic tips, especially in a narrow, fragile root tip. Cracks in the root can result.46,55

FIGURE 16-26 A, Maxillary premolar with a post and broken instrument in the apical few millimeters. A draining sinus tract is traced to the pontic area of the fixed prosthesis. Surgery is necessary. B, The bony window has been cut, and just the tip of the broken instrument is becoming visible (arrow). C, An apical preparation has been initially cut, and both the broken instrument and post are visible. D, An ultrasonic instrument was used to remove the broken segment. E, A bur is used to cut into the root and the end of the post. F, Apical cavity is prepared. G, Intermediate restorative material (IRM) is placed. H, Radiograph showing the final root-end fill. (Case courtesy Dr. Fasial Amir.)
It is beyond the scope of this text to present all the variations of surgical anatomy, issues of access to apices, and the techniques to accomplish root-end filling of canals in the posterior teeth. Subsequent discussions will focus on problem-solving techniques designed to prevent problems when performing periapical surgery on the anterior teeth, which for the novice are the best experiences for developing skills and experience.

Prior to considering a clinical application, the techniques for root-end cavity preparation and root-end filling of an anterior tooth will be illustrated in vitro. Preparation of the root apex consists of two operations, the first being root-end resection with an apical bevel that is made primarily to visualize the terminus of the root canal. Historically, the bevel was usually made at an angle of 45 to 60 degrees from the long

**FIGURE 16-27** A, Case of apparent surgical failure on a maxillary central incisor. B, Canal negotiated. Note that the amalgam root-end filling is not in contact with the canal or the apical radiolucency.

**FIGURE 16-28** A, Maxillary second premolar presenting with tenderness to percussion and palpation. Surgical treatment completed with an amalgam root-end fill approximately 10 years previously. B, Six-month reevaluation radiograph indicating excellent postsurgical healing. The patient was asymptomatic, and the tooth was functional. The apex is filled with MTA.

### Surgical Access and Manipulative Techniques: In Vitro Directives

From the examples presented in the previous section, it can be seen that endodontic surgery is applicable to almost all roots of all teeth. It is also true that the objective of periapical surgery is invariably the same for all applications: the cleaning and proper filling of the apical portion of the root canal at the level of the resected root face. From a practical standpoint, however, the more posterior the tooth, the more difficult the actual procedures become, owing to complexity of tooth anatomy and the anatomy of the alveolar arches.
axis of the canal (Fig. 16-29). This angle may open many bacteria-laden dentinal tubules in cases of persistent periapical pathosis. When the root is resected at any bevel, the canal orifice should be near the center of the beveled surface. With modern ultrasonic preparation techniques and the impact of magnification, the bevel can be made at right angles to the canal if visualization and access permit.

The second step is enlargement and cleaning of the apical portion of the root canal to permit placement of a root-end filling. Studies have focused on the direction and permeability of the dentinal tubules. The diameter of the tubules is sufficient to permit leakage of fluid and could permit ingress of bacteria into the root canal. In the midroot region, the dentinal tubules are roughly perpendicular to the root surface and pulp chamber. In the apical region, however, the dentinal tubules angle coronally from the root surface to the pulp chamber. With an apical bevel of 0 degrees (perpendicular to the long axis of the tooth), the angulation of the dentinal tubules would require canal preparation to a depth of 1 mm to adequately seal the dentinal tubules. If the bevel was cut at an angle of 45 degrees, the depth of preparation would need to be increased to 2.5 mm. For this reason, many if not most ultrasonic tips manufactured for apical surgery are designed with an effective cutting length of 3 mm (Fig. 16-30).
Preparation of the apical canal space has two objectives: (1) removing necrotic debris, bacteria, and any previous filling materials and (2) enlarging the space sufficiently to permit compaction of a dental material to fill the preparation. Currently, the apical preparation is usually performed with an ultrasonic instrument. Manufactured tips are available in various angle configurations, either plain or diamond coated. They can be used to prepare an adequate apical preparation for root-end filling in most anterior teeth (Fig. 16-31). A particular advantage of manufactured diamond-coated tips is their ability to cut metal such as silver cones, posts, and previous amalgam fillings. In practice, this may be a laborious and time-consuming approach, but in combination with high-speed burs, the diamond ultrasonic tip is a valuable surgical aid for removal of metallic materials.

Manufactured ultrasonic tips may also have some distinct disadvantages in certain cases. Due to their relatively large diameter and rigid construction, they do not necessarily follow the pathway of a prepared canal (Fig. 16-32). However, smaller, narrower diamond-tipped instruments are available (Fig. 16-33). This issue also involves visibility, surgical access, and clinician experience in the application of these tips. Diamond ultrasonic tips can be quite aggressive at higher energy levels, may cut in any direction (Fig. 16-34), and may create fractures on the resected root face. Caution must be exercised in maintaining a diamond tip in the long axis of the canal; short bursts of activation in applying the tip are suggested.

Another potential disadvantage is limitation to a 3-mm preparation depth (Fig. 16-35). Often it is desirable to clean the canal to a greater depth, especially if there is unclean space (Fig. 16-36). This situation may very well occur in the mesial buccal root of maxillary first molars. Fortunately, an alternative approach to apical canal preparation is possible with an ultrasonically energized K-file. The file will follow the pathway of the canal, and small, previously uncleaned canals can be negotiated (Fig. 16-37). Gutta-percha/sealer and paste filling materials are removed easily (Fig. 16-38), while the depth of preparation can be much greater than 3 mm, limited only by the space available in the lesion to place the instrument in the canal (Fig. 16-39).

The chief disadvantages of the ultrasonic file technique are the need to curve the file by hand and the potential for
**FIGURE 16-34** A, Demonstration of the cutting efficiency of an ultrasonic diamond-coated tip. There is no defect or canal on the lateral surface of the extracted tooth. B, Hole prepared in the root surface in less than 1 minute. At the apex, there is a risk of overpreparation and failure to remain centered in the canal.

**FIGURE 16-35** A, Preoperative radiograph of a previously treated lateral incisor. The tooth has a deeply seated intraradicular post, and patient is symptomatic. B, Postoperative image of the apical surgery completed with a manufactured ultrasonic tip. Depth of penetration is limited to 3 mm or less. It would have been desirable to remove all of the gutta-percha to the level of the post.

**FIGURE 16-36** A, Large post core restorations in two maxillary central incisors without previous root canal. Surgery is indicated. Ideally, penetration of the apical canal space should be to the level of the posts. B, Postoperative image of surgery on an open-apex lateral incisor. Note penetration and placement of filling material adjacent to the post.

FIGURE 16-38  A, Demonstration of apical preparation in a canal filled with gutta-percha. B, Larger-sized endodontic file used in the ultrasonic unit on a high setting only long enough to remove the gutta-percha. The power is reduced to complete the preparation.
FIGURE 16-39  A, Maxillary central incisor indicated for apical surgery. B, Postoperative image indicating removal of the gutta-percha and filling the canal to the level of the intraradicular post.

FIGURE 16-40  Precuring the file using a surgical needle holder; avoid sharp angle bends that will cause rapid instrument breakage when used ultrasonically.

FIGURE 16-41  Ultrasonic unit set at a low power potential for apical instrumentation.

FIGURE 16-42  Completed apical preparation.

instrument breakage during use. The curve can be made with a surgical needle holder or hemostat (Fig. 16-40). To minimize instrument breakage, care should be taken to avoid a sharp angle bend, and the ultrasonic device should be kept on a lower setting, which will vary depending on the unit (Fig. 16-41).

The completed preparation should be sufficiently large to permit compaction of the root-end filling material (Fig. 16-42). Contemporarily, the most commonly used root-end material may be mineral trioxide aggregate (MTA), but intermediate restorative material (IRM) is also favored by many clinicians. In randomized, prospective clinical studies, both
materials have shown equivalent healing responses over time as evaluated radiographically.6,35

Both materials can be carried to the apical preparation in a number of ways. There are commercially available miniature carriers of various designs originally designed for amalgam (retrofill amalgam carrier [Miltex, York, PA, USA]) or newly developed systems (MAP system [Roydent Dental Products, Johnson City, TN, USA]; Dovgan MTA carriers [Quality Aspirators, Duncanville, TX, USA]) (Fig. 16-43). A more recent approach is the formation of small columns of MTA in a block which are carried to the preparation on a half Hollenbeck carver (Lee MTA Forming Block [G. Hartzell & Son, Concord, CA, USA])33 (Fig. 16-44). The material is then compacted with small pluggers available commercially or can be handmade from dental instruments such as endodontic or operative dentistry explorers (Fig. 16-45). Following compaction, the excess is removed with slightly moistened cotton pellets (Fig. 16-46).

**FIGURE 16-43** A, Syringe-type carrier for the placement of mineral trioxide aggregate (MTA) at the apex (MAP system). B, Amalgam miniature carrier used for placement of MTA.

**FIGURE 16-44** Lee MTA Block for the formation of small columns of mineral trioxide aggregate. The material is carried to the apical preparation with a half Hollenbeck carver.

**FIGURE 16-45** Compaction of filling material with miniature pluggers. Pluggers are available commercially or custom made from endodontic explorers, periodontal probes, or other restorative hand instruments that can be fashioned into a plugger-shaped instrument.
For larger lesions in the maxilla, palatal anesthesia should always be administered. It is also occasionally necessary to supplement the local anesthesia with direct infiltration of the tissue lining the apical lesion.

**Surgical Access and Manipulative Techniques: In Vivo Directives**

**Surgical Anatomy**

In both the maxillary and the mandibular arches, there are no anatomic complications to routine surgery on any of the six anterior teeth. There are no major blood vessels, nerve canals, sinus cavities, or excessively thick bone structures, with the possible exception of the anterior nasal spine. In some cases, surgical access to the apex may be restricted by a very shallow vestibule or unusually long roots, in particular with both mandibular and maxillary canines. Excessive anterior protrusion of the tooth will angle the apex deeper into the alveolus, making the canal less accessible as well.

**Soft-Tissue Considerations: Flap Design**

There are four tissue-flap designs suitable for anterior apical surgery. The most convenient to elevate and close is the triangular flap, which consists of one vertical incision and an intrasulcular incision (Fig. 16-47). The vertical incision is usually placed at least one tooth width mesial to the tooth being operated and should include the papilla. The sulcular, or horizontal, incision usually extends at least one tooth width distal to the operated tooth. This design will provide adequate exposure of the apical area in almost all cases. If insufficient exposure is obtained with one vertical incision, a second vertical incision can be made at the distal end of the flap, creating a rectangular flap (Fig. 16-48). Again, the papilla should be included, and the incisions should be angled to make the base of the flap wider than the margin. This is to ensure a generous vascular supply to the flap.

A third type of tissue flap design is the submarginal flap. This tissue flap has been suggested to prevent recession of the papilla.
consists of two releasing vertical incisions connected by the papilla-base incision and intrasulcular incision in the cervical area of the tooth. A microsurgical blade should be used that does not exceed 2.5 mm in width, because intricate, minute movement of the surgical blade within the small dimensions of the interproximal space is crucial.

Two different incisions are made at the base of the papilla. A first shallow incision severs the epithelium and connective tissue to the depth of 1.5 mm from the surface of the gingiva. The path is a curved line connecting one side of the papilla to the other. The incision begins and ends perpendicular to the gingival margin. In the second step, the scalpel retraces the base of the previously created incision while inclined vertically towards the crestal bone margin. The second incision results in a split-thickness flap in the apical third of the base of the papilla. From this point on, moving apically, a full-thickness mucoperiosteal flap is elevated. While the papilla-base flap can result in predictable healing results, this technique is challenging to perform and is not recommended for the neophyte. However, knowledge of this approach is especially helpful in treatment planning surgery in the presence of soft-tissue or esthetic concerns in the anterior portion.
of the mouth. When considered, cases can then be referred to someone more experienced in using this surgical approach.

Atraumatic handling of the soft tissues with the papilla-base flap is of utmost importance in order to obtain rapid healing through primary intention. The epithelium of the partial thickness flap has to be supported by underlying connective tissue; otherwise, it will necrose and lead to scar formation. On the other hand, excessive thickness of the connective-tissue layer of the split flap portion could compromise the survival of the buccal papilla left in place.

Incisions are always made firmly to bone so the periosteum can be elevated with the flap and to prevent the tearing of the tissue. Sharp periosteal elevators will ensure a uniform exposure of the alveolar bone (Fig. 16-50). The vertical and horizontal incisions can always be extended if the tissue cannot be elevated or is not relaxed over the intended apical portion of the surgical site.

Curettage and Enucleation of the Soft-Tissue Lesion When the Lesion Penetrates the Bone

Frequently the apical lesion will have perforated the labial plate of bone. The lesion will be plainly visible after the tissue is retracted. If there is a draining sinus tract, a portion of the lesion will be attached to the inferior surface of the tissue flap and will require extra care in tissue elevation and retraction. In these cases, it is wise to identify the circumferential margin of the lesion on bone before attempting to separate all of the attachment between the lesion and the flap. Once the margins have been located, the soft tissues may be cut carefully with a scalpel. This approach will avoid cutting the tissue so as to perforate it or make it excessively thin. The tissue within the apical lesion may then be curetted to expose the apex of the tooth.

Root Apex Exposure in the Absence of a Periapical Lesion

If there is no visual sign of the soft-tissue lesion after retraction of the flap, which routinely occurs in cases of small apical lesions, the buccal plate must be penetrated to gain access to the lesion. Initially, the bone should be probed, looking for a possible defect or an area in which the bone has been thinned out over the root. Subsequently, the bone is removed using a surgical-length round bur with a shaving action under copious irrigation (Fig. 16-51). Periodically explore the bone with a periodontal curette or an explorer as the opening in the buccal plate is being made. The walls of the lesion and the tooth itself can be palpated, and the opening can be reoriented so it is centered over the apex. Ideally, for purposes of healing, keeping the opening of the bony window to a minimum in a mesial-distal dimension is recommended. If the patient has any painful sensation when this exploration is performed, anesthetics should be injected into the tissue of the lesion at this time. The tissue within the apical lesion may then be curetted free from the bone, exposing the root apex (Fig. 16-52).

CLINICAL PROBLEM

Problem: A 49-year-old patient presented with acute sensitivity over the apex of the maxillary right central incisor. The periapical film indicated that previous root canal treatment was performed with an apparently overextended intraradicular post, leaving barely 1 mm of gutta-percha root filling material (Fig. 16-53, A). Only a small radiolucency was present on the x-ray, but palpation over the apex indicated a distinct localized swelling. How could an acute lesion develop with minimal radiographic evidence of pathosis?

Solution: Periapical surgery was indicated. After elevation of a submarginal flap, it was apparent that the apex was anatomically superficial relative to the labial plate. In this case, the infection and associated swelling that extended easily into the overlying soft tissues did not cause sufficient bone loss to create a radiographic lesion (see Fig. 16-53, B).
Root-End Resection and Identifying the Root Canal Space

Once the apex is exposed, the apical bevel is prepared so that the canal is plainly visible, centered in the beveled surface as was described previously (Fig. 16-54, A). Because 98% of apical canal anomalies and 93% of lateral canals exist in the apical 3 mm, it is important to resect at least 3 mm of the root end. An ideal bevel would be close to perpendicular to the long axis of the root, but often various angles of resection must be used for both visual and surgical access without sacrificing tooth structure. If the bevel is too great, there is a spatial disorientation that is difficult to overcome, and the root-end preparation and filling may fall short of ideal. When considering the angle of the bevel, each and every case will be different. For anterior teeth, the smallest bevel possible should be considered. For posterior teeth, the considerations change significantly because of the root anatomy. Once the root end has been resected, it should be carefully examined for cracks or fractures as well as extensions and irregularities such as isthmuses, anastomoses, and the like. These anatomic variations will then dictate the procedures to follow, such as a further extension of the resection or extension of the root-end cavity.

Root-End Cavity Preparation

The apical portion of the root canal is prepared with the ultrasonic instrument as described in vitro (see Fig. 16-54, B). Miniature surgical mirrors can enhance visualization of the canal preparation and insure the cleaning of all areas of the preparation wall (see Fig. 16-54, C). In preparation for the placement of the root-end filling, dry cotton balls may be placed into the bony cavity surrounding the apex to prevent scatter of any excess filling material (see Fig. 16-54, D and E). If there is bleeding emanating from within the bony walls following curettement, cotton pellets impregnated with racemic epinephrine can be substituted (Racellet [Pascal Co., Bellevue, WA]; or cotton pellets with Vicostat [Ultradent Inc., South Jordan, Utah, USA]) (see Fig. 16-54, F). Other hemostatic products based primarily on collagen have also been recommended (e.g., Colla-Cote [Integra LifeSciences Corp., Plainsboro, NJ, USA]). These can even have drops of 2.25% racemic epinephrine (Nephron Pharmaceutical Corp., Orlando, FL, USA) added to enhance hemostasis.

FIGURE 16-52 Apex exposure after bone removal with the round bur and curettage of the tissue within the lesion. Note the interruption of the crestal bone from the sulcular drainage tract. It is important to inspect the area for a vertical root fracture. In this case, no fracture is present. To ensure postoperative reattachment, it is vitally important to avoid curettage of the root surface in this area.

FIGURE 16-53 A, Radiograph of the maxillary right central incisor with minimal evidence of periapical pathosis. Clinically, there was an acute local swelling. B, Elevation of the tissue indicates that the apex is located superficially relative to the labial plate of bone. The infection involved the overlying periosteum and mucosal tissues.
Figure 16-54  A, Surgical exposure of the apex in a routine periapical surgery. Note the black stain around the gutta-percha, indicating leakage. B, Ultrasonic preparation. C, Miniature mirrors for surgery. D, Placement of cotton around the prepared apex. E, Apex ready for placement of a root-end filling. F, Epinephrine-impregnated (1:1000) cotton pellets can be placed if bleeding continues in the bony crypt around the root end.
In a rare occurrence, a vertical root fracture may be discovered in the apical portion of the root, moving in a coronal direction. If the fracture line does not extend through the attachment, it can be prepared with a half-round (0.5 mm) bur and filled with MTA as a part of the root-end filling (Fig. 16-55).

**CLINICAL PROBLEM**

**Problem:** A 37-year-old male presented with a moderate, localized swelling over the root apex of the maxillary left central incisor. The tissues were tender to palpation, and the tooth was tender to percussion. The tooth had a post core and crown and very poor root canal filling that appeared to be of a paste nature. There was a large apical radiolucency (Fig. 16-56, A). Based on the data available and the clinical circumstances, periapical surgery was treatment planned.

**Solution:** Once the tissue was reflected and the soft tissue curetted, a small portion of the root was resected at almost 90 degrees to the long axis of the root. This was followed by cleaning the canal down to the extent of the post with a K-file attached to the ultrasonic handpiece (see Fig. 16-56, B). Subsequently the canal was filled with MTA (see Fig. 16-56, C).

**Root-End Fillings: Materials and Placement**

MTA is the current material of choice for the root-end filling, although IRM has also shown favorable results. In its present formulation, MTA is a difficult material to manage, but for apical applications, it is often effective to leave the canal wet and place the material in a relatively dry mix. As the material becomes hydrated during compaction, excess moisture can be absorbed with additional dry cotton pellets. After the material completely fills the cavity preparation, the apical bevel is wiped with a dry or lightly moistened cotton pellet to remove any excess (Fig. 16-57). This procedure is quite easy with IRM.

If MTA is mixed wet on a slab, avoid compaction and tease or lightly pat the material into the cavity preparation. This is followed by placing the compactor in contact with the MTA in the preparation and gently touching the nonworking end of the instrument with an activated ultrasonic tip. The material will flow into the preparation as the trapped air is released. This is referred to as ultrasonic densification.

The cotton pellets surrounding the apex should then be removed along with any excess material. A careful accounting of the pellets should be done. Leaving a cotton pellet in the lesion will result in an acute foreign body reaction.

![Figure 16-55](image_url)

**Figure 16-55** A, Exposure of a root apex that exhibits a small vertical fracture line extending coronally on the labial. B, Preparation of the apical canal space and the crack line. The apex canal was prepared in the usual manner with an endodontic file. The crack line was enlarged with a half-round (0.5 mm) bur. C, Mineral trioxide aggregate filling the apex and fracture line.
**Tissue Repositioning and Stabilization**

Prior to wound closure, the surgical site should be irrigated with saline solution to remove debris, and the tissue edges are approximated in their correct position to promote healing by primary intention. Compressing the repositioned tissue with a saline-moistened piece of gauze will reduce the coagulum to a thin fibrin layer between the repositioned tissue and cortical bone (Fig. 16-58). This will enhance tissue healing.

**FIGURE 16-56** A, Maxillary central incisor with a radiolucency around the root apex. An intraradicular post is present, root canal treatment is incomplete, and patient is symptomatic. Treatment done in Cambodia 20 years previously. B, After tissue reflection, apical curettage, and root-end resection, the root canal is cleaned and prepared to the level of the post. When soft tissue was removed, there were clumps of yellowish material mixed in with the granulomatous tissue. C, Canal filled with mineral trioxide aggregate. Biopsy of lesion identified as granuloma with islands of actinomycoses dispersed throughout.

**FIGURE 16-57** Apex of a routine surgical case filled with gray mineral trioxide aggregate.

**FIGURE 16-58** A, Compression of the repositioned tissue with a moist gauze for 3 to 5 minutes before suturing. B, Note the minimized coagulum (C) adjacent to the bone (B) following good tissue compression; repositioned tissue (T). This minimizes swelling while enhancing early tissue healing.
stabilization and reduce bleeding and swelling. The tissue is now stabilized with monofilament sutures, which are the best to eliminate wicking of bacteria and their byproducts into the wound site. Smaller-gauge sutures, 4-0 and 5-0, are indicated because sutures are tissue irritants, and the smallest possible size for adequate wound support is preferred. In papilla-base incisions, sutures as small as 6-0 and 7-0 are indicated. Likewise, nonresorbable sutures are recommended, since the tissue irritation terminates as soon as the sutures are removed. Suture removal can take place as early as 48 hours but not later than 4 to 5 days. For a triangular flap design, a sling-type suture will secure the papillae, and a single simple suture will often close the vertical incision. For a submarginal type of flap, a continuous mattress suture is efficient, but interrupted simple sutures will function just as well. If the suture material is resorbable, a return visit for suture removal can be eliminated.

**Postsurgical Care and Potential Complications**

Postoperatively, swelling can be reduced by immediate application of an ice pack, which should be used for the rest of the day of operation. The typical pattern of ice application is 20 minutes in place alternating with a 20-minute interval of rest. This is followed by the use of moist heat the day following the surgical procedure.

It is wise to have the patient take an analgesic prior to the surgical procedure or at least while the area is still anesthetized. A highly effective analgesic without the effects of a narcotic is 600 mg ibuprofen plus 1000 mg of acetaminophen. These over-the-counter medications are not only readily available but are frequently already possessed by the patient. If not taken prior to surgery, an effective regimen can be eliminated because sutures are tissue irritants, and the smallest possible size for adequate wound support is preferred. In papilla-base incisions, sutures as small as 6-0 and 7-0 are indicated. Likewise, nonresorbable sutures are recommended, since the tissue irritation terminates as soon as the sutures are removed. Suture removal can take place as early as 48 hours but not later than 4 to 5 days. For a triangular flap design, a sling-type suture will secure the papillae, and a single simple suture will often close the vertical incision. For a submarginal type of flap, a continuous mattress suture is efficient, but interrupted simple sutures will function just as well. If the suture material is resorbable, a return visit for suture removal can be eliminated.

**Complications**

Fortunately there are few complications to apical surgery. The most common is postoperative infection under the tissue flap. Infection is characterized by local swelling and increasing pain, typically developing 2 to 3 days after the procedure. A prescription for amoxicillin 500 mg to be taken 4 times daily will usually resolve the infection. There is no alteration of outcome or prognosis with this approach.

Occasionally the margin of the flap may necrose and slough. No treatment is required. The outcome of eventual healing may be root or crown margin exposure, for which there are few simple options as remedies. The most effective would be orthodontic extrusion and replacement of the crown.

**REFERENCES**


RECOMMENDED ADDITIONAL READING
Problem Solving in the Management of Teeth With Subgingival Carious and Fractured Margins Including Radicular Defects

Problem-Solving List

Problem-solving issues and challenges in managing compromises in sound tooth margins and radicular defects addressed in this chapter are:

- Normal Periodontium in Relation to Surgical Treatment Planning
- Indications for Crown Lengthening
  - Convenience of tooth isolation
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- Application of Crown Lengthening Techniques to Other Endodontic Problems
  - Iatrogenic perforations in the marginal periodontium
  - Resorption defects in the marginal periodontium
  - Vertical root fracture repair

― Once the biologic width of the supporting periodontal attachment apparatus has been severely violated, more extensive procedures are often necessary to manage compromised root structure and supporting bone.20

J.L. Gutmann, 1991

Preserving the natural dentition in symptom-free clinical function is a major goal of dentistry and its specific disciplines. Prosthetic dentistry has provided fixed and removable substitutes for teeth that have been lost, and the advent of implant dentistry has brought about a new concept, replacement of the natural dentition. While the development of implantology has been a marvelous addition to the practice of dentistry and has enhanced patient well-being,9,35,42 the enthusiasm for this option has in some cases clouded the process of sound treatment planning.8,43 However, many teeth that could be preserved in normal function through reasonable and adjunctive procedures (nonsurgical endodontic revision, surgical endodontic revision, crown lengthening, orthodontic root extrusion, root resection, etc.) are removed in favor of replacement with implants. Data do not support the superiority of implants over these other procedures when treatment planned and executed properly.24,25 In many respects, implant dentistry is not an option for a great many people, and tooth retention is not only possible but in the patient’s best interest and the best choice.

In this chapter, surgical procedures will be presented that can be used effectively to retain teeth with a variety of complications in addition to pulpal disease. The most common problems encountered are clinical crowns with subgingival
carious or fractured margins and insufficient tooth structure to retain a restoration. In many of these cases, crown lengthening is an ideal solution. Exposure of sound tooth structure can make restoring certain types of compromised teeth a routine procedure, enhancing not only the restoration of the tooth but the biologic widths of the supporting periodontium. The basic techniques of this surgical intervention can be extended to the management of other endodontic problems such as resorption and perforation defects.

A discussion of average sulcus depth was included at the beginning of Chapter 4. The essential anatomic relationships between the tooth, bone, and soft tissues of the average healthy periodontal sulcus are depicted in Fig. 17-1. These dimensions have been described as the biologic width,* defined as the physiologic dimension of the junctional epithelium and connective tissue attachment.16,33

The width of the attached gingiva varies from 1 to 9 mm,6 with an average of 3.7 mm in the anterior areas, 3.8 mm in the premolar regions, and 4.2 mm in the molar37 (Fig. 17-2). However, at least 5 mm of attached gingiva are recommended for restorative dentistry.32 Ideally, areas of attached gingiva with less than 5 mm should be considered for augmentation procedures if restorative margins are to be placed in the sulcus.4 The healthy gingival sulcus has been shown to have an average depth of 0.69 mm.33

Normal Periodontium in Relation to Surgical Treatment Planning

Prior to considering periodontal surgical procedures, a review of the normal anatomy of these tissues is essential.

FIGURE 17-1 A, Normal periodontium. B, Histologic section through normal periodontium (H&E stain ×10).

FIGURE 17-2 A, Attached gingiva of normal, ample width. B, Width of attached gingiva in this maxillary right premolar area is 1 mm or less.
The contours of the normal alveolar bone are also of great significance. Most often, surgical crown lengthening cannot be achieved without removing some crestal bone. Postoperatively, the measure of success is not only increased clinical crown length but also restoration of a normal periodontium circumferentially. In recontouring bone, the clinician should reproduce or create the contours of normal periodontium. Except in the mandibular second and third molar areas, the buccal and lingual plates are usually fairly thin throughout the dentition (Fig. 17-3). If the buccal plate appears excessively thick with a shelllike contour, it can be reduced (Fig. 17-4). Occasionally, a dehiscence or fenestration will be found after the flap is elevated (Fig. 17-5). The only significance of this finding is that the exposed areas of the root should be left untouched. Reattachment will invariably occur, providing that these root surfaces are not curetted.

**CLINICAL PROBLEM**

**Problem:** Can the interproximal bone throughout the mouth be recontoured using a standardized technique?

**Solution:** No, because there is a significant difference between the interproximal contours of the bone between the posterior teeth and the contours found between the anterior teeth. The normal contour between posterior teeth is flat buccolingually (Fig. 17-6). Crown lengthening will require an apical relocation of the bone while maintaining the identical form. Frequently, bony defects from chronic periodontitis are found interproximally, leaving intact ridges of the buccal and lingual or palatal plates. These ridges are normally reduced to restore as flat a buccal lingual contour as possible (Fig. 17-7). Conversely, in the anterior dentition, there is an interproximal crest (Fig. 17-8). In crown lengthening, the reproduction of these contours is necessary for optimal periodontal healing and also esthetics (Fig. 17-9). The interdental papillae are supported and shaped by the underlying bone. If the supporting bone is either lost by periodontal disease or failure to recreate the proper contour during surgery, the papilla will collapse (Fig. 17-10).

**FIGURE 17-3** A, Labial plate of bone is normally thin. B, Cross-section of maxilla in the first molar area, showing buccal and palatal plates of bone.

**FIGURE 17-4** A, Excessive width of buccal plate of bone. B, Recontoured buccal plate during periapical surgery procedure.
**Figure 17-5** Dehiscence of root surfaces after flap elevation. These areas should not be curetted.

**Figure 17-6** Normal interproximal anatomy of bone is flat in posterior dentition.

**Figure 17-8** Normal interproximal anatomy of bone in the anterior dentition is characterized as a crest.

**Figure 17-9 A,** Crown lengthening on fractured maxillary central incisors. **B,** Restoration of interproximal bony crests which will support the papillae.

**Figure 17-7 A,** Periodontal surgery for severe chronic periodontitis. **B,** Following osseous recontouring and pocket elimination. Note ramping of buccal plate into interproximal spaces. (Courtesy Dr. Curtis Wade.)

**Figure 17-10** Loss of the interproximal crest of bone results in collapse of the interdental papilla and an unesthetic “black triangle.”
Indications for Crown Lengthening

There are multiple considerations in which crown lengthening can and should be considered in the treatment planning for tooth retention.

Convenience of Tooth Isolation

Before arriving at crown lengthening as the treatment of choice, a discussion of common alternatives is indicated. Most teeth with significant carious lesions can be isolated without crown lengthening. One simple solution is to place the dental dam clamp directly on the gingiva and complete the root canal treatment (Fig. 17-11). The difficulty of this approach is that it merely postpones the problem of treatment planning the final restoration. A second method of isolation is caulking the gaps around the dental dam with temporary filling materials or a specialized putty (Fig. 17-12). Once again, root canal treatment can usually be completed without leakage, but the restorability issues remain. Temporary filling materials can be used to seal large excavations within the tooth as well (Fig. 17-13). Unless the caries is thoroughly removed and a high quality restoration is placed, leakage can be a problem, especially if the root canal treatment requires multiple visits. Leakage between appointments is a very common cause of reinfection.

Many clinicians favor complete restoration of the endodontically involved tooth. Access is then made through the new restoration (Fig. 17-14), which helps prevent leakage. After the root canal treatment is completed, however, the restoration often does not provide sufficient structural integrity to support a full crown.\textsuperscript{30,31} Crown lengthening satisfies all the endodontic and restorative needs. Isolation is excellent, while access and visibility are unimpeded. Issues of restorability can be determined early, and the final restoration can take advantage of the treated canals for retention if necessary (Fig. 17-15).

Establishing Increased Clinical Crown for the “Ferrule Effect”

This key restorative goal is discussed in detail in Chapter 20. Full crown restorations require retention on sound tooth structure as well as any restorative foundation that is

\textbf{FIGURE 17-11} Placing dental dam clamp directly on gingival margin does not address subgingival caries or restorability following root canal treatment.

\textbf{FIGURE 17-12} Dental dam sealers are effective, but restorability of the deep fracture in this case remains a problem.

\textbf{FIGURE 17-13} Temporary restorations often leak.

\textbf{FIGURE 17-14} Complete permanent restorations are effective in achieving tooth isolation. The access cavity could weaken the structural support if this restoration were included in a crown preparation.
Problem Solving in the Management of Teeth With Subgingival Carious and Fractured Margins

FIGURE 17-15  A, Mandibular molar with severe caries extending subgingivally on the distal. B, Clinical view of same tooth. Restorability appears to be questionable. C, Following crown lengthening; restorability is confirmed and isolation for root canal treatment is excellent.

FIGURE 17-16 Lack of “ferrule effect” in previous crown preparation led to post fracture.

Preventing Restorative Failure

Lack of a ferrule also can focus excessive occlusal forces on the post and core and eventually cause the post to loosen or fracture. This also provides an additional barrier to marginal leakage that may adversely affect the prognosis of the root canal treatment (see Fig. 17-15, C).

Avoiding Marginal Problems With Restorations

Excavation of caries below the free gingival margin or a fracture requires subgingival margin placement, or impressions and restorations will be faulty (Fig. 17-17). Exposure of all margins will ensure the chance for an excellent restorative result.

Managing Deep Fractures

Many deep subgingival fractures cannot be restored adequately, and over time the tooth may develop periodontal complications. Crown lengthening addresses such

constructed. This also provides an additional barrier to marginal leakage that may adversely affect the prognosis of the root canal treatment (see Fig. 17-15, C).

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FIGURE 17-17 Failure to include entire tooth circumference in crown preparation, owing to lack of visibility of mesial aspect of tooth. Marginal leakage is also a result. Crown lengthening might have been the means to avoid this outcome.

FIGURE 17-18 A, Fractured palatal cusp on a maxillary first premolar. This would be a restorative challenge and a long-term periodontal liability. B, After crown lengthening, the periodontium is in a normal relationship, and the restoration will be routine.

FIGURE 17-19 A, A fractured maxillary lateral incisor with a calcified canal and hyperplastic gingiva covering part of the remaining tooth surface. B, Locating the canal is much easier after crown lengthening.

complications prior to restoration, resulting in a routine procedure with an excellent, uncomplicated prognosis (Fig. 17-18).

Location of Obscure Root Canal Orifices

A specific endodontic indication is the case in which a coronal fracture has resulted in hyperplasia of the marginal gingiva, obscuring the location of a canal orifice. Often, if these fractures were present as mere cracks for any length of time, narrowing and calcification of adjacent root canal orifices occurred secondary to long-term bacterial ingress and pulp tissue irritation. After crown lengthening, orientation is greatly improved, enhancing access preparation and canal orifice location (Fig. 17-19).

Following Orthodontic Extrusion of Teeth or Roots

The techniques for orthodontic extrusion are discussed in previous editions of this text and in the orthodontic
literature. The periodontal consequence of extrusion is coronal movement of the attachment.\(^5\) Crown lengthening will usually be necessary to reposition the gingival margin apically for both restorative and esthetic purposes (Fig. 17-20).

**Potential Contraindications for Crown Lengthening**

There are both general and local considerations in which crown lengthening may not be considered in the treatment planning for tooth retention.

**Medical Status**

Generally, the medical status and current medications prescribed for the patient are reviewed for the same conditions that would contraindicate any surgical procedure. The reader is referred to other texts on oral surgery for a discussion of these issues.

**Esthetic Zone**

Loss of a clinical crown through fracture is a common indication for crown lengthening. In the esthetic zone, however, apical repositioning of the gingival margin may be unacceptable esthetically,\(^3\) particularly in a patient with a prominent “gingival smile.” Even though the restorative results may be technically excellent, the crown may be unacceptably long (Fig. 17-21).

**Minimal Vertical Dimension of the Root Trunk**

On molar teeth, the *root trunk* is defined as the distance from the furcation to the level of crestal bone. If the trunk distance is less than 4 mm, crown lengthening cannot establish the 4 mm of tooth exposure without extending past and into the furcation\(^1\) (Fig. 17-22).

**Surgical Techniques for Crown Lengthening**

Surgical crown lengthening does not require an extensive list of instruments or supplies. Generally the procedure will
include a standard oral surgery setup to incise, elevate, reflect, reposition, and suture tissue. In addition, a set of periodontal curettes, a small chisel, and a series of surgical-length round burs will be sufficient to complete most procedures. If the clinician is already equipped to perform periapical surgery, few additions to the instrument list will be necessary. A suggested instrument list is provided in Table 17-1; all instruments listed have functional substitutes.

**Surgical Procedures**

The objective of the surgical procedure is to place a sound dentinal margin at least 2 mm above the free gingival margin. Since the average sulcular depth of the normal periodontium is greater than 2 mm, the dentin margin will have to be at least 4 mm above the crestal bone. At the very least, in areas with minimal attached gingiva, horizontal surgical incisions should be placed in the sulcus to preserve all available gingival tissue. On the other hand, in areas of attached gingiva that measure over 5 mm, including the entire palate, the surgical plan may include resection of gingival tissue from the margin to effect crown lengthening. Following crown lengthening, biologic width will be restored and stable at 6 months from the date of surgery. At 1 year, the gain in exposed tooth structure has been observed to diminish as gingival tissue appears to rebound. For purposes of discussion, the step-by-step labial or buccal approach will be described in an uncomplicated case with a healthy, normal preoperative periodontium.

**Envelope Tissue Flap**

An envelope flap is the design of choice for crown lengthening, because the keratinized gingival tissues are much easier to elevate, retract, and suture. Postoperatively, the course of healing is more rapid and less uncomfortable than flap designs with a vertical incision into the mucosa.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Suggested Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalpel</td>
<td>Bard-Parker No. 15</td>
</tr>
<tr>
<td>Periosteal elevator</td>
<td>No. 7 Spatula or Woodson No. 1*</td>
</tr>
<tr>
<td>Periosteal retractor</td>
<td>Seldin No. 23 or Minnesota*</td>
</tr>
<tr>
<td>Periodontal curettes</td>
<td>Gracey 1-2, 11-12, 13-15, and 15-16*</td>
</tr>
<tr>
<td>Surgical-length burs</td>
<td>Round (USA) No. 2, 4, 6, 8; ISO 1.0, 1.4, 1.8, and 2.3 mm (Fig. 17-23)</td>
</tr>
<tr>
<td>End-cutting bur</td>
<td>Brasseler (USA) 958C WDEPTh† (Fig. 17-24)</td>
</tr>
<tr>
<td>Chisel</td>
<td>Wedelstadt 1-2‡</td>
</tr>
<tr>
<td>Needle holder</td>
<td>Mayo-Hegar 140 mm, preferably with tungsten carbide†</td>
</tr>
<tr>
<td>Suture</td>
<td>4-0 Resorbable</td>
</tr>
</tbody>
</table>

* Hu-Friedy Co., Chicago, Illinois, USA.
†Brassler USA, Savannah, GA, USA.
‡CK Dental Industries, Orange, CA, USA.
Under appropriate local anesthesia, a reverse-bevel sulcular incision (Fig. 17-25) is made to the crestal bone, beginning in the mesial labial aspect of the tooth immediately anterior to the tooth that requires crown lengthening, continuing through the mesial and distal papillae, and ending distal labial to the tooth immediately posterior. The incision line should be scalloped to recreate the papillary form (Fig. 17-26, A-C). If there is more than 5 mm of attached gingiva, the incision can be placed submarginally so as to leave 5 mm of gingiva. Removal of the excised, marginal tissue will effect crown lengthening in this area. If there is insufficient relaxation for the tissue, a vertical incision is indicated. It should be located anterior to the tooth being treated and should include the papilla (see Fig. 17-26). This often occurs in the canine area where the flap is covering a convex bony anatomy.

If crown lengthening is to be circumferential, the identical tissue incision and reflection would be done on the palatal or lingual aspects. Procedures on the lingual aspect of mandibular teeth are always done with envelope flaps. Since it is very difficult to obtain vertical mobility of a lingual flap, a submarginal incision is indicated to create a more apical flap margin. The palatal soft tissues are completely keratinized, which allows for apical placement of the incision line at any desired level (Fig. 17-27). All tissue excised from the margins of the flap are removed with periodontal curettes.
**Thinning or Undermining the Tissue**

Using the scalpel, a second “undermining” incision to the bone is made parallel to the surface of the gingiva through the papillae to produce a uniform flap thickness of approximately 2 mm (Fig. 17-28). The connective tissue severed from the papilla is continuous with the interproximal tissue (Fig. 17-29). All of this connective tissue is now removed with periodontal curettes. If crown lengthening is limited to either the buccal or lingual, the interproximal tissue must be severed from the papillae on the opposite side prior to curettage.

Undermining of the entire tissue flap is frequently required on palatal surgeries to achieve mobility of the flap margin. The excised connective tissue is then removed with periodontal curettes. Mobility will allow the tissue to be drawn against the tooth during suturing. Often, palatal crown lengthening can be accomplished by soft-tissue reduction alone (Fig. 17-30).

**Recontour of Alveolar Bone**

The tissue is now retracted, and the distance between crestal bone and the tooth margin is measured. A minimum of 4 mm of exposed root structure is required. If the patient
has lost supporting bone due to chronic periodontitis, the entire crown lengthening operation may be completed by repositioning of the soft tissues alone. In most cases, however, the crest of alveolar bone will be less than 4 mm from the margin of the tooth, and osseous recontouring will be necessary.

The No. 6 (1.8 mm) or 8 (2.3 mm) round bur is used to thin the alveolar crest of bone surrounding the tooth. The recontouring should include ramping into interproximal areas and should not leave sharp ridges or grooves (Fig. 17-31). Recalling the normal anatomy of these areas in the anterior region, the interproximal crest form should be preserved or recreated, and in posterior areas, the interproximal contour should be flat buccal lingually. The smaller No. 2 (1 mm) and No. 4 (1.4 mm) round burs are used to reduce bone when more narrow interproximal areas are present. As the tooth surfaces are approached, the bone is made as thin as possible while avoiding contact with the tooth surface. Subsequently, the Wedelstadt chisel (CK Dental Industries, Orange, CA, USA) and periodontal curettes are used to remove the remaining bone up to the root surface at right angles (Fig. 17-32).

The Brasseler end-cutting bur (Brasseler USA, Savannah, GA, USA) may also be of use at this point if the interproximal space is accessible vertically—that is, there is no coronal tooth structure in contact with the adjacent tooth. The advantage of the end-cutting bur is that the interproximal surface of the bone is left in a flat plane, requiring less use of the Wedelstadt chisel, and there are no cutting surfaces on the lateral surface of the bur, which protects the proximal root surfaces from unintended injury.

To assess the sufficiency of bone recontouring, it is useful to release the tissue and allow it to lie passively along the tooth. If it must be forced into the desired position, more bone should be removed. Ultimately, with the tissue flap passively in place, 2 mm or more of tooth structure should be visible above the tissue margin.

**Tissue Closure**

The tissue is now repositioned and stabilized with sutures apical to its original position (Fig. 17-33, A-C), owing principally to the recontouring of the underlying bone. Two simple sutures or a sling suture from the mesial papilla to the distal papilla around the palatal surface of the tooth are usually sufficient to secure the flap. Generally, 4-0 suture material with a small curved needle will be the easiest to manipulate, but any type of suture material can be used. If the suture material is resorbable, an additional appointment for suture removal will not be required. Plain gut and chromic gut resorbable suture materials should be hydrated before use to reduce breakage when the knots are tied. The easiest method is to open the sterilized packet and drop the suture on its cardboard mount into a cup of water before beginning the procedure, but this retains some of the bends in the suture and may not eliminate all the alcohol used as a preservative.
FIGURE 17-32  A, Diagram of proper use of the Wedelstadt chisel to remove the thin bone remaining on root surface. The chisel is shown in a horizontal position elevating the thin remaining bone over the root surface to expose 3 to 4 mm of root surface. B, The chisel is now shown removing bone in the vertical position. C, Photograph of the chisel finishing the crestal bone at right angles to the root surface. This procedure is continued through the interproximal spaces. If necessary, this procedure can extend around the palatal (or lingual) surfaces as well.

FIGURE 17-33  A, Diagram of postoperative result. B, Photograph of completed crown lengthening. C, Cross-sectional diagram of postoperative result, showing desired restoration of biologic width and 2 mm exposure of tooth structure.
Ideally, the suture material should be completely removed from the stint and placed in 100 mL of sterile water, where it will unwind in a jerky, undulating fashion and become hydrated. After 3 or 4 minutes, the suture material will have absorbed the maximum amount of water. Upon removal, the hydrated gut material will be smooth, devoid of residual knots, and pliable, with manipulative properties similar to silk suture.

Periodontal Surgical Dressing

In most cases, a periodontal dressing will not be necessary. The tissue flap should remain passively in its position on the bone. If, however, the suture tends to draw the margin of the flap over the tooth, a periodontal dressing will hold it in the desired position. Occasionally, an oversized temporary crown is useful to contain the pack material (Fig. 17-34). For patient comfort, a dressing might also be considered if the area of surgery includes multiple teeth or there is exposed bone not covered by the flap. The dressing should be left in place for no more than 2 to 3 days, because a bacterial biofilm will gradually form on the inferior surface adjacent to the tissues, impeding the process of healing, although some authors have recommended that it be left on for at least 1 week. Often, with instructions, the pack can be removed by the patient, which eliminates the inconvenience of a return visit.

Healing

The usual healing period after crown lengthening is about 3 to 4 weeks (Fig. 17-35). This may vary from patient to patient and is dependent on the quality of dental hygiene during the healing phase. The accumulation of plaque promotes inflammation and delays healing. This can be a problem if the patient is reluctant to disturb the area because it is sore and apt to bleed with normal brushing. Nevertheless, light brushing should be encouraged; softening the bristles of the toothbrush in hot water may lessen trauma on newly healing tissues. Alternatively, a cotton-tipped applicator with 3% hydrogen peroxide or 0.12% chlorhexidine 2 or 3 times a day can be recommended. Most often, within 7 days the area can be brushed as normal.

CLINICAL PROBLEM

Problem: A 36-year-old male was referred for extraction of the mandibular second premolar. The treatment plan was to then construct a fixed partial denture from the first premolar to the first molar. The second premolar had carious margins below the free gingival margin (Fig. 17-36, A). The patient preferred to retain and restore the premolar if possible.

Solution: Crown lengthening was proposed as a possible solution for the problem of restorability. Assessing the depth of caries was difficult preoperatively, so the patient agreed that surgical crown lengthening would be the treatment of choice. The option of extraction remained if the caries proved to be too deep. In such cases, removal of excessive alveolar bone would compromise the periodontal support for the adjacent teeth.

A reverse-bevel, mucoperiosteal flap with an anterior vertical releasing incision was reflected from the distal of the canine to the distal of the first molar on the buccal. On the lingual, an envelope flap was elevated. Using a high-speed No. 6 (1.8 mm) round bur, the bone was carefully removed and contoured to expose sufficient tooth structure on both the buccal and lingual surfaces. Interproximally, a No. 2 (1.0 mm) round bur was used to apically reposition the crest of the interproximal bone. The Wedelstadt chisel was used to remove the remaining interproximal bone on the root surfaces. At the same time, the new osseous contours were blended with contours of the bone around the adjacent teeth. The root canal treatment can be completed at any time, including immediately following the surgery while anesthesia is in effect. Four weeks later there was excellent postoperative healing with supragingival exposure of 2 mm of sound tooth structure (see Fig. 17-36, B and C). The tooth is ready for the completion of restorative treatment with a post, core buildup, and crown.

FIGURE 17-34  A periodontal dressing retained by an oversized temporary crown.

FIGURE 17-35  Three-week postoperative reevaluation.
The mucosal extensions of vertical incisions will heal slower than incisions in the keratinized tissues. While the soreness of these mucosal areas is a common postoperative complaint, there is usually no treatment indicated, and ultimately the wound will heal normally. This occurrence is another argument for use of the envelope flap design as much as possible.

Complications With Surgical Crown Lengthening

There are few complications to crown lengthening, and some problems are only complications as treatment planning concerns. These issues should be discussed with the patient before treatment is initiated. For example, an adjacent third

**FIGURE 17-36** A, Severely carious mandibular right premolar. B, Four-week reevaluation after crown lengthening indicating complete healing. C, Lingual view of the healed tissue.

**FIGURE 17-37** A, The distal caries on the second molar would be difficult to expose with crown lengthening alone. B, Removal of the third molar greatly improves the crown lengthening result.
molar is occasionally an impediment to adequate crown lengthening exposure. Extraction of the third molar should be considered as a part of the crown lengthening procedure (Fig. 17-37). In the same way, the restorability of some teeth may be difficult to assess preoperatively. If during the procedure, the tooth appears unrestorable, extraction would be indicated (Fig. 17-38).

Generally, patients will not have significant discomfort following the procedure unless a great deal of bone contouring was necessary. Mandibular posterior surgeries tend to cause more discomfort than other areas. The most common postoperative complication is the formation of granulation tissue during the immediate postoperative healing period. This tissue is very tender to touch and bleeds easily; patients are reluctant to brush, which promotes further granulation tissue formation. This will sometimes occur if a temporary restoration is placed and makes postoperative hygiene more difficult (Fig. 17-39). Granulation tissue is easily removed under anesthesia with a periodontal curette. If the restoration appears to be a contributing factor, it should be reshaped or removed for the remainder of the healing phase.

A second complication is sloughing of the tissue margins. One contributing factor is making the flap too thin with the undermining incision. The flap margin should be no thinner than 2 mm. A more serious contributing factor is smoking. Heavy smoking has a very detrimental effect on healing of oral tissues. There is no treatment other than palliative. It will gradually heal, but it may be a slow and painful
Crown lengthening techniques will be of use in managing perforations that have occurred at the level of the marginal periodontium and have resulted in a periodontal lesion. Often the chief complaint is chronic gingival soreness. Inflammation related to the defect in the root and the physical damage to the tissues will result in a periodontal defect that can be probed. Typically these perforations result from misdirected high-speed burs during endodontic access or during preparation for an endodontic post.

**Application of Crown Lengthening Techniques to Other Endodontic Problems**

**Iatrogenic Perforation in the Marginal Periodontium**

Iatrogenic perforations are found at every level of the root. Radiographic interpretation and diagnosis of lesions associated with perforations were discussed in Chapters 3 and 4. This section will focus on treatment approaches for those that occur in the marginal periodontium. Perforations can occur during a search for a calcified canal or in the attempt to penetrate one to the apex. As discussed in Chapter 8, most perforations that occur in this way are small. If it is fresh and the pulp chamber did not contain necrotic tissue, it will be uninfected, and the healing response will be good.\(^4\) Immediate internal repair with MTA (mineral trioxide aggregate; Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is the treatment of choice.\(^7\) The repair of very small perforations is likely to be successful whether they are above the attachment or below.

Perforations that occur well below the level of periodontal attachment, such as stripping perforations or lateral perforations from misdirected post preparations, are generally larger, more irregular, and difficult to repair internally. In these cases, the prognosis may be questionable.\(^6\) It is still worthwhile to attempt an internal repair with MTA if the perforation has just occurred. Chapter 18 will discuss surgical repair of perforation defects that are located well below the level of the gingival attachment and have caused lateral lesions to develop in the periodontium. A distinction should be made between perforations located well below the level of the attachment and those exposed to the oral environment. Perforations that occur in the marginal periodontium are rarely treatable nonsurgically (see Chapter 8 for discussion of these perforations).

Crown lengthening techniques will be of use in managing perforations that have occurred at the level of the marginal periodontium and have resulted in a periodontal lesion. Often the chief complaint is chronic gingival soreness. Inflammation related to the defect in the root and the physical damage to the tissues will result in a periodontal defect that can be probed. Typically these perforations result from misdirected high-speed burs during endodontic access or during preparation for an endodontic post.

**CLINICAL PROBLEM**

**Problem:** A 39-year-old patient presented with a perforation that was made during access for root canal treatment in a mandibular second molar (Fig. 17-41, A). Note the two sections of a lentulo spiral that are embedded in the adjacent periodontal tissues. The chief complaint of the patient was chronic soreness of the gingival papilla between the first and second molars (see Fig. 17-41, B). Probing indicated periodontal bone loss only in the area adjacent to the perforation site.

**Solution:** Surgery was performed only in the mesial papilla area, not circumferentially. An envelope flap was elevated in the same manner as for crown lengthening. The lentulo spiral fragments were removed, and the bone was recontoured so the tissue could be repositioned apically. The biologic width was restored below the perforation site (see Fig. 17-41, C). Healing was uneventful, and the root canal treatment was revised.

In the preoperative evaluation of perforation defects, periodontal probings will give an accurate assessment of the potential for successful pocket elimination. There is virtually no potential for regaining normal attachment over a periodontal pocket caused by a perforation. The basic approach of surgical crown lengthening is pocket elimination. If the pocket is too deep for successful elimination, extraction should be considered (Fig. 17-42).
**FIGURE 17-41** A, Radiograph of a mandibular second molar with a repaired perforation to the mesial buccal. Note the two segments of lentulo spirals which are external to the root canal system. B, Clinical view of one segment of the lentulo spiral protruding into the gingival attachment (arrow). C, With flap reflected. The lentulo spiral segments are removed, and crestal bone is recontoured as with crown lengthening to restore biologic width.

**FIGURE 17-42** A, Radiograph of a maxillary second premolar with a deep periodontal defect on the mesial secondary to an access perforation. B, Surgical exposure of the osseous defect. The probe indicates a depth of 6 mm from crestal bone level. Extraction is indicated.
CLINICAL PROBLEM

Problem: A 48-year-old patient presented with a perforation in the marginal periodontium (Fig. 17-43). The chief complaint was chronic gingival soreness for at least 7 years (see Fig. 17-43, A). The defect could be felt with an explorer in the sulcus. The periapical radiograph indicated the perforation undoubtedly occurred in an unsuccessful attempt to locate an obscure or calcified canal (see Fig. 17-43, B).

Solution: The area was exposed with a typical envelope flap, revealing a large perforation on the midlabial surface of the root, with approximately 2 mm of crestal bone loss (see Fig. 17-43, C). The defect was repaired with routine restorative techniques and composite filling material (see Fig. 17-43, D). The tissue was repositioned to the preoperative level, but inevitably 1 to 2 mm of recession will occur (see Fig. 17-43, E). The patient was advised and was not concerned. No attempt was made to locate the canal; the apex was well healed from the apical surgery performed at the time of the original attempt at nonsurgical root canal treatment failed.

In the esthetic zone, a 1- or 2-mm loss of crestal bone will usually not pose an esthetic postoperative problem.

Deeper lesions as a result of a perforation ultimately turn into periodontal pockets. Pocket reduction or elimination may resolve the periodontal lesion but leave an unacceptable esthetic result. Repositioning the tissue flap apically would leave margins exposed (Fig. 17-44) or require an unacceptably long coronal anatomy (see Fig. 17-21). One solution to this problem may involve orthodontic extrusion. Extrusion could level the attachment and elevate the repair to a point where it can be covered by a crown margin (Fig. 17-45). Crown lengthening will still be necessary.

Fig. 17-46, A illustrates a second case in which the nonsurgical repair of a furcation perforation has failed. Since the attachment was lost and there was a bony defect in the furcation already, the result of any treatment will be a compromise to the periodontium. Nevertheless, the prognosis was fairly good, and such a compromise is common in the long-term maintenance of periodontally involved teeth. Under local anesthetic, an envelope tissue flap was elevated.
and granulomatous tissue was curetted from the furcation area (see Fig. 17-46, B). Using the same techniques as in crown lengthening, the bone was reduced in the interproximal areas to the level found in the furcation. The bone in the furcation was recontoured inferiorly (see Fig. 17-46, C). Finally, the furcation itself was enlarged superiorly and laterally to facilitate oral hygiene. A 6-month recall indicated excellent healing and good maintenance (see Fig. 17-46, D).

**Resorption Defects in the Marginal Periodontium**

Radiographic interpretation and diagnosis of lesions of internal and external resorption were discussed in Chapters 3 and 4. This section will focus on the treatment of resorption defects that occur in the marginal periodontium. It is possible for internal resorption to perforate the dentinal and cemental wall and cause a periodontal defect in the marginal periodontium (Fig. 17-47). Because the relative occurrence of internal resorption as opposed to external resorption is infrequent, this is a rare occurrence.
The majority of resorptive lesions are found to originate in the periodontium, approximately at the level of the attachment. Sometimes this pathologic process is also referred to as cervical resorption or invasive cervical resorption. A variant has been described as invasive extracanal resorption, distinguished by the fact that radiographically and at surgery, the resorption process does not involve the pulp. Confirmed etiologies for these resorptive defects are often intertwined with orthodontic treatment (the most common sole factor), trauma, and a history of internal bleaching using the heated technique as the prime etiologies. Young female patients appear to be predisposed to this pathologic process. Because the lesions usually originate in the marginal periodontium, the surgical techniques used for crown lengthening are easily adapted for the repair of resorptive defects (see Chapter 13).

Most lesions of external resorption are more extensive than the case presented in Fig. 17-48. Since the process appears to originate at the level of the attachment, most resorptive lesions involve crestal bone as well.

**Clinical Problem**

**Problem:** A 28-year-old female was evaluated on referral for a presumptive diagnosis of internal resorption (Fig. 17-48). Angled radiographs demonstrated an external location, fortunately on the labial surface.

**Solution:** A mucoperiosteal flap was elevated from the position of a sulcular incision, and a vertical incision was included because of the lack of sufficient exposure with an envelope design. Generally, vertical incisions are necessary when the flap extends around a curved area of the dental arch (see Fig. 17-48, C). The defect was repaired with composite resin (see Fig. 17-48, D), and the tissue he was repositioned apically to avoid closure over the repair material, which would likely have resulted in a periodontal pocket.

However, in these types of cases it may be possible to use a resin composite (Geristore; Den-Mat®, Santa Maria, CA, USA), since human gingival fibroblasts have shown preferential attachment to this product, with minimal cytotoxicity. This material is a dual-cure, hydrophilic, nonaqueous, polyacid-modified composite resin. Its advantages are being insoluble in oral fluids and having increased adherence to tooth structure, low cure shrinkage, low coefficient of thermal expansion, radiopacity, fluoride release, and biocompatibility. Geristore has been used to repair mechanical root perforations. MTA (ProRoot MTA; Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) has also been used in combined endodontic-periodontic problems due to cervical resorption.

**Figure 17-47** A, Photograph of a drainage tract originating from perforation from internal resorption on the second molar. The defect could be detected in the sulcus with a No. 17 explorer. B, Radiograph illustrating extensive internal resorption. C, Surgical exposure of the small perforation using an envelope tissue flap. The defect was repaired and root canal treatment followed.
**CLINICAL PROBLEM**

**Problem:** A 44-year-old patient was seen following nonsurgical and surgical root canal treatment of a lesion found in a mandibular canine (Fig. 17-49, A). The first premolar also had extensive resorption well below the level of the attachment and on the lingual surface. Repair was not possible, and it was treatment planned for extraction.

**Solution:** Under local anesthesia, a mucoperiosteal envelope tissue flap was elevated in the same manner as for crown lengthening. In the area of the resorption, the tissue in the resorptive defect was severed from the lining of the tissue flap, leaving the tissue with adequate thickness (approximately 2 mm). Next, the defect was curetted to eliminate the soft tissue. Commonly, the gingival and lateral margins of the resorption defect can be indistinguishable from the surrounding bone (see Fig. 17-49, B), but in some cases, bone will extend into the resorptive defect. Using the same approach as in crown lengthening, the bone surrounding the lesion was removed to expose the margins of the resorptive defect (see Fig. 17-49, C). The bone was contoured interproximally with the intent of repositioning the tissue apically to a level below the resorptive repair. After healing, normal probings were expected in all areas. Next, the margins of the defect were refined for a Class I composite or compomer restoration (see Fig. 17-49, D). Glass ionomer restorations are not recommended, owing to their tendency to degrade subgingivally and because they are cytotoxic, so the use of a resin ionomer may be indicated. To maintain root canal patency during placement of the restoration, calcium hydroxide was placed into the exposed canal and packed densely with dry cotton pellets (see Fig. 17-49, E). Routine restorative procedures were used to place the resin filling. With the densely packed calcium hydroxide in place, the cavity can be etched and dried (see Fig. 17-49, F). The resin restoration was placed (see Fig. 17-49, G). Following the restoration, the tissue was repositioned and stabilized with sutures—in this case, after extraction of the premolar (see Fig. 17-49, H). Routine root canal procedures can be performed immediately or on a subsequent visit (see Fig. 17-49, I). Reevaluation at 5 years (see Fig. 17-49, J) indicated excellent healing. Recurrence is possible but is fortunately uncommon with this approach.
FIGURE 17-49 A to J, Illustrations of a routine repair of a cervical resorptive defect.
The basic concepts of surgical crown lengthening are also useful for exploratory purposes. For resorption defects, exploration may be required to determine if the problem can be treated. Some defects may extend well below crestal bone into inaccessible interproximal surfaces or into the furcation. Even if repairable, the prognosis for periodontal maintenance may be poor (Fig. 17-50). In some cases, efforts have been made to consider intentional replantation, which allows for repair in these isolated, difficult-to-get-to defects.

Vertical Root Fracture Repair

Although the periodontal probing pattern of most vertical root fractures is virtually diagnostic in itself, some fractures may be atypically located, may not probe in the usual vertical manner, or may present as a lesion of periodontal origin. The true diagnosis may not be known without surgical exploratory exposure. The flap designs for surgical access would be the same as those used in surgical crown lengthening. In most cases, the presence of a vertical root fracture to the apex requires either extraction of the tooth, or in the case of some multirooted teeth, removal of the individual fractured root (Fig. 17-51). Root resection and hemisection techniques will be discussed in the following chapter. A rare case of a successful treatment of a vertical root fracture is presented in Fig. 17-52.
Problem Solving in the Management of Teeth With Subgingival Carious and Fractured Margins

**FIGURE 17-50**
A, Sinus tract near the maxillary left first molar is the chief complaint. B, Radiograph indicates extensive resorption. C, Exploratory surgery reveals furcation defect with poor prognosis. D, Extracted tooth reveals an extensive furcation defect.

**FIGURE 17-51** Elevation of mucoperiosteal flap for diagnosis of a vertical root fracture (arrow). Flap technique is the same as for crown lengthening.
FIGURE 17-52  A to G, Illustrations of a successful vertical root fracture repair with mineral trioxide aggregate. The repair was performed in February of 2006. The reevaluation radiograph and photos were made in September 2007. Probings were 4 mm in the site of the repair.
Problem: A 46-year-old woman reported chronic soreness in the buccal gingiva adjacent to the mandibular right second molar. A periapical film indicated the tooth had previous root canal treatment that appeared technically excellent, and there was no evidence of pathosis (see Fig. 17-52, A). Clinically, however, probing revealed a narrow defect on the buccal surface over the distal root, consistent with a vertical root fracture (see Fig. 17-52, B). However, unlike the majority of root fractures that probe to the apex, the probing depth was only 6.5 mm. Exploratory surgery was recommended.

Solution: An envelope tissue flap was elevated on the buccal side as in crown lengthening (see Fig. 17-52, C). The exposure revealed a vertical fracture line extending apically from the crown to a level about 4 mm below crestal bone. The generally poor long-term prognosis was discussed with the patient, but due to the minimal depth of the fracture line, the decision was made to attempt a repair. The fracture line was enlarged with a No. 2 (1 mm) round bur and filled with the white formulation of MTA (see Fig. 17-52, D and E). MTA is not reported to be successful in repair of defects in contact with oral fluids but has been successful in the repair of a variety of defects below the level of the attachment, which will be discussed in the next chapter. The patient returned for reevaluation 7 months after the procedure, reporting no symptoms. Probing indicated a 4.5-mm attachment level in the surgical area (see Fig. 17-52, F), and the gingival margin was approximately at the same level as it was preoperatively. No crown lengthening was included in the original procedure. The radiograph made at reevaluation indicated healing of the post-surgical radiolucency (see Fig. 17-52, G). This case appears to offer hope that continued research in the area of surgical repair will provide materials capable of producing this result routinely on fractures of any depth.

REFERENCES

RECOMMENDED ADDITIONAL READING
Chapter 18

Problem-Solving Challenges That Require Periradicular Surgical Intervention

Problem-Solving List

Problem-solving challenges requiring periradicular surgical considerations addressed in this chapter are:

Surgical Management of Problems Associated With Lateral Canals
Surgical Repair of Root Perforations Below the Attachment
Surgical Repair of Problems Associated With Some Root Fractures
Surgical Techniques for Resection of Roots and Teeth
   - General considerations
   - Case selection criteria
   - Endodontic considerations prior to root resection
   - Periodontal considerations prior to root resection
   - Restorative considerations before and after root resection
   - Surgical techniques for root resection
   - Basic recommendations for all root resections
   - Surgical techniques for tooth resection (hemisection)
   - Basic recommendations for all tooth resections
Outcomes Assessment for Teeth With Root or Tooth Resection
   - Maxillary molar roots
   - Mandibular molar roots

The successful management of perforative defects is dependent not only on the etiology of the perforation, but also on the early diagnosis of the defect, choice of treatment, materials used, host response and practitioner expertise.

J.L. Gutmann, 1991

Surgical Management of Problems Associated With Lateral Canals

Periapical surgery (see Chapter 16) and surgical management of defects in the marginal periodontium (see Chapter 17) address many of the problems encountered in tooth retention. However, other challenges to tooth retention also exist on root surfaces below the level of periodontal attachment, and for the most part do not involve the marginal periodontium or the root apices. Often these issues are not considered in treatment planning in favor of tooth extraction and implant placement. Furthermore, many of these issues are never explained to the patient relative to the treatment options and the potential outcomes.

There are two general approaches to problem solving the treatment of lesions or defects on root surfaces below the attachment. The first is aimed at the repair of defects on the root surfaces, with the nature of the defect and its location being of major importance. The surgical techniques advocated are modifications of the periapical surgical procedures discussed in Chapter 16. The second approach is to consider surgical techniques that result in complete root removal. These surgical concepts apply to a wide variety of clinical problems that can be addressed in a positive manner and result in a good prognosis for tooth retention, documented levels of positive outcomes, enhanced patient satisfaction, and economic feasibility for a wide range of patients.

The clinical incidence of problems associated with natural lateral canals does not rise to the statistical percentage of roots that actually have anatomically demonstrable lateral canals. Additionally, the incidence of lateral canals in the middle and coronal thirds of roots is statistically rare. Most bony lesions that arise from necrotic debris in a nonvital tooth heal with routine nonsurgical treatment (Fig. 18-1).
In the preoperative evaluation, determining the location of the lateral canal is a diagnostic challenge. Lateral canals can occur on any surface of the root and are rarely visible radiographically. Perhaps the easiest to locate are those that have clinical signs of a draining tract but no radiographic changes. These canals will usually be found on the labial aspect of the root (Fig. 18-4).

The presence of most lateral canals is inferred by the presence of a previously treated tooth, most lateral lesions resolve with revision, as demonstrated in Chapter 14, Fig. 14-6. This is all the more amazing because although many clinicians take personal pride in being able to extrude sealer, gutta-percha, or both through these canal spaces (Fig. 18-2), there are no proven techniques to actually clean and disinfect these aberrant channels. Furthermore, the empirical concept that pushing filling materials through these canals will debride this small space of its irritants is faulty.

There are relatively few teeth with lateral lesions that fail to heal after root canal treatment. Even fewer are those which develop lateral lesions after root canal treatment. Unfilled or poorly obturated canal spaces can be a predisposing factor to the development of a lateral lesion, especially spaces between a gutta-percha filling and an intraradicular post (Fig. 18-3; see Chapter 20). Nonsurgical revision is usually the treatment of choice but not always feasible. Lesions that fail to heal, as well as those associated with teeth that cannot be revised, generally require surgical intervention.

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The greatest difficulty is determining the location in a horizontal orientation. Lesions often extend circumferentially from their sources. What is observed radiographically as a lesion on the mesial or distal surface of the root may in reality originate from a lateral canal on either the palatal or labial aspect of the root. Palatally or lingually located lateral canals will generally not be accessible to surgical repair.

A second anatomic problem is the surgical accessibility of the canal in interproximal or interradicular spaces. Lateral canals occurring in fluting of molar roots can be impossible to see at surgery, although some may be large enough to locate tactilely with an explorer. Even if they can be located, space limitations can prevent successful completion of the repair. The only avenue for possible resolution of these dilemmas is surgical exploration. Preoperatively, the patient should be informed that if the lateral canal is not accessible, the root may have to be removed in its entirety or the tooth may have to be extracted (Fig. 18-6).

The essential elements of the surgical procedure are the same as for periapical surgery, which is described in detail in Chapter 16. The lateral communication is located, cleaned, enlarged, and filled exactly as one would surgically fill the prepared apical foramen on the resected root surface. A small ultrasonic tip or No. 15 or 20 K-file in the ultrasonic handpiece will usually follow the course of a lateral canal and enlarge it to the point at which a larger file or a diamond tip could follow the initial pathway. As with apical preparations, the size of the preparation must be sufficient for the placement of the filling (preferably mineral trioxide aggregate [MTA]).
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A. 47-year-old male presented with a draining sinus tract on the midline of the labial papilla adjacent to the maxillary right central incisor. The lesion was difficult to discern radiographically (Fig. 18-7, A). A periodontal probe indicated normal sulcular probing but probed through the draining tract to the side of the root.

**Solution:** Because of the presence of a post in the root and the absence of any periapical pathosis, the midroot area was exposed surgically, and the presence of a lateral canal was confirmed and repaired. A 9-year, 3-month reevaluation radiograph indicated excellent healing with restoration of the periodontal ligament space and lamina dura in the surgical site (see Fig. 18-7, B).

**FIGURE 18-6** A, Lateral canal lesion located on the distal aspect of the mesial root of the mandibular right first molar. B, Extracted mesial root. Surgical repair was attempted, but it was not possible to visualize the lateral canal, owing to deep fluting of root surface. Note lateral canal (arrow). C, A radiograph of the root. Note the distance of the lateral canal (yellow dot) from the treated canals. Revision would have had no effect on this problem.

**FIGURE 18-7** A, Preoperative radiograph of maxillary right central. Lesion associated with lateral canal extends from midroot level to alveolar crest in the midline. B, Reevaluation at 9 years, 3 months, demonstrating excellent healing.
As described for apical surgery in Chapter 16, some diamond-coated or metal ultrasonic instruments may be too large to begin the preparation, so a smaller-tipped instrument or a small endodontic file must be selected. Low to medium power is indicated to prevent aggressive and indiscriminate cutting of root structure. Instruments with ideally angled tips for access to these aberrant canals should be considered (see Figs. 16-33 and 16-34).

**Surgical Repair of Root Perforations Below the Attachment**

Most perforations during access opening occur in the marginal periodontium (see Chapters 8 and 16). The only common exception to this observation is the case where the access perforation occurs in the furcation. If the attachment tissues are not disturbed, small furcation perforations have a good chance of long-term stability with an internal repair using MTA (Fig. 18-8).

Larger perforations in the furcation can be problematic. If significant portions of the floor of the pulp chamber have been removed, the chance of successful repair is poor (Fig. 18-9). Similarly, cases that have been repaired with materials other than MTA may have poor long-term outcomes, especially if the material is forced through the defect into the periodontal tissues. It is almost impossible to remove the excess nonsurgically, and attempts are likely to make the perforation larger. In this regard, even surgical repairs with MTA of larger perforations of the roots in the furcation can have mixed results. Fig. 18-10 illustrates a case in which a perforation was initially repaired internally with MTA. After 6½ years, a furcation radiolucency lesion had developed, and a surgical repair was attempted. One year later, the bone had not healed completely. Although the patient was symptom free and the tooth functional, the prognosis was guarded.

Lateral strip perforations can occur during root canal cleaning and shaping, generally with hand instruments or excessive use of large nickel-titanium instruments (see Chapter 10). Often the anatomy of the root plays a role (Fig. 18-11); deep flutes or invaginations of the proximal root surfaces cannot be discerned radiographically. Although anti-curvature filing (see Chapter 10), skewed positions of the access cavity, and other techniques are effective in reducing this problem, it cannot be avoided completely.

![Image](image.png)

**FIGURE 18-8** A, Furcal bone loss associated with an access perforation through the floor of the furcation. B, Calcium hydroxide used as a temporary seal during completion of the endodontic treatment. C, Reevaluation after 1 year. The perforation was permanently sealed with mineral trioxide aggregate. Note the restoration of normal bone architecture in the furcation.
FIGURE 18-9 Extrusion of cement repair material through a furcation perforation. Chronic drainage through the gingival sulcus was apparent at the time of examination. Extraction was recommended.

FIGURE 18-10 A, Referral radiograph of mandibular left first molar. The furcation was perforated in the access procedure and was temporarily repaired with calcium hydroxide (arrows). B, Root canal treatment completed and perforation filled with mineral trioxide aggregate. It was a challenge to pack the material and not have extrusion. C, Reevaluation radiograph after 6½ years. Probing was normal but tooth was symptomatic, and the tooth had a sinus tract on the buccal mucosa. D, Surgical repair in progress. Note the intact crestal bone over the furcation. E, Fifteen-month reevaluation. Patient was asymptomatic, sinus tract had not reappeared, but prognosis was guarded.
As with lesions adjacent to lateral canals, accessibility to the defect can be a major problem for repair, but these defects are usually larger and much easier to locate. If the defect is visible, the repair can be made in the same manner as with the repair of defects from lateral canals. Often the preparation must be longer vertically because of the thin dentin above and below the perforation itself (Fig. 18-12).

Strip perforations can also occur from excessive enlargement of the canal during post space preparation. This is seen most often in roots with thin mesial-distal widths and roots with fluted anatomy on the proximal surfaces. If accessible, the techniques for placing an MTA filling are effective (Fig. 18-13). Many strip perforations resulting from post preparations are particularly difficult to repair because very thin dentin remains around the perforation defect. The greater the post diameter, the thinner the tooth structure will be. Cutting into the metal of the post requires a high-speed handpiece and good access. Some creative, specialized approaches may be considered to repair these defects, but they are beyond the scope of this text. It is usually better to remove the post if possible (Fig. 18-14).

Perforations with endodontic instruments can occur deep in the root from failure to negotiate curves, attempting to bypass blockages, or failing to consider the normal anatomy of the tooth during cleaning and shaping procedures. If discovered early, internal repairs may effectively resolve the perforation problem; if not possible, then surgery will probably be necessary.
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FIGURE 18-13  
A, Lateral lesion associated with a stripping perforation due to overenlargement of the canal for post preparation.  
B, Five-month reevaluation indicating healing of the lesion.

FIGURE 18-14  
A, Intraradicular post protruding through a perforation.  
B, Removal of the post is preferred, rather than attempting to cut the post back into the root prior to repairing the perforation.

CLINICAL PROBLEM

Problem: A 38-year-old female presented with what was considered to be a failing root canal procedure on a maxillary right central incisor (Fig. 18-15, A). The tooth had been root treated approximately 6 years previously. At the time of examination, the symptoms were palpation tenderness, dull aching, and percussion tenderness. The periapical film indicated a well-filled root canal, but a large periapical radiolucency was present, and nonsurgical revision of the previous treatment was recommended.

Solution: The tooth was reopened, and while the existing filling material was being removed, the patient felt pain at a level well short of the estimated tooth length. An instrument was placed, and a radiograph was made. A labial perforation was revealed that proved to be the etiology of all the current pathosis (Fig. 18-15, B). Reparative surgery was performed, and the perforation was repaired with MTA. A 1-year reexamination indicated excellent healing of the original lesion without revision of the root canal treatment in the apical half of the canal. A porcelain veneer crown had been placed by another dentist in the interim, but unfortunately, the post space that had been prepared for the final restoration was not properly used.
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Surgical Repair of Problems Associated With Some Root Fractures

The etiology of partial root fractures on the lateral root surface of some teeth is unknown. Clinical findings are typical of lesions associated with lateral canals or strip perforations along with normal periodontal probings. Often the signs of acute or chronic inflammation/infection (midroot swelling, sinus tracts, etc.) are present.

Radiographic findings are similarly nonspecific. The radiolucency is characterized by an apical and a coronal border. In these cases, the apex is usually not involved (see Fig. 18-16, A). Consequently, it is not possible to make the specific preoperative diagnosis of partial vertical root fracture. In all cases, they are discovered at surgery. The clinical appearance is a vertical fracture line located in the midroot area on the palatal surface (see Fig. 18-16, B).

If the fracture line is in a position where repair is possible, the techniques for lateral repairs will be effective. The most significant and difficult modification is the preparation that
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must follow the crack line to its full extent. The result is a narrow slot preparation similar to the preparation of an isthmus between two canal orifices in periapical surgery.

If straight-line access is possible, a quarter-round (0.5 mm) bur is ideal. For maximum control, the straight, low-speed handpiece, held in the pencil grip, works well. If straight-line access is not possible, the ultrasonic instrument can be used with either a small, angled apical surgery tip or an endodontic file that has been shortened to increase stiffness and placed in a special ultrasonic adaptor.

Surgical Techniques for Resection of Roots and Teeth

**General Considerations**

Root resection, or root amputation, involves removing the root and either leaving the crown intact (Fig. 18-18) or additionally removing the portion of the crown that overlies the removed root. In the treatment of maxillary molars, this procedure is also known as trisection. This concept also applies to the removal of a single-rooted tooth from a multiabutment fixed bridge or splint.

Tooth resection, or hemisection, is a technique in which a tooth is “cut in half.” As with root resection, multiple techniques can be used: cutting the tooth in half and retaining both segments, known as bicuspidization (Fig. 18-19),

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**FIGURE 18-17** A, Preoperative radiograph of a lateral radiolucency assumed to be associated with a lateral canal on the treated first premolar. B, Surgical exposure reveals a vertical midroot fracture line (arrows). C, Repair of the fracture line with MTA. D, Four-year reevaluation radiograph indicating excellent healing.

**CLINICAL PROBLEM**

**Problem:** A 40-year-old patient presented with a swelling in the midroot area of the mandibular left second premolar. The tooth had a previous root canal procedure and was restored with a post and crown. Radiographically, a large midroot radiolucency was present, and a large uncleaned lateral canal was suspected (Fig. 18-17, A).

**Solution:** Nonsurgical revision was not considered and the defect was exposed surgically. Following curettage, a midroot fracture line was observed on the distal buccal aspect (see Fig. 18-17, B arrows). Because of accessibility, the fracture line was prepared with a quarter-round (0.5 mm) bur and an ultrasonic tip. The preparation was filled with gray MTA (see Fig. 18-17, C). A reevaluation radiograph made 4 years later demonstrates excellent healing with restoration of a normal periodontal ligament space and lamina dura (see Fig. 18-17, D).
Performing root/tooth resections to allow retention of compromised teeth has been all but abandoned owing to the success of contemporary implants. However, resective procedures are viable treatment considerations in preserving natural tooth structure and can provide the patient with a reasonable alternative in many critical clinical situations. When done properly and the patient practices good oral hygiene, success rates can be quite high and comparable to other treatment choices.

Multiple published studies in the periodontal literature have supported root resection as a successful long-term treatment. Success with this treatment modality is generally defined as tooth retention with probing depths of less than 4 mm, no bleeding on probing, no exudation, and no evidence of root caries or fracture. The success rates overall for resected molars in these studies can be judged comparable to the success rates of implants in the same locations.

**Case Selection Criteria**

Root resection (root amputation) and tooth resection (hemisection) procedures are useful solutions for a variety of clinical problems. From a periodontal standpoint, the most common indication is significant periodontal bone loss localized to one root, with adequate bone support for the adjacent roots. Additional periodontal indications are grade II or III horizontal furcation involvement, dehiscence/fenestration, invasive resorption, and adverse root proximity.

Although it is not within the scope of this text to provide a comprehensive discussion of periodontal diagnosis or surgical procedures, there are many clinical problems that require knowledge of both endodontic and periodontal disciplines to

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**CLINICAL PROBLEM**

**Problem:** A 58-year-old male presented for examination with palpation tenderness and dull pain in the area of the maxillary left first molar. A periapical radiograph indicated a large radiolucency over the apex of the mesial buccal root, suggesting periapical pathosis of pulpal origin, specifically associated with a necrotic pulp (Fig. 18-20, A). Pulp sensibility test responses, however, were normal, and periodontal probing indicated a loss of periodontal attachment over the mesial buccal root (see Fig. 18-20, B). Calculus was observed on the exposed root surface and could be felt with the periodontal probe subgingivally on the root surface.

**Solution:** Surgical exploration of the lesion confirmed bone loss of periodontal etiology (see Fig. 18-20, C). The mesial buccal root had no remaining bone support, and it was quite simple to resect (see Fig. 18-20, D). When vital root amputations are dictated by the findings at surgery, a pulpectomy should be performed on the remaining roots immediately after the tissue is repositioned and sutured or as soon as possible postoperatively.
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arrive at the correct diagnosis and treatment plan. For example, it is not uncommon to identify a tooth with peri-
radicular pathosis presumed to be of pulpal origin, only to
identify instead that the lesion is of periodontal etiology and
that the pulp is normally responsive to sensibility tests.

From an endodontic standpoint, problems for which root
or tooth resection are options include: vertical root fractures
(Fig. 18-21), coronal fractures (Fig. 18-22), furcation perfora-
rations (Fig. 18-23), post perforations (Fig. 18-24), irrepara-
table strip perforations (Fig. 18-25), nonnegotiable root
canals (Fig. 18-26), irretrievable separated instruments (Fig.
18-27), irremovable canal filling materials (Fig. 18-28), cervi-
cal resorptions (Fig. 18-29), extensive caries (Fig. 18-30), and
periodontal defects (Fig. 18-31). With creative endodontic
treatment planning, retention of teeth and prostheses is both
reasonable and feasible.

Endodontic Considerations
Prior to Root Resection

While it is generally thought that root canal treatment is
always indicated because of the pulp exposure at the
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**FIGURE 18-22** A, Significant coronal fracture of the palatal cusp of a maxillary first molar due to intense bruxism. B, Preoperative radiograph. Case is continued in Fig. 18-46.

**FIGURE 18-23** Post perforation into furcation in a mandibular second molar. Note the periodontal defect in the furcation. The furcation had chronic purulent drainage. Removal of the mesial root would eliminate the furcation and prolong retention of the bridge.

**FIGURE 18-24** A, Distal lateral lesion associated with perforation from aberrant intraradicular post. The tooth was hemisected. B, Reevaluation radiograph of the restored mesial root after 3 years.

are necessary for healing and maintenance. Despite the results of these studies, complete root canal treatment still appears preferable on teeth with resected roots.

As described in the case presented in Fig. 18-20, the decision to resect a root may not always be anticipated preoperatively. In most cases, however, root or tooth resection can be treatment planned well in advance of the actual surgery. If the tooth requiring root removal does not have root canal treatment, it is usually more convenient do the treatment before surgery, for two important reasons. First, it is much more difficult to complete root canal treatment on the retained root postsurgically. Tooth isolation and canal management are much easier with an intact crown. Second, the difficulty of root canal treatment cannot be determined preoperatively in some cases. If treatment is done before the surgery and the canals prove to be difficult to penetrate, or if a procedural accident compromises the anticipated result, the treatment plan can be altered to extraction.

Although complete root canal treatment is not necessary in the root that will be removed, it is wise to seal the orifice permanently through the access cavity. The orifice should be enlarged more than would be necessary for routine cleaning and shaping procedures so that a permanent restorative material can be compacted past the point of amputation (Fig. 18-32). This procedure eliminates the need to place a
FIGURE 18-26 A, Periapical and periodontal pathosis on a mandibular molar due to inadequate root canal treatment. Revision was initiated but the mesial canals proved impossible to renegotiate to the apical foramina. B, Hemisection retained the distal root as a terminal abutment for a removable partial denture. Treatment revision of this root was uncomplicated.

FIGURE 18-27 A, Mandibular second molar with a separated instrument in one of two distal roots. B, The instrument was irretrievable; the root was resected, preserving the tooth in function.
Symptomatic mandibular second molar requiring revision. The silver cones in the mesial canals proved to be irretrievable. The mesial root was resected. Reevaluation radiograph at 14 years, 7 months; the distal root continued to function as the distal abutment for a fixed bridge.

Acute palatal abscess-associated cervical resorption. Surgical exposure. Lesion found to extend into the furcation on the mesial. Postoperative photograph of hemisection.

Distal caries to the furcation in a mandibular first molar. Resection of the distal root. Mesial root retained to be restored as a functional premolar, similar to Fig. 18-24, B.
**FIGURE 18-31** A, Mandibular central incisor with a periapical lesion suspected to be of pulpal origin. Probing revealed bone loss consistent with chronic periodontitis. B, Root was resected, preserving the fixed splint in function.


**FIGURE 18-33** A, Immediately post root resection, indicating exposure of the orifice of the mesial buccal canal. B, Amalgam restoration of the exposed orifice to prevent coronal leakage.
restoration in the external orifice at the time of resection (Fig. 18-33). These procedures are important to prevent coronal leakage into the retained roots.

If teeth indicated for root resection have already been root treated, preoperative evaluation of the root fillings in the roots to be retained is essential. Revision of previous root canal treatment should be done if there is any concern with the quality of the obturation or if there is evidence of periapical or lateral pathosis. Furthermore, presurgical revision of the root canal treatment should be done in any roots with metal-core gutta-percha fillings or silver cone fillings because of the likely need for post space.

**Periodontal Considerations Prior to Root Resection**

The level of supporting bone is of primary importance in assessing the periodontal condition of the root to be retained. Even with splinting, a root with only 5 mm of supporting bone must be considered unsuitable. A safe minimum would be 50% bone loss; that is, a crestal bone height no lower than half the distance from the cemental-enamel junction to the apex. There must also be a relatively uniform crestal bone height around the root and no localized deep periodontal defects.

Of equal significance is the level of the furcation bone relative to the level of crestal bone on both the mesial and distal aspects of the tooth. A favorable relationship would be a furcation height at the level of interproximal bone height (Fig. 18-34). Occasionally the furcation may even be above this level, as might be found in a tooth with bone loss from chronic periodontitis (Fig. 18-35).

Teeth with long root trunks and furcations 2 mm or more below the crestal bone are less suitable for resection. The bone level on the furcation side of the retained root can heal no higher than the furcation itself (Fig. 18-36). Root resection would result in periodontal pocket formation postoperatively on the furcation side of the root. For example, if the furcation level is 3 mm below crestal bone, the sulcus depth on the untreated surface of the retained root would be 2 mm. On the furcation surface, it would be 5 mm, which is clearly undesirable and difficult to maintain. This problem may be avoided in some cases with sufficient root length or by recontouring the crestal bone circumferentially to make it level with the furcation. This approach should generally be limited to resection of teeth without immediate neighbors. Routine removal of large amounts of alveolar bone supporting adjacent teeth is seldom indicated. Extrusion is another alternative if the root is long enough (see Chapter 20).

Teeth with fused roots or roots with a C-shaped configuration (primarily mandibular second molars) are not suitable for resection (see Chapter 13). Although fusion of roots in maxillary molars does occur, it cannot be seen radiographically, nor can the level of the furcation between the palatal root and the buccal roots be determined in this manner (Fig. 18-37). In cases where this problem is suspected, the patient
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FIGURE 18-37  A, Clinical photograph of a maxillary molar considered for resection of the palatal root. B, Radiograph suggesting a possible fused root anatomy. During surgery, the fusion of the distal buccal root with the palatal root was confirmed. The tooth was extracted. C, Lateral view of an extracted maxillary molar showing fusion of distal buccal and palatal roots. This tooth is not a candidate for either palatal or distal buccal root resection.

Restorative Considerations Before and After Root Resection

During the treatment planning process, the clinician must determine whether the resected tooth or root will be restorable. In cases of minimal clinical crown height, crown lengthening at the time of root removal should be considered, and the adjacent teeth should also be considered in the treatment plan. It must be decided at the outset whether tooth resection would be superior to extraction of the involved tooth (Fig. 18-38). There is seldom an advantage to retaining a molar root if both adjacent teeth are suitable abutments for a fixed bridge or if an implant would be indicated. Although the remaining root could be retained, the additional choices of hemisection and root canal procedures add complexity, cost, and time to the treatment plan. The simplicity of extraction of the whole tooth and placement of a fixed bridge or implant must be considered and discussed with the patient. After resection, the final restoration of the root-resected tooth will depend significantly on the nature of the resection, the amount of remaining tooth structure, and the patient’s occlusion and periodontal status.

Surgical Techniques for Root Resection

The basic surgical procedure will be similar to crown lengthening in flap design, osseous contouring, closure, and postoperative periodontal objectives. However, in many cases a vertical releasing incision may be indicated. The surgical instruments are essentially the same as for the crown-lengthening procedure (see Chapter 20). Fig. 18-39 depicts the removal of the mesial buccal root from a maxillary first molar.

Initially, a horizontal sulcular incision is made both buccally and lingually (or palatally) at least one complete tooth width mesial and distal to the tooth that is to have a root removed (see Fig. 18-39, B). If the root intended to be amputated is very short, it may be possible to use an envelope flap. If a vertical releasing incision is used, it should be placed to align with the interproximal space one tooth anterior to the...
operated tooth and should include the papilla (see Fig. 18-39, B). Subsequently, the interproximal tissue is curetted, removing any connective-tissue tags and identifying the precise location of the furcation. Using a surgical-length round bur, any exostosis or excessive thickness of the buccal plate is reduced (see Fig. 18-39, C), and the buccal plate is removed over the root to be extracted (see Fig.18-39, D).

Using a surgical-length straight fissure or similar bur, begin the section on the root to be removed. Do not begin in the furcation, where danger of cutting into the surface of the retained tooth is great. It is always easier to remove more tooth structure after the bulk of the root has been resected and anatomic landmarks are clear (see Fig. 18-39, E). Once the root has been completely severed from the retained tooth structure (verified radiographically and clinically), the segment to be removed is carefully extracted through the prepared opening in the buccal plate without elevating against the retained tooth (see Fig. 18-39, F). If necessary, cut a trench in the bone mesial and distal to the root, using fine burs; stay as close as possible to the resected root to avoid cutting into the adjacent roots. Diamond burs, carbide finishing burs, and polishing points can be used to shape the surface of the cut crown so that a smooth transition exists from the crown surface to the root surface. Verify radiographically that no fluting or overhanging spurs of furcation tooth structure are left protruding into the furcation (see Fig. 18-39, G). If not already completed as a preoperative procedure, repair the canal opening at the site of the amputated root with a permanent filling as discussed earlier (see Fig. 18-33). Then compare the level of bone on the furcation side with the level of bone on the opposite side of the root. If there is a discrepancy in height, use a combination of a round bur, an end-cutting bur and the Wedelstadt chisel to level the bone height, as in the crown-lengthening technique. Interproximal bone on the buccal and lingual is ramped toward the interproximal space (see Fig. 18-39, H). Wound closure and dressing are the same as described for the crown-lengthening procedure (see Fig. 18-39, I).

For purposes of simplicity, only this one technique of resection will be presented. This approach is used primarily for maxillary molars, but it can be used in selective cases for mandibular molars. (See the case presentation in Fig. 18-51; in-depth details on this approach are available in other publications.) 26,27

**Basic Recommendations for All Root Resections**

With all root resections, using any of the techniques to be described, there are some basic principles that will prevent problems both during and subsequent to the resective procedures. However, not all these concerns will apply to each and every clinical situation for which resective procedures are treatment planned.

- Use transillumination before and after resection to examine for crazes, cracks, or fractures.
- Use a brush stroke with sufficient coolant when cutting root and bone.
- Identify the anatomy of the root junction in the furcation to protect the retained roots and furcation anatomy.
- Reduce occlusals prior to resection to better distribute the functional forces; if necessary, further refinement can be done after resection.
- Whenever in doubt, a surgical incision and tissue reflection permitting direct inspection will always enhance the procedure, especially in cases resected for perforative, resorptive, or carious damage in the furcation region.
- Surgical-length burs are essential; surgical handpieces with angled heads are desirable.
- Restore the pulp chamber with a bonded restoration (composite or core material) prior to resection if possible.
- Resect roots at the expense of the root to be removed, and avoid gouging the segments to be retained.
- Establish sufficient dentin and bone clearance as necessary for root removal.
- Use a splint if mobility of the retained segments is an issue.

**Surgical Techniques for Tooth Resection (Hemisection)**

In mandibular molars, multiple approaches to tooth resection are available and are often dependent on the retention or removal of the resected segments. A vertical cut can be made continuously from the buccal to lingual. If there is through-and-through furcal bone loss, a silver cone or wire can be inserted to mark the furcation path. Movement of the metallic marker will indicate the depth of penetration. Cuts can also be made starting at the buccal to the tooth center and joined with a cut from the lingual furcation inward. A precontouring technique can also be used in which the segment(s) to be retained are prepared for restorative purposes with the internal proximal cut carried through the furcation (Fig. 18-40, A).22,34 This approach has the added advantage of reducing the amount of debris that may enter into the adjacent root socket if a segment is prepared for a retainer prior to the removal of the other segments,27 and creates a preparation for the immediate fabrication of a temporary prosthesis (see Fig. 18-40, C to E).

The need for provisional splinting following tooth resection must be determined for each case and is dependent on root position, occlusal function, and whether or not segments sectioned are retained or removed. Splinting after tooth resection is more common than after root resection alone. Provisional splints can be constructed from wire and acrylic resin, wire and amalgam, orthodontic bands, acrylic resin, or the use of preexisting restorations.3,40 Centric occlusion contacts which prevent supra-eruption should be maintained, but lateral interferences should be eliminated.4 The final restoration of resected posterior teeth will often be in the form of single crowns or copings with telescopic crowns resembling premolars.32 Pontics are easily used in cases where a resected portion has been extracted. If proper adjunctive osseous
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in the access opening to the position of a line drawn from the buccal to lingual furcation. Zinc oxide eugenol (ZOE) is placed in the other half of the access opening. During sectioning, the coronal cut can be made along the amalgam/ZOE interface, always favoring the segment to be retained.

Improper angulation of the handpiece or an excessive deep cut during sectioning may lead to gouging of the optimal root segment and ultimate loss of the entire tooth. The vertical cut technique has many advantages: direct visualization during resection, removal of potential occlusal problems when the root is to be removed, precise sectioning based on the tooth anatomy, and excellent access for the smoothing of resected tooth margins.

In cases where both resected segments are to be retained (bicuspization), the vertical cut technique allows for the creation of proper embrasures and, if necessary, orthodontic separation of the segments. This approach to resection of all segments would be indicated in periodontal furcation management and in cases of furcation perforation where the horizontal osseous level is high and the furcation is

contouring and soft-tissue adaptation and healing have occurred, resected tooth margins are easily prepared for fixed prostheses. Many singular resected root segments can serve as viable abutments or as support for overdentures.

The process and completeness of tooth resection in mandibular molars should be verified radiographically and clinically. This is especially true with teeth exhibiting roots angled from the crown. However, radiographs must be exposed in the direct line of the cut to be diagnostic (Fig. 18-41, A to C). If an elevator is used to determine segment freedom or mobility prior to radiographic demonstration of complete sectioning, fractures of valuable tooth structure to be retained may occur, compromising the ultimate restorative treatment.

In addition to the use of a silver cone or wire, a periodontal probe can be used to identify the path of tooth resection through the furcation, or placing different restorative materials in the endodontic access opening can provide a guide during the coronal cut (see Fig. 18-41, D). For example, on the half of the tooth to be retained, an amalgam is placed on

FIGURE 18-40 A, Precontouring method of resection, with a bur cutting into the furcation area on the buccal and lingual to provide a guide for full resection. B, Two mandibular molars requiring hemisections due to furcation bone loss. C, Teeth have been resected. Segments to be retained are prepared for crown coverage prior to extraction of the other segments to prevent debris from going into the extraction sockets. D, Segments have been extracted. E, Immediate preparation and placement of temporary coronal restorations.

In cases where both resected segments are to be retained (bicuspization), the vertical cut technique allows for the creation of proper embrasures and, if necessary, orthodontic separation of the segments. This approach to retention of all segments would be indicated in periodontal furcation management and in cases of furcation perforation where the horizontal osseous level is high and the furcation is
Basic Recommendations for All Tooth Resections

With all root resections using any of the techniques to be described, there are some basic principles that will prevent problems both during and subsequent to the resective procedures. However, not all of these concerns will apply to each and every clinical situation for which resective procedures are treatment planned.

- Use transillumination before and after resection to examine for crazes, cracks, or fractures.
- Surgical tissue reflection may be necessary, therefore plan for such.
- Root curvatures may require bone removal.
- Good visibility is essential at all times.
- Expose radiographs in mandibular resections to determine the thoroughness of the cut (see Fig. 18-41, A to C).
- Ensure the resection is complete prior to root elevation and extraction.
- Use periodontal probes to ensure complete resection.
- Verify furcation pathways with probes, wires, and so forth (periodontal probes, endodontic files, or silver cones if available [see Fig. 18-41, D].
- Recontour and adjust occlusion prior to removal of the unwanted segment.

**CLINICAL PROBLEM**

**Problem:** A 39-year-old female sought care for a draining sinus tract in the area of the mandibular right first molar. She had root canal treatment and a crown 1 year previously, and the sinus tract has been present for about 3 months. Clinical examination confirmed a draining tract that probes into the furcation of the first molar (Fig. 18-42, A). A radiograph (see Fig. 18-42, B) supported the differential diagnosis of a possible lateral canal or strip perforation.

**Solution:** The decision was made to attempt a surgical repair, but if the area was not accessible, to resect the tooth. The crown was removed and a full mucoperiosteal tissue flap, using a vertical releasing incision, was elevated on both buccal and lingual sides of the tooth. The location of the furcation was clear because of the drainage tract (see Fig. 18-42, C), but repair of the defect was not possible. Sectioning began over the distal root to avoid cutting into the distal side of the mesial root (see Fig. 18-42, D). The distal root had a strip perforation resulting from a post preparation (see Fig. 18-42, E). Following removal of the distal root, the distal surface of the mesial root was recontoured vertically to the crest of the furcation, and the tissue was repositioned and stabilized with sutures (see Fig. 18-42, F). The mesial root was then restored with a premolar-sized crown. Fig. 18-42, G illustrates the restored mesial root in normal function after 1 year.
FIGURE 18-42  A, Sinus tract on the buccal of the mandibular first molar probing into the furcation. B, Radiograph demonstrating a furcation lesion. C, After flap elevation on both sides and curettage of the granulomatous tissue in the furcation, the location of the furcation and distal aspect of the mesial root are determined. D, Section is made through the crown over the distal root, avoiding the distal surface of the mesial root. E, Resected root showing the strip perforation. F, Flap closure. G, One-year reevaluation with crown restoration.
Outcomes Assessment for Teeth With Root or Tooth Resection

Most root-resected teeth are able to function normally but are susceptible to the same influences that can negatively affect any root-treated tooth. Chapter 5 explored the parameters of negative or questionable outcomes for nonsurgical root canal treatment. The quality of root canal treatment provided for teeth with resections is crucial to their long-term outcomes. In many cases, because of the unusual shape of the tooth and with cut margins positioned differently than those found with normal restorations, poor restorations will result in coronal leakage. The evaluation and alteration of the occlusal table and functional contacts, as already stressed earlier, are essential to prevent aberrantly placed forces on the altered tooth with the possibility of a resultant vertical fracture (see Chapter 6). The following discussion will assume that tooth anatomy and levels of furcation and crestal bone are suitable for resection. Although it is possible to remove roots from any multirooted tooth, practical experience has shown that case selection is critical to long-term success.

Maxillary Molar Roots

Mesial Buccal Root

The mesial buccal root may be the most frequently vertical-fractured root in maxillary molars. Following resection, periodontal maintenance may be more challenging because of the wide and deep interproximal space. Long-term prognosis is good, however, with careful attention to oral hygiene practices (Fig. 18-43).

Distal Buccal Root

Perhaps the most successful outcome for root resection is the removal of this root. Following resection, periodontal maintenance is not typically a problem. This is especially true if the tooth is the last member of the arch (Fig. 18-44). The occlusion should be altered to ensure the repositioning of occlusal forces primarily over the palatal root; often the remaining mesial buccal root may be narrow and unable to withstand significant functional stresses.

Palatal Root

A critical factor in evaluating the outcome of this treatment option is the sulcus depth on the palatal surface. The anatomic relationship of the palatal furcation to the level of surrounding bone usually cannot be determined preoperatively. If a long root trunk should be discovered at surgery, the choice must be made between an unfavorable periodontal result or extraction. If the furcation is near crestal bone, the periodontal result will be optimal with a normal biologic width on the palatal surface (Fig. 18-45).

Resection of the palatal root, leaving the crown intact is indicated in but a few situations, one of which is economy of treatment cost due to the retention of the existing crown. If chosen, there must be a significant altering of the occlusal table, with forces directed buccally (see Fig. 18-45, D). Continued heavy occlusion on the palatal cusp in the long term tends to cause mobility and possible fracture.

Hemisection with removal of the palatal half is more preferable than palatal root resection. Fig. 18-46 documents the treatment of a maxillary first molar with palatal cusp fracture. The fracture depth made restoration impossible without removal of the palatal root. The furcation was at a level favorable for an optimal periodontal outcome. This approach has a more favorable long-term prognosis. The occlusal forces can be better managed with a narrower crown (Fig. 18-47).

Maxillary Premolars With Resection of the Buccal Root

Because of the relatively long root trunk, resections from crestal bone level are rarely if ever possible. Consequently, there are few indications for root resection on a premolar. Vertical fractures, periodontal defects, perforations, and resorption tend to involve the root trunk or both roots. One valid indication is to gain access to the furcation or to the palatal root. A postoperative radiograph of a maxillary first premolar with two roots is seen in Fig. 18-48, A. Root canal treatment was satisfactory but the patient returned 2 years later, and there was a lateral lesion present in the apical third
and removal of gutta-percha from one canal (see Fig. 18-48, B). The buccal root was resected, giving access to the palatal root (see Fig. 18-48, C). The postsurgical radiograph is seen (see Fig. 18-48, D) with two MTA root-end fillings.

**Mandibular Molar Roots**

There are two general applications for root/tooth resection in mandibular molars: the retention of existing prostheses and the use of individual resected roots as abutments or as functional premolars. Root resection can be a comparatively inexpensive approach to problem solving in the case of existing fixed bridges. Fig. 18-50 illustrates a case of severe periodontal bone loss around the distal root of the mandibular first molar. The long-term prognosis for the bridge appears poor, but the 1-year reevaluation indicates excellent healing and satisfactory function of the remaining mesial root.
The most common indication for root resection in endodontics is vertical root fracture (Fig. 18-51). Occlusal loading appears to be a major factor in their development. Once again, removal of the fractured root can preserve a bridge (Fig. 18-52), but the remaining root can be susceptible to the same occlusal forces. It is vitally important to reduce the occlusion on any tooth with root resection, especially if there are signs of bruxism, such as large wear facets. Even with extensive occlusal modification at the time of resection, intense bruxism can ultimately cause fracture of the remaining root as well (see Fig. 18-52, C). The prognosis for prostheses in which there has been root fracture is guarded, but here again, force distribution is essential, along with proper maintenance of the periodontium.

Root resection on unsplinted mandibular molars may not be as successful as with maxillary molars, although this should not be a major deterrent in considering this option during treatment planning (Fig. 18-53). This is a relatively inexpensive approach to tooth retention and has a reasonably good prognosis if the tooth opposes a full denture or the occlusion is otherwise very light. If occlusal forces are heavy, especially on the unsupported half of the crown, fracture of the remaining root is likely (Fig. 18-54).

Hemisection is a much more predictable treatment plan for retention of an unsplinted molar. Generally, the value
FIGURE 18-46  A, Maxillary first molar with significant fracture of the palatal cusp due to bruxism. B, After palatal root resection. The midpalatal furcation level should be nearly equal to the level of interproximal crestal bone for optimal postoperative biological width. C, Three weeks posttreatment. D, Posttreatment radiograph of the same molar after palatal root resectional (see Fig. 18-22, B, which is the preoperative radiograph of this tooth). E, One-year reevaluation photograph of the molar, indicating normal palatal sulcus depth.

FIGURE 18-47  Full crown on a resected maxillary first molar with the palatal root removed is narrower buccal lingually than a normal molar crown.

**FIGURE 18-49** A, Preoperative radiograph of maxillary first premolar with lateral lesion due to furcation perforation from post preparation. B, Postoperative radiograph indicating resection of buccal root and repair of perforation with mineral trioxide aggregate. C, One-year reevaluation indicating root fracture that occurred under normal function. The tooth was extracted.
A, Vertical fracture of the mesial root of the mandibular first molar was confirmed by surgical exploration. This is unusual in a tooth without previous root canal treatment. B, Completed treatment in the distal root; note the two canals. C, Reexamination radiograph 9 months. Patient is symptom free, and tooth/bridge is functional.

FIGURE 18-50 A, Surgical exposure of a mandibular first molar with severe periodontal bone loss around the entire distal root. B, Immediate postoperative radiograph indicating resection of distal root. Prognosis is guarded for tooth and prosthesis because of minimal bone support. C, One-year posttreatment reevaluation indicating complete healing of original lesion. The bridge is in normal function, and the prognosis is greatly improved.

FIGURE 18-51 A, Vertical fracture of the mesial root of the mandibular first molar was confirmed by surgical exploration. This is unusual in a tooth without previous root canal treatment. B, Completed treatment in the distal root; note the two canals. C, Reexamination radiograph 9 months. Patient is symptom free, and tooth/bridge is functional.
FIGURE 18-52  A, Mandibular left first molar with vertical fracture of the distal root. The entire bridge was in heavy occlusion. Occlusal reduction of wear facets was done at the time of surgery.  
B, One-year post root resection, radiograph shows complete healing of the operative site. The bridge was in normal function.  
C, Three-year reevaluation radiograph shows vertical fracture of the mesial root. The tooth and pontic were extracted.

FIGURE 18-53  A, Resection of a mesial root of a mandibular molar.  
B, Tooth was not splinted, but occlusal forces were minimal on the mesial of the tooth. Reexamination at 12 months indicates complete healing. The tooth was in normal, if light, function.

FIGURE 18-54  A, Immediate postoperative radiograph of root resection of the distal root of a mandibular second molar due to vertical root fracture.  
B, Reevaluation radiograph at 1½ years shows vertical fracture of the mesial root; the tooth was extracted. Hemisection would have been a better original solution.
of retaining of either root of a mandibular molar is questionable if there are potential bridge abutments on both sides (see Fig. 18-38), but there can be exceptions. Possibly the most useful application of hemisection in mandibular molars is for terminal teeth in the arch. A mesial root of either the first or second molar in contact with the neighbor can function quite well as a third premolar, as depicted in Fig. 18-55. Fig. 18-56 documents a very useful conversion of a molar tooth with extensive caries into a functional premolar.

Retention of the distal root will require splinting or a small bridge to the adjacent tooth. This treatment plan will serve the patient well, with a retained functional tooth having a very good prognosis (Fig. 18-57).

With the techniques described to manage problems encountered in osseous and root defects below the attachment of the periodontal ligament, many but not all teeth with various problems can be successfully retained in full function and without patient symptoms. Furthermore, prostheses that are in place and functional can be maintained as opposed to dismantling and rebuilding when not necessary.

Recent retrospective studies attempt to dispute the value of mandibular molar resections in favor of implants. The level of evidence for this claim is less than ideal (non-prospective, non-randomized, retrospective, mixed data on the causes for failure with 12 patients out of 56 having non-resective failures [21%], small “n” size study) versus a contemporary prospective study with a large “n” size, a highly controlled population, and a 10-year reexamination period that showed in excess of 93% success with the resective treatments (site-specific differences on the two studies). It is obviously difficult in these situations to make claims of superiority with one technique or the other unless careful treatment planning and treatment execution are at their highest levels.

The major challenges are to recognize these alternative possibilities during the treatment-planning phase and to either have the expertise to manage these challenges or refer the patient to someone who can. These approaches to tooth retention are reasonable, cost effective, and successful and will provide an excellent service for many patients who cannot afford or who do not desire tooth removal and replacement with fixed prostheses. Success rates for root/tooth resection are quite high based on the studies, but do also require commitment on the part of the patient to practice excellent home oral physiotherapy daily.

**FIGURE 18-55**  
*A*, Radiograph of mandibular molar that has had mesial roots treated; the distal root was not treated fully, since it will be resected (tooth hemisection) due to the large bony defect and evidence of a fracture. This approach to treatment is generally intended to be a short-term solution.  
*B*, Reevaluation radiograph at 2 1/2 years, indicating complete healing of the surgical site. The tooth was in normal function against natural teeth.
**FIGURE 18-56**  
A, Mandibular first molar with extensive caries in the distal half of the clinical crown.  
B, Occlusal relationship with opposing second premolar.  
C, After excavation, indicating unrestorability of the distal half.  
D, Posttreatment radiograph indicating resection of distal root and root canal treatment of mesial root.  
E, Functional relationship of retained mesial half with the opposing premolar.

**FIGURE 18-57**  
A, Mandibular second molar bridge abutment with advanced chronic periodontitis. The osseous defect on the mesial root is not amenable to pocket elimination surgery. Hemisection was elected as the treatment of choice.  
C, A reevaluation radiograph made 24 years later. The bridge is in normal function against natural teeth.
REFERENCES


RECOMMENDED ADDITIONAL READING
Chapter 19

Problem Solving in the Management of Tooth Fractures and Traumatic Tooth Injuries

Problem-Solving List

Problem-solving issues and challenges in the management of traumatic tooth injuries addressed in this chapter are:

**Tooth Crazes, Cracks, and Fractures**

**Traumatic Tooth Injuries**
- Concussion
- Subluxation
- Extrusive luxation
- Lateral luxation
- Intrusive luxation

**Sequelae to Luxation Injuries**
- Pulp canal obliteration
- Marginal bone loss
- Coronal discoloration
- Transient apical breakdown
- Pulpal necrosis

**Avulsion Injuries**

**Resorption Associated With Traumatic Tooth Injuries**
- Inflammatory replacement resorption and ankylosis

**Horizontal Root Fractures**
- Apical-third fractures
- Middle-third fractures
- Coronal-third fractures

**Healing Responses to Horizontally Fractured Teeth**
- Calcified union between the segments
- Bone and connective-tissue healing
- Connective-tissue or soft-tissue union
- Failure of fracture to heal

**Splinting of Traumatized Teeth**

When a Tooth is loosened by violence, but not moved out its socket, ligature alone, and astringent washes to brace the gums, are sufficient for the cure. In this case the pain ceases with the looseness of the Teeth; but if it be violent in the beginning, sedatives must be applied.11

T.G. Berdmore, 1768

Tooth Crazes, Cracks, and Fractures

The diagnosis and management of structural defects in teeth other than those caused by accidental trauma pose a unique challenge for the clinician. These defects involve posterior teeth and are usually slow to develop and manifest themselves within a variety of intertwined variables. They can be on the surface and stable, or they can migrate into the tooth, resulting in significant structural defects and clinical challenges. All defects may involve the crown, root, or both, in addition to being horizontal, vertical, or angulated.

The types of alterations in tooth structure include crazes, cracks, and fractures. Diagnosis, management, and prevention of these alterations is dependent on thorough patient assessment, identification of those factors that contribute to these defects, management of those factors when possible by the clinician, and creative measures in the overall prevention of these problems. Fractures that are the result of accidental trauma and that occur primarily in the anterior teeth are addressed in the next section of this chapter.

For purposes of clarification and clinical differentiation, the following descriptions are provided. *Crazes* are areas of...
weakness in the tooth structure where further propagation may result in a crack or fracture. These are not visible radiographically but can be seen with fiberoptic transillumination. Cracks are definite breaks in the continuity of the tooth structure beginning in the enamel or cementum. No separation is evident clinically, and these are visible with fiberoptic transillumination in which light transmission is impeded across the crack line. They may often be stained due to patient diet. Fractures exhibit definite separation of the tooth structure into two or more distinct segments and are visible clinically and sometimes radiographically. They also may exhibit stain when located coronally.

**FIGURE 19-1** A, Mandibular molar with crack lines on the mesial and marginal ridges (arrows). B, Mandibular molar with a crack running parallel to the buccal developmental groove (arrows).

**FIGURE 19-2** A, Image shows a symptomatic molar that was excavated and stained with methylene blue on the cavity floor. Note the mesial-to-distal fracture. B, Evidence of a fracture on the distal marginal ridge often results from weakened tooth structure in that area. C, Extracted tooth shows the crack (arrows) running apically down the root in a diagonal manner. Also the periodontal ligament forms a tract as the crack is propagated. Note the lack of divergence in the occlusal preparation that is necessary for seating inlays. This was probably the contributing factor in this tooth’s demise. D, After access opening, the distal fracture line can be seen to run down the distal wall. The tooth was extracted.
Many factors that predispose to these tooth defects cannot be altered or controlled by the clinician. These include masticatory accidents, bruxism, and thermal cycling. Clinical detection of these defects can be exceedingly difficult, especially in their initial stages of development or beneath extensive restorations. Additionally, radiographs are of little value in these initial stages. In some cases, surgical intervention may actually be necessary for fracture identification. Patient symptoms may mimic many other possible diagnoses, such as temporomandibular disease, sinus problems, vague headaches, and ear pain. Efficacious management of fractured teeth is highly dependent on a complete set of variables that are often not controllable by the practitioner, such as extent and size of the defect, tooth and root anatomy, position of fracture, masticatory function, and previous dental intervention.

There is a paucity of new information regarding these types of tooth defects, and therefore the reader is referred to previous editions of this text and other supportive references that will detail the challenges of the clinician faces with these types of problems. However, in the series of figures (Figs. 19-1 to 19-5), the main concepts will be highlighted for reader reference and clinical recognition. This will help differentiate these defects from those found with accidental trauma. The reader is referred to early chapters in this text that discuss many aspects of these structural defects relative to identification and management (see Chapters 1 to 5, 15, and 18).

FIGURE 19-3 Open anterior bites (A) and cross bites (B) contribute to excessive occlusal forces on the posterior teeth. C, Placement of multiple pins in a tooth for retention may lead to fractures. Note the fractures at the base of this pin (scanning electron microscopy photo). D, Traceable sinus tract to the midroot of this premolar. Note the size and shape of the intraradicular post. The tooth was fractured vertically.
Problem Solving in the Management of Tooth Fractures and Traumatic Tooth Injuries

The first and most important step in understanding how to treat these injuries is to determine the nature of trauma. This chapter will provide fundamental concepts in diagnosing and treating traumatic injuries of the more severe nature in the permanent dentition. It will also address the more common sequelae of traumatic injuries and the most appropriate methods to manage them effectively for the best outcome. Trauma ranging from luxation injuries and avulsions to horizontal root fractures will be covered in a clinically relevant manner.

Active prevention of coronal fractures in normal day-to-day living is unrealistic and a moot point. Prevention during hazardous activities such as job-related activities (e.g., during sports), however, may occur in the form of mouth protection and on-the-job training to avoid circumstances that may predispose to traumatic incidents. Although such incidents are uncommon, the major result of these types of fractures is dental trauma, whether direct or indirect; accidental injuries remain the predominant type reported. This implies that management of the crown fracture will usually fall into the category of a dental emergency, and principles cited in Chapters 1, 4, and 15—diagnosis, treatment planning, anesthesia, analgesics, and antibiotics—should be integrated into the total case management.

In cases in which an acute trauma accident has resulted in a crown fracture (Fig. 19-6), pulpal preservation is crucial when root formation is incomplete (see Chapter 7). Teeth with coronal and coronal-root fractures and completed root development can and should be retained, even if adjunctive treatment is indicated. The range of management may be limited to dentin protection and a bonded restoration to a root canal procedure and, in some cases, root extrusion, crown lengthening, a post, a core buildup, or acid-etched bonded core and crown (Figs. 19-7 and 19-8).

Traumatic Tooth Injuries

The management of traumatic injuries is a constant source of difficulty for the clinician because of the complexity in diagnosing and treating these injuries properly. The most important concept of managing dental trauma is to feel confident in the diagnosis. By knowing the type of damage that has occurred to the dentition and supporting tissues, the clinician will be better suited to treat the affected tooth or teeth and the sequelae of these types of injuries. In the present litigious society, every clinician should know the proper guidelines for treatment of traumatized teeth to avoid the potential risk of litigation.

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**FIGURE 19-4** A, Placement of a fiberoptic on a symptomatic maxillary premolar. Note that the light does not pass the fracture line. Transillumination can be more dramatic without the overhead light. B, Clinically deep probing in a narrow channel. C, Tissue reflection allows for visualization of the fracture (arrows).

**FIGURE 19-5** A proximal view of the extracted tooth; note the oblique fracture line. Clinical view in Fig. 19-4, A.
Luxation injuries present a greater demand for the clinician in their management, as they must be diagnosed accurately.1,2,4,17,22,23 The following are the more commonly accepted definitions of luxation injuries, arranged (in order of damage to the tooth and surrounding tissues) from the least severe to the most destructive type. A **luxation** is defined as a dislocation of the tooth from its normal physiologic position in the socket. However, as will be seen in the specific descriptions of these injuries, a large variety of luxation injuries exist, so a number of different classifications have been suggested.4

**Concussion**

A **concussion injury** is defined as a relatively minor blow to the tooth in which the affected tooth is not damaged, but the periodontium becomes inflamed. Typically, patients experience mastication sensitivity or pain on brushing or pressure on the tooth. No splinting is required in these types of luxation, and only palliative treatment is required. In most instances, reducing the occlusion is all that is required. Patients should be reevaluated within the first 2 weeks after the injury to ensure that no further treatment is required. In the vast majority of cases, root canal therapy is not indicated, because only a small percentage of these injuries become necrotic. Monitoring pulpal status for 1 year is recommended (Fig. 19-9).23

**Subluxation**

A **subluxation** is slightly more severe than a concussion of the tooth, because increased mobility exists that is comparable with a periodontally involved tooth (mobility +1 to +2).4,23 Although the tooth is more mobile than it was before the injury, it is at the discretion of the clinician to determine whether splinting is required. In most instances, no splint is required unless additional trauma to the tooth or the area is...
Problem Solving in the Management of Tooth Fractures and Traumatic Tooth Injuries

Chapter 19

Figure 19-10
A, Subluxated tooth with the typical clinical presentation of a bleeding epithelial attachment apparatus. B, 30 months after a subluxation injury, radiograph shows ankylosis in the midroot portion. The patient is symptom free.

Figure 19-9
History of a concussion injury on the right central incisor with no signs or symptoms at the time of injury. Six-month reexamination shows a darkened tooth that does not respond to sensibility testing.

Figure 19-11
An extrusively luxated central incisor. Note that the tooth is dislocated along its long axis.

Extrusive Luxation

In extrusive luxation injuries, the tooth is dislocated along its long axis and can be displaced almost entirely out of the socket (Fig. 19-11). These injuries are significantly more severe than either concussion or subluxation injuries. Radiographically there may be an increased periodontal ligament space apically. Extrusive luxation injuries account for only 1% of total traumatic dental injuries. Although the use of anesthesia is not always required when dealing with younger patients, it is strongly recommended.

Initially the soft-tissue damage must be assessed and managed properly. The tooth is carefully and accurately repositioned in the socket. This procedure may be performed manually with gauze or with forceps (if significant dislocation has occurred) to replace the tooth gently into its original position. Keep in mind that teeth will usually realign into their original position in the socket without significant forces being required. However, the greater the post-trauma time period before treatment, the higher the likelihood of coagulation in the socket; therefore additional force may be required to accomplish the repositioning.

Sensibility testing is used initially, with variable or no responses expected, and again on reexamination to determine the pulpal status. This is especially important in teeth with immature root formation. If there is no response in the tooth with a fully formed apex, necrosis can be assumed to have occurred.

In extrusive luxation injuries, the neurovascular bundle is usually disrupted, and therefore the blood supply is lost to the tooth. In adult patients and in young patients with
closed apices, the likelihood of revascularization is extremely low and should not be considered a likely consequence of the healing process. Because the majority of these cases become necrotic, the patient should be notified that a root canal procedure will be necessary within a couple of weeks of the trauma or earlier at the time of splint removal. In all cases of extrusive luxation injuries, the teeth must be splinted.12

All luxation injuries require splints, using one nontraumatized tooth on either side of the traumatized tooth. For example, if only one tooth is luxated, then one healthy tooth on either side of the traumatized tooth should be included in the splint. If two teeth are luxated, then a total of six teeth should be included in the splint (two teeth on either side of the two teeth that are traumatized for a total of six). The type of splint (physiologic, rigid, or passive) is inconsequential to the healing process. However, in most instances, a nonrigid splint is easier to place and will avoid the possibility of exerting excessive pressure on the damaged periodontal ligament.37

The splint should be placed for up to 2 weeks. During this period, the periodontium will stabilize the tooth sufficiently, and minor to normal mobility will be noted following splint removal. Should the tooth be excessively mobile compared with a nontraumatized contralateral tooth, the splint may remain in place until normal mobility is noted. The use of a physiologic passive or flexible splint is indicated for any type of luxation injury.4,37 Most clinicians can use a composite-based splint, because it is the most convenient to use and place on the traumatized teeth. Should the splint remain in place for longer periods of time, no negative sequelae will result. Non-rigid splinting does not cause damage to the supporting tissues or to the tooth.

Lateral Luxation

Lateral luxation injuries are defined as a dislocation of the tooth in a mesial, distal, facial, or lingual (palatal) direction, with comminution or fracture of the bony alveolar socket. It is rare for a patient to have a pure lateral luxation. Most cases will have both a lateral and an extrusive component (Fig. 19-12). Lateral luxation injuries are considered more severe than extrusive luxation injuries because of the associated fracture or splintering of the bone in the alveolar socket.22

The assessment phase is similar to that for extrusive injuries. In these instances, a blunt instrument should be inserted gently into the alveolar socket to move the fractured bony segment back to its original position before the tooth can be properly repositioned.4,23 Care should be exercised to prevent damage to the healthy periodontium remaining in the socket or on the tooth. Once the tooth is repositioned, a splint should be placed to hold the traumatized tooth (or teeth) in position for 10 to 14 days. If bony fracture is noted, the splint should remain in place for 6 to 8 weeks to allow proper healing of the alveolar socket. Whenever bone is fractured, a more rigid splint should be placed in lieu of a flexible or physiologic splint.

Because of the nature of the damage with lateral luxation injuries, the probability of pulp damage and subsequent endodontic therapy is high.4,18,22,32 As with all luxation injuries, the older the patient (i.e., the smaller the diameter of the apical foramen), the less likely the tooth will regain its vascular supply; therefore a root canal procedure will be necessary. With both lateral and extrusive luxation injuries, external resorption (ER) or internal resorption (IR) is not a typical sequela; the patient should be informed that the long-term prognosis of these teeth is excellent.

Intrusive Luxation

Intrusive luxation injuries are the most severe type of luxation injury and therefore have the poorest prognosis.4,7,9,30,33 With intrusive luxation injuries, the tooth is dislocated apically into the alveolar socket. The tooth is sometimes displaced so far apically that the clinician may not be able to visualize the incisal edge. There is seldom any observable mobility because of its new position deep within the alveolar bone. These injuries cause severe damage to the neurovascular bundle, pulp, and periodontium.18 The blood supply and neurovascular tissues are crushed completely. In teeth with partially to completely closed apices, the pulpal prognosis is extremely poor, with almost a 100% probability of pulpal necrosis. Because of the severe damage to the periodontium,
the probability of ER is extremely high in these injuries; therefore the patient should be warned that the prognosis of an intrusively luxated tooth is guarded.

Clinically, the tooth is usually immobile and gives a high metallic sound similar to what would be found in ankylosis. Sensibility tests will probably be negative. In teeth with immature root formation, pulpal revascularization may occur (see Chapter 13).

Unfortunately, the proper treatment of intrusive luxation injuries remains a mystery, because numerous clinical research articles with various treatment protocols have led to conflicting results. Current philosophy of management includes the following. Teeth with incomplete root formation should be allowed to reposition spontaneously. If no movement is noted within 3 weeks, rapid orthodontic extrusion is recommended. Teeth with complete root formation should be repositioned as soon as possible. The pulp will probably be necrotic and root canal procedures indicated using calcium hydroxide (Ca(OH)₂) as a temporary dressing. Appropriate treatment regimens are based on severity of the injury, age of the patient, status of the root development, and time subsequent to injury. Patients should be informed in a compassionate manner of the extremely poor prognosis associated with these injuries.

In some cases, the ideal treatment is to allow the teeth to erupt passively on their own. This treatment modality appears to be better suited for patients who are young with minimal intrusion. Teeth that are actively repositioned with forceps, without the use of a surgical flap, have also been successful. However, several authors suggest that the ideal treatment for intrusively luxated teeth is a function of the degree of damage and the age of the patient.

If the teeth do not or are not allowed to re-erupt into their normal physiologic position in the arch (Fig. 19-13), then a high probability exists that the intruded teeth will undergo inflammatory replacement resorption (IRR). This type of resorption is also mistakenly called ankylosis; however, replacement resorption is the active process of tooth destruction, and replacement with bone ankylosis is the result of this process.

Because of the severe damage to the periodontium in an intrusive luxation injury, the traumatized tooth will often begin to resorb, although the process is chronic in nature, taking months or years to eventually destroy the affected tooth. The tooth is literally locked into position and cannot be moved orthodontically or manually with forceps. If an extraction is attempted, the bone surrounding the tooth will often be extracted along with the tooth. Unless the apices are wide open and the tooth spontaneously re-erupts, root canal treatment should commence as soon as possible after the tooth is stabilized.

Because the pulps in the vast majority of these teeth become necrotic shortly after the injury, root canal treatment is indicated in 100% of the cases if the apices are closed. The only exception is whether the tooth with an open apex remains vital during its spontaneous re-eruption to its original position in the arch. In these few selected cases, the pulp remains vital, and little or no resorption of the root surface occurs. These cases are the exception rather than the rule; in the vast majority of intrusively luxated teeth, the pulp will become necrotic, and the root surface will undergo IRR.

**FIGURE 19-13** A, Radiographic appearance of an intrusively luxated tooth. B, During reeruption, resorption is evident.
Sequelae to Luxation Injuries

Luxation injuries have numerous sequelae. The most typical will be presented here with the appropriate treatment, when indicated, and the probabilities of each so that the patient can be provided with the appropriate information regarding the long-term status of the luxated tooth. The most typical sequelae to luxation injuries are pulp canal obliteration (PCO), marginal bone loss, discoloration of the crown, transient apical breakdown (TAB), pulpal necrosis, and resorption of the root.

The patient should be advised of the sequelae that have the greatest probability relative to the nature of their trauma. This also implies that the patient must be told of the potential for long-term treatment and follow-up of these injuries. On the other hand, a knowledgeable patient can aid the clinician in monitoring the typical sequelae to injury of both the tooth and its supporting structures.

Pulp Canal Obliteration

Pulp canal obliteration (PCO) is a typical sequela to many forms of trauma, in particular to luxation injuries. In the literature, PCO has been found clinically to range between 6% and 35%, averaging about one in five luxated teeth (20%). In these situations, the pulp chamber, the root canal system, or both becomes partially or completely calcified to the extent that the canal system may become undetectable on the radiograph (Fig. 19-14 [see Chapter 13]). The presence of PCO is not an indication for a root canal procedure. In the majority of cases, PCO does not lead to pulpal necrosis. In fact, the probability of pulpal necrosis after PCO is quite low, ranging from 1% to a high of 13%.

Marginal Bone Loss

The probability of marginal bone loss is less than one in four patients and ranges between 5% and 24%. An extreme example of this type of bone loss is seen in Fig. 19-15, which demonstrates severe marginal bone loss after an extrusive luxation injury in a medically compromised patient. This bone loss occurred over a 6-week period and was likely the result of both the luxation injury and the medical condition of the patient. In most instances, little can be done to prevent marginal bone loss; however, palliative treatment should be...
instituted (e.g., 0.12% chlorhexidine rinses and oral hygiene instruction) when appropriate.

**Coronal Discoloration**

A typical sequela to trauma is a discoloration of the crown of the traumatized tooth. Color changes are not an automatic indication for root canal treatment. Fundamentally, two types of discoloration are seen in traumatized teeth. The first type of change in color that can occur as a result of trauma is that of a deep yellow coloring of the crown. These teeth are typically vital and are discolored because of severe calcification of the crown and root canal system. These teeth may or may not respond to the electric pulp tester (EPT) or thermal tests. Regardless of the results of sensitivity testing, root canal treatment is indicated only when the patient has symptoms of irreversible pulpitis or pulpal necrosis. A calcified tooth typically gives no response to either the EPT or a cold test. However, without radiographic evidence of periapical pathosis, no root canal procedure is indicated. The pulps in these teeth often remain vital and do not become necrotic.

If teeth display a grayish, pinkish, or reddish hue, and an intense light source will not pass through the tooth (fiberoptic), the pulp is usually necrotic or damaged significantly, and a root canal procedure is indicated (Fig. 19-16; see Fig. 19-8).

**Transient Apical Breakdown**

The term transient apical breakdown (TAB) refers to a persistent radiolucency associated with a luxated tooth; however, sensitivity tests indicate a normal pulp. The radiolucency may persist for upwards of 1 year before a normal bony architecture is noted. This is an uncommon sequela to luxation injuries, and less than 4% of all traumatized teeth will be affected by this condition.

**Pulpal Necrosis**

Pulpal necrosis is a common sequela after luxation injuries of the more severe type, but the age of the patient (i.e., maturity of the apex) and severity of the trauma play a role. The more severe the trauma, the more likely a pulp will become necrotic. In younger patients, the maturity of the apical foramen will play a significant role in revascularization of the tooth. Revascularization is not a common sequela to luxation injuries and is always the exception rather than the rule. When all forms of luxation injuries are grouped together, the probability of pulpal necrosis ranges from a low of 15% to a high of 98%. Again, pulpal necrosis in luxated teeth is a function of the maturity of the tooth and, more specifically, the type of luxation injury.

**Avulsion Injuries**

Avulsion injuries are defined as a complete dislocation of the tooth from its alveolar socket (Fig. 19-17). Regardless of the extraoral period or the age of the patient, these injuries always have a guarded prognosis. Even under controlled conditions when a tooth is intentionally extracted and replanted within its socket, the prognosis is guarded because the likelihood of IRR is high (Fig. 19-18); therefore this sequela should be discussed with the patient. Avulsion injuries must be treated aggressively and competently for the patient to maintain the avulsed tooth for a reasonable period of time (Fig. 19-19).

The ideal treatment for the avulsed tooth is to replace it into the socket as soon as possible after the injury. If the patient or someone at the scene of the trauma can replant the tooth, a better prognosis will be obtained versus placing the tooth in a storage medium. If replantation is not possible, then placing the tooth in milk is the next best treatment option. To date, no studies have demonstrated that any substance other than milk is a better storage medium within the first couple of hours after the avulsion injury. Once the patient has arrived at the dental office, the tooth should be

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**FIGURE 19-16** Hemorrhage and pinkish to red discoloration in the crown of a central incisor following trauma.

**FIGURE 19-17** Tooth avulsion with minimal tissue damage.
A, This 24-year-old female presented with an irregular tooth margin on her central incisor that was irritating her gingival tissues. The tooth had been avulsed 10 years previously, and no treatment other than replantation was performed at that time. B, Radiographic image shows extensive inflammatory root resorption. C, The extracted crown shows the moth-eaten nature of the process.

A, Avulsed right central incisor out of the socket less than 1 hour. Replanted and splinted. B, Within a few weeks, significant inflammatory replacement resorption is present. C, Placement of calcium hydroxide at various intervals. D, Advanced replacement resorption at 12 months, yet the lamina dura has reformed over the resorbed root end.
briefly rinsed in saline and replanted. Determine whether the traumatic injury was a clean or dirty wound.

If a high probability exists that a foreign body (e.g., stone, metallic object, or dirt) may have entered the alveolar socket, a radiograph of the empty socket should be taken before replantation. If the radiograph reveals any foreign body inside the alveolar socket, it should be rinsed aggressively to eliminate the object. After the socket is clean of any foreign object or objects, the tooth should be replanted as quickly as possible. The only exception to this rule is whether the tooth has been extraoral and dry for more than 60 minutes. Root canal treatment may then be performed before replantation, because a few extra minutes will not affect the prognosis negatively.

If the avulsed tooth has a closed apex and has already been replanted or has been kept in a special storage medium (e.g., milk, saline, Hank's Balanced Salt Solution) and the extraoral dry time for the periodontal ligament and its cells is less than 60 minutes, adhere to the following guidelines:

- Clean the area and replant the tooth as soon as possible if not already done (Fig. 19-20). Suture any lacerations. The possibility of revascularization is higher than in any other situation, but the probability is nevertheless quite low.
- Administer systemic antibiotics: doxycycline 200 mg immediately and 100 mg twice daily for 7 days. Consider age of the patient for possible discoloration; if necessary switch to penicillin V. Consider tetanus depending on case circumstances.
- Root canal treatment within 7 to 10 days; place Ca(OH)₂.
- Splint the tooth for 10 to 14 days with composite, wire, or a combination of flexible methods.
- Reevaluate the patient every 2 weeks for the first 3 months.

Under the same circumstances, if the tooth extraoral dry time is greater than 60 minutes, the prognosis is poor. Remember that if a closed-apex tooth has been avulsed and dry for more than 1 hour, the prognosis is poor. Because the probability of IRR is extremely high (Fig. 19-21), inform the patient that the long-term prognosis will be a function of how rapidly replacement resorption may occur. Nonetheless, because teeth that have been extraoral and dry for up to 48 hours have been shown to be functional for 7 years, keep in mind that few contraindications prevent the practitioner

FIGURE 19-20 Traumatic avulsion with adjacent soft tissue damage.

FIGURE 19-21 A, Extensive external resorption following replanted central incisors. Calcium hydroxide was placed. B, Histologic appearance of inflammatory external resorption. Note how the multinucleated cells invade the dentin (H&E stain ×100).
Problem Solving in the Management of Tooth Fractures and Traumatic Tooth Injuries

From replanting an avulsed tooth regardless of the extraoral time period. The tooth is splinted for 10 to 14 days and root canal procedures started within 7 to 10 days after replantation. Ca(OH)₂ is also indicated in these cases until the root canal is obturated.

Unlike most other cases of healing, an older patient has a better prognosis than a young patient with respect to avulsed teeth. In the adult patient, the root canal system and pulp chamber has become more calcified and is usually smaller in volume than it is in the young patient. In addition, the dentinal tubules are more calcified and smaller in volume. This prevents the spread of inflammatory resorption and provides the older patient with a more favorable prognosis with respect to avulsed teeth.

Should the tooth begin to demonstrate IRR, over time, the patient will lose the tooth. However, IRR is chronic, and the process takes months to years before the tooth is completely resorbed. The advantage of allowing the tooth to resorb is that the alveolar socket will gradually fill in with bone. Additionally, the patient will not have an esthetic defect such as is the case if the tooth were not replanted or extracted prematurely and the socket had to fill in with bone. By letting the tooth resorb, the entire root will be eventually replaced with bone, and the alveolar socket will completely fill in with healthy bone that can be used for an implant or an esthetic bridge.

If the avulsed tooth has an open apex and the extraoral drying time is less than 60 minutes, consider the following guidelines:

- Replant the tooth as quickly as possible. The possibility of revascularization is higher than in any other situation, but the probability of revascularization is nevertheless quite low.
- Recall the patient for evaluation every 2 weeks for the first 3 months to determine whether the revascularization process is occurring. In all cases where revascularization is attempted, both the patient and the clinician should know that the prognosis is guarded; without proper follow-up treatment, the tooth can be lost in as little as 5 weeks. If possible, include the contralateral tooth in the follow-up radiograph to compare the development of the avulsed tooth with the nontraumatized contralateral tooth.
- Splint the tooth for 10 to 14 days with a flexible device if possible. The type of splint, rigidity, or length of time the splint is in place are not critical to the success of the replantation; however, the splint should be secured to stabilize the tooth for the time period. Fig. 19-22 shows wire and composite splints. A bonded composite is ideal for traumatic injuries and the tooth can be checked for stabilization without ruining the splint. Should additional time be required for stabilization of the tooth, replace the wire with rubber bands, and the splint will again be functional. The use of wires to splint interproximally is discouraged because significant soft-tissue damage usually occurs (Fig. 19-22).
- Any evidence of resorption or lack of development of the traumatized tooth noted radiographically warrants root canal treatment (Fig. 19-23) with apexification procedures (see Chapter 13). Teeth with open apices typically have extremely large canals and pulp chambers. Should the revascularization procedure fail, a large quantity of necrotic pulpal tissue and bacteria will induce a rapid and extremely destructive resorption of the root. This can result in loss of the tooth in less than 2 to 3 months.

If the avulsed tooth has an open apex and the extraoral drying time is more than 60 minutes, consider the following guidelines:
• Little chance exists that revascularization will take place under these circumstances.
• The ideal treatment for these cases is to replant the tooth after performing root canal therapy extraorally and placing root-end filling.
• In all cases of an avulsed tooth with open apex and more than 1 hour of extraoral dry time, the prognosis is very poor; eventual loss of the tooth should be considered in the long-term treatment plan. If so, the tooth can be decoronated at a later time with a tissue flap covering the root to preserve the alveolar ridge.
• If replanted before root canal procedures, access the tooth, place Ca(OH)\(_2\) and perform root canal treatment within 7 to 10 days.

These areas cannot be treated; however, removing the necrotic and bacteria-infested pulpal tissue within the root canal system can prevent additional damage. Studies suggest the long-term use of Ca(OH)\(_2\) (6 to 12 months) as a therapeutic agent to prevent resorption, but this treatment has recently been shown to decrease the fracture resistance of dentin and the ability of healing periodontal ligament cells to proliferate, thereby causing an increase in IRR (Fig. 19-26).\(^{10,13,21}\) This resorptive process is seen in intrusive luxation injuries and will eventually cause loss of the tooth. The process occurs

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**Resorption Associated With Traumatic Tooth Injuries**

Resorption can and does play a significant role as a more severe sequela to traumatic injuries. The basic concepts in resorption are discussed in Chapter 13. The process as it relates to the unique challenges faced in managing traumatic injuries will be discussed here, focusing primarily on external inflammatory resorption (Fig. 19-24).

Inflammatory resorption that occurs externally is rapid and extremely destructive, but for the most part it can be prevented or minimized by proper cleaning and shaping of the root canal system. This resorption is characterized radiographically by moderate to large “scooped-out” radiolucent areas on the root of the traumatized tooth (Fig. 19-25).

**FIGURE 19-24** Excessive drying and treatment mismanagement prior to replantation resulted in significant resorption.

**FIGURE 19-25** A, The central incisor was avulsed and left out of the mouth for over 48 hours. Root treatment was then done, and the tooth was replanted and splinted. B, One year later, there is evidence of healing following a small amount of resorption on the mesial surface (arrow). The tooth is stable and functional.
over several months to years before it becomes critical and the tooth is subsequently lost. The patient should be made aware of this type of sequela, and its ramifications should be included in the long-term treatment plan of the patient. Avulsion injuries will also demonstrate IRR, but this can take months to years before it becomes apparent. The process is not self-limiting, and no known treatment prevents its occurrence or spread throughout the root.

**Inflammatory Replacement Resorption and Ankylosis**

As noted earlier, IRR is commonly and mistakenly called ankylosis. *Inflammatory replacement resorption* is the term used to designate the actual process of root resorption and its replacement with hard tissue. Ankylosis is the result of this process by which the tooth (specifically the periodontium and radicular structures) becomes locked in the cancellous bone (Fig. 19-27). As defined in the medical literature, it is a solid fixation of a tooth resulting from fusion of the cementum and alveolar bone. As IRR destroys the cementum and dentin, bone is deposited directly and contiguously within the resorbed tooth structure. The PDL is lost, and bone is adjacent to cementum and dentin. No soft tissue or PDL exists between the bone and tooth, and because the resorptive process is irregular and quite invasive, the tooth becomes locked into the cancellous bone, resulting in no mobility of the affected tooth.

The currently accepted cause of IRR is severe damage or complete loss of the PDL, usually associated with an avulsion injury or intrusion of a tooth into its socket. It is also seen in the elderly and occasionally in younger patients. There seems to be virtually no correlation of IRR with bacteria or necrotic pulpal tissue, because it can and does occur in avulsed teeth with previous root canal therapy. In addition, patients who have avulsed a tooth and have no occurrence of IRR will still demonstrate inflammatory resorption in the affected tooth. Once initiated, inflammatory resorption can and usually does continue until the entire tooth is lost.

Two types of IRR should be noted. The first type is transient RR in which the tooth undergoes IRR, but the damage to the PDL is minor and the ligament is able to heal, which prevents the continuation of the resorptive process. The other type that is more common is progressive IRR in which the resorptive process continues and eventually destroys the entire root structure, thereby causing premature loss of the tooth. IRR is chronic in nature and therefore usually a very slow process that occurs over several months to years. The resorption is always initiated on the external root surface where the PDL was damaged, usually by trauma (i.e., avulsion or intrusive luxation). Similar to inflammatory resorption, IRR is not self-limiting and therefore will continue until the entire tooth is lost.

The radiographic characteristics of IRR are completely unlike those of inflammatory resorption. Because the etiology is entirely different from inflammatory resorption, the radiographic presentation is also unique. IRR results in destruction of the root; however, this destruction is rapidly replaced with bone, and therefore the radiographic characteristic is that of a radiopacity and not a radiolucency, as is the case with IRR. Similar to inflammatory resorption, the defects are usually irregular and asymmetric, presenting initially on the mesial or distal root surface. Younger patients will have a more rapid course of RR, whereas older patients have the best prognosis because of the chronicity of this very destructive process.

The onset of IRR is insidious and difficult to see unless specifically looking for signs of IRR and minor changes in

**FIGURE 19-26** A, Both central incisors were avulsed and replanted within 2 hours. B, The root canal treatment was done within 1 month. C, Three years later, the resorptive process is present in both teeth and more advanced in the left central incisor.
Inflammatory resorption and IRR are similar in their clinical presentation. Neither is associated with symptoms or soft-tissue changes. Because of their insidious onset, the diagnosis is often made during review of routine radiographs. These types of resorptive defects should be anticipated whenever a history of trauma exists (i.e., avulsion or luxation injury) or attempts have been made to treat the traumatic injury. Sinus tracts or other soft-tissue manifestations are rarely associated with either of these resorptive processes.

Treating IRR by removing the infected pulpal tissue is of little value, unlike with inflammatory resorption. In fact, no current techniques or medicaments have demonstrated reliable and valid therapeutic advantages for the prevention or inhibition of IRR. Enamel matrix proteins have been recommended as a medicament to inhibit inflammatory resorption, IRR, or both in animal models. However, investigators have...
Chapter 19 | Problem Solving in the Management of Tooth Fractures and Traumatic Tooth Injuries

failed to substantiate these recommendations, and it is likely that until the cause of IRR has been discovered, a suitable treatment to prevent or inhibit its occurrence will not be available. When IRR is identified, the patient must be informed of the extremely destructive nature of this process and advised to consider the long-term consequences of loss of the affected tooth.

Horizontal Root Fractures

Horizontal root fractures (HRF) are classified into one of three categories: apical-, middle-, or coronal-third fractures. Most apical and many middle-third fractures may require splinting; however, because these teeth should be immobilized for at least 6 to 8 weeks, some type of stabilization is strongly recommended depending on the individual case circumstances. Most of these patients are young and often extremely active. During the healing period, fractured teeth, although not necessarily mobile from the trauma, must be splinted to prevent additional damage during the 6 to 8 weeks in which healing takes place. Unlike luxation and avulsion injuries, rigid splinting of HRF teeth is mandatory in all cases to obtain successful healing and prevent undesired sequelae.

Apical-Third Fractures

Apical-third HRF, as the name implies, occur in the apical third of the root through cementum, dentin, and pulpal tissue. A radiograph should always be exposed before the tooth is repositioned to determine the extent of the fracture.

Apical-third fractures, especially in the central incisors, typically do not require splinting because of the amount of bone surrounding the coronal segment of the root that has been displaced (Fig. 19-29). The tooth should be repositioned if displaced, and an additional radiograph should be exposed to verify correct repositioning of the two segments. Splinting is indicated if the coronal segment is mobile (usually 6 to 8 weeks or longer); however, because most HRF occur in anterior maxillary teeth, the roots are stable because of the amount of supporting bone. In horizontal fractures, two teeth on either side of the traumatized tooth should be splinted because of the need for rigid splinting of the segments.

Root canal treatment is not indicated in most instances, because only 20% to 44% of the pulps become nonvital. When treatment is indicated, only the coronal segment should be treated. The apical segment will maintain its vitality and usually undergoes significant calcification of the canal system. Sensibility tests should not be considered until at least 4 to 6 weeks after the trauma, because these tests are usually invalid immediately after the trauma.

Middle-Third Fractures

As is the case with apical-third fractures, all middle-third HRF should be radiographed to determine the extent of damage to the root and surrounding tissues. Repositioning of the tooth should be completed with forceps or 2 × 2 gauze, and the splint should remain in place for at least 6 to 8 weeks (Fig. 19-30). If a root canal procedure is indicated from radiographs, patient symptoms, or clinical tests, it should be completed as soon as the diagnosis of necrotic pulp is established. As with apical-third fractures, the apical segment will remain vital, and this segment will not need treatment unless radiographic signs indicate pathologic changes.

Coronal-Third Fractures

Coronal root fractures are the most difficult cases to treat because of their location and the possibility for extreme
mobility of the fractured coronal root segment (Fig. 19-31). Depending on the location of the fracture, immediate stabilization is required, and the need for root canal treatment is more probable than in the other two situations. If the clinician can probe periodontally to the fracture site, then the coronal segment should be removed, and a treatment plan for the apical segment must be determined. In these cases, salivary contamination will have occurred and the two segments will not heal properly. In these circumstances, once the coronal segment is removed, the apical segment can be orthodontically moved coronally and a post, core, and crown can be fabricated to save the apical segment of the tooth. However, depending on the length of the tooth and the shape of the root, this is not always feasible; in these cases the tooth must be extracted.

### Healing Responses to Horizontally Fractured Teeth

Four types of healing or tissue responses typically occur with horizontally fractured teeth: calcified union between the segments, bone and connective-tissue healing, connective-tissue or soft-tissue union, and failure to heal. The first three represent an adequate healing response from proper stabilization, but a calcific union is the desired ideal result.

#### Calcified Union Between the Segments

This type of healing occurs when rigid stabilization of the two segments has been maintained. In this case, a calcific union occurs between the two segments, and radiographically little or no radiolucent line is seen from the original fractured segment (Fig. 19-32). The mobility of the tooth is within normal limits, and the pulp maintains its responsiveness to sensibility testing. The patient remains symptom free and is able to function normally on the tooth. This healing usually takes at least 8 to 12 weeks to occur. If the tooth should darken coronally and healing of the horizontal fracture is evident, then a root canal procedure is indicated (Fig. 19-33).
Bone and Connective-Tissue Healing

This type of healing usually occurs in young patients in whom the maxillary bone is still developing (Fig. 19-34). The two segments become separated over time (usually months), with normal periodontal ligament surrounding each segment. There may be several millimeters between the two segments, which are separated by normal bone. Additional treatment is not needed, and the patient can function normally on the previously fractured segment. The pulp maintains its vitality in both segments, and no additional follow-up is required. However, in those cases in which the pulp has not retained its vitality and root canal treatment is indicated, mineral trioxide aggregate (MTA) can be used (see Fig. 19-34, B). In this case, the segments were not closely approximated, and the apical portion was filled with gutta-percha and sealer. Then there was an unsuccessful attempt to orthodontically reposition the coronal segment. The coronal portion was filled with MTA and over time actually separated even more with an ingrowth of bone and connective tissue between the segments—8 years following the original trauma.

Connective-Tissue or Soft-Tissue Union

These cases heal with a normal periodontal ligament between the two segments that are in close approximation to each other (Fig. 19-35). Radiographically a normal periodontal ligament is noted between the two segments, and mobility is within normal limits. Both segments maintain their vitality, and no additional treatment is indicated.

Failure of Fracture to Heal

In cases in which a union of the two segments is not achieved, the patient may become symptomatic during the splinting period, or radiographic signs of failure to heal will be apparent. The classical presentation is a semilunar radiolucency at the fractured segment on both sides of the fracture, and often a sinus tract develops that can be traced to the fractured area (Fig. 19-36). Depending on whether a periodontal probing to the fractured area can be determined,
the prognosis is guarded to poor in most cases. Whenever the periodontal probe can be placed to the fracture site, the prognosis is poor, and the tooth will not heal properly. In most instances, the coronal segment must be removed and a determination made regarding saving the apical segment. These cases involve complex treatment plans, and usually integrated (periodontal, restorative, and endodontic) treatment is required. The clinician must determine whether an implant versus an extensive and complex treatment plan to save the tooth is warranted. If the periodontal probings of the coronal segment are within normal limits, then stabilization of the coronal segment, root canal treatment of that segment, and appropriate restorative treatment can be used to save the fractured tooth. The determining factor in these cases is always whether the coronal segment can be stabilized adequately. Significant mobility of the coronal segment always contraindicates any additional treatment of this segment.

### Splinting of Traumatized Teeth

Over the years, there has been an interesting evolution on whether or not to splint, when to splint, the type of splint, and the length of splinting times. The previous discussion provided indications for each trauma type, but as a summary, the concise information provided in Table 19-1 should guide the clinician in splinting times for traumatized teeth.

#### TABLE 19-1 Splinting Times

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>Splinting Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subluxation</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Extrusive luxation</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Avulsion</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Lateral luxation</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Root fracture (middle third)</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Alveolar fracture</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Root fracture (coronal third)</td>
<td>4 months</td>
</tr>
</tbody>
</table>

**FIGURE 19-35** Connective-tissue healing of the two segments in horizontally fractured roots and various levels.

**FIGURE 19-36** A and B, Examples of horizontal root-fractured teeth that failed to heal properly. Note the semilunar radiolucencies on either side of the fracture line in A. A sinus tract can be traced to the fracture line in A, while resorption of the coronal segment is beginning in B.
REFERENCES

8. Andreasen JO, Bakland LK, Andreasen FM: Traumatic intrusion of permanent teeth Part 2. A clinical study of the effect of preinjury and injury factors, such as sex, age, stage of root development, tooth location, and extent of injury including number of intruded teeth on 140 intruded permanent teeth, Dent Traumatol 22:90-98, 2006.

RECOMMENDED ADDITIONAL READING

Chapter 20

Problem Solving the Challenges Faced in the Restoration of Endodontically Treated Teeth

I have made a diligent search to find whether or not teeth from which the pulp had been removed, and the canals and pulp chamber filled without admitting the fluids of the mouth, were subject to a similar deterioration of strength. It is now well known that teeth treated in this way retain their color almost perfectly; and from my observation of the relation of color to strength of the teeth I am prepared to entertain the suppositions that they retain their strength also. Only one tooth came into my hands with a root filling. It was a central incisor, and had not sufficient tissue for me to obtain a block; but it showed no undue percentage of water, and the color was good. Up to the present time I have been unable to obtain the history of the filling of this root.21

G.V. Black, 1885

The concept of restoring endodontically treated teeth usually evokes challenging images of teeth with significant coronal tooth loss. In reality it may be the simple closure of an access cavity in a satisfactory coronal restoration to the total reconstruction of a tooth with no clinical crown due to the ravages of caries, faulty restorations or traumatic episodes, both short and long term (e.g., accidents, occlusal wear, abnormal function, etc.). Regardless of the clinical situation, the two primary objectives are to preserve the integrity of the root canal filling and rebuild the tooth into a symptom-free, functional, stable contributor in the patient’s dentition.29,47,51,90

In the last 25 to 30 years, a plethora of scientific studies, clinical-technique articles, and the introduction of new materials have addressed the enigmatic issue of restoring an endodontically treated tooth.49,93 During this same period, however, the significance of coronal leakage relative to endodontic failure has been highlighted, although this problem was identified over 90 years ago.33 The application of the principles of problem solving must now include, through careful and deliberate diagnostic assessments, the elements of identification and prevention as well as the need to manage these issues using either evidence-based or the best evidence directives. Although scientific insights and technologic improvements have provided a clearer understanding of this issue, sound clinical judgment and experience must still enter into the decision-making process in the restoration of these teeth. This includes the choice and placement of interim restorations before and during root canal treatment as well.

In Chapter 8, the importance of removing questionable restorative materials and all caries, along with proper tooth isolation, was stressed in conjunction with (1) the assessment of the restorability of the tooth, (2) identification of defects in the tooth structure, and (3) the development of a functional endodontic access opening in the tooth to be treated. To enhance this important phase of treatment, the use of

Problem-Solving List

Problem-solving issues and challenges in the restoration of endodontically treated teeth addressed in this chapter are:

Postendodontic and Intertreatment
Temporary Restorations
Restoring Access Openings
Problem-Solving Key Factors That Influence Restorative Choices in Anterior and Posterior Teeth
- Restoration of anterior teeth
- Restoration of posterior teeth
- Intraradicular posts
Exposed and Contaminated Root Fillings Due to Coronal Leakage
magnification and a caries detector is usually beneficial, but the latter may also stain sound dentin that has decreased mineral content. Recent advances in the development of caries-detecting agents may have eliminated this problem. In many cases requiring root canal treatment, two or more treatment visits may be indicated, and this requires that a proper interim temporary restoration be placed. The same dictate applies to each tooth upon completion of the root canal treatment if a permanent restoration is not going to be placed immediately. However, the effectiveness of temporary cements can vary, so the importance of these temporary restorations cannot be overemphasized relative to the prognosis for positive treatment outcomes.

Postendodontic and Intertreatment Temporary Restorations

With the initial access opening preparation, all caries, undermined tooth structure, and areas that are questionable relative to their integrity are to be removed or investigated (cracks, stained lines, etc.) so the tooth can be assessed for restorability prior to the actual root canal procedures. Some clinicians choose not to do these procedures, claiming there might be leakage if a wall were removed or if all the caries under a crown were eliminated. The claim is also made that the tooth cannot be isolated properly if specific tooth structure is removed. In essence, these approaches destroy the problem-solving concept and actually create environments conducive for problems. For example, salivary and bacterial leakage through carious dentin or poorly placed temporary materials can cause interappointment flare-ups and the opportunity for bacteria and their biofilms and byproducts to gain a foothold into an open canal or even one that has been obturated (see Chapter 5).*

As a basic principle in restorative dentistry, restorations usually leak in time, and no materials are perfect. When considering temporary restorative materials for endodontic access openings, everything will leak sooner rather than later. Even in well-done root canal procedures, coronal leakage can result in reinfection of the apical tissues in as little as 19 days with relative certainty within 3 months. Therefore prevention is essential in these cases by first considering immediate, permanent restoration following root canal treatment. If not possible, preventive techniques are necessary to minimize the possibility of this devastating occurrence.

Many premixed preparations have enjoyed popularity as interim or post-root-treatment temporary filling materials, such as Cavit (3M ESPE, St. Paul, MN, USA) or IRM (Dentsply Caulk, Milford, DE, USA). Laboratory studies indicate, however, that their ability to prevent the ingress of bacteria over time is poor. A second complication arises in that cotton, which is commonly used to maintain space in the pulp chamber prior to permanent restoration, may become entrapped in the materials along the cavity wall and provide an avenue for leakage. A well-placed temporary restoration can be expected to protect against bacterial leakage no longer than 1 month. While all materials leak to some extent, zinc oxide eugenol cements have long been regarded as possessing the best sealing properties of all cement materials because of their antimicrobial properties. However, zinc oxide/calcium sulfate materials such as Cavite tend to be more resistant to leakage than zinc oxide eugenol materials. The combined use of both materials may minimize leakage, but in either case, a minimum of 3 mm of thickness is essential. Resin-based materials can be used, but they have a tendency to shrink and result in leakage.

The placement of a temporary post and core creates a different set of circumstances, especially as it relates to an impervious seal. In these circumstances, a barrier using a self-curing material may need to be placed over the coronal, intracanal termination of the root canal filling material.

A better consideration for a temporary filling, if the tooth is not to be restored permanently in the immediate future, would be placement of a temporary material to the pulpal chamber floor without the use of a cotton pellet. The seal may be enhanced by thickness (usually greater than 3 mm). If a cotton pellet is to be used, however, orifice barriers are recommended. First, countersink the orifice with a small round bur, followed by a thorough cleaning with alcohol or a detergent to remove excess cement and debris. Second, if possible use air abrasion to free the dentin from films and debris. Third, place a temporary or permanent restoration in the orifices and over the floor of the chamber. In this regard, bonded materials or glass ionomers are favored.

Mineral trioxide aggregate (MTA) may also be considered, but a clear material would assist the restoring clinician in identifying the orifice(s).

If temporary materials are used to fill the entire chamber in lieu of an orifice barrier, they may create a problem for the restoring clinician for two reasons. Firstly, careful removal of the material at the time of restoration is essential to prevent gouging the pulp chamber floor or walls or removing excess tooth structure in the cervical area. Secondly, weakening of the tooth in this area is a potential problem relative to future tooth fracture. Retention of sound dentin, especially in the cervical portion of the tooth, is very important. Thirdly, if eugenol-based materials have been used, future bonding in the chamber may be affected.

None of the laboratory studies that have investigated the efficacy of many of the temporary filling materials has included perhaps one of the most devastating of complications, namely the forces of occlusion on a temporary filling over time. Under clinical conditions and involving access cavities in the occlusal surfaces of teeth in function, the ability of any temporary restoration to maintain a seal is questionable. This is especially true in occlusional relationships with deep plunging cusps that can destroy the

*References 1, 7, 11, 13, 14, and 16.
temporary, resulting in coronal leakage or in tooth fracture. These potential problems have been identified by some as a rationale for one-visit root canal treatment for all teeth; however, it does not consider those patients who delay the ultimate restorative process.

For interappointment temporary fillings, the most reasonable approach to prevent bacterial ingress would be to use calcium hydroxide as an intracanal medicament or, as some studies have pointed out, the combination of chlorhexidine and calcium hydroxide (see Chapter 11). This material or combination is not only antibacterial but also provides a physical barrier at the orifice. Secondly, if desiccated, it will not compress when the temporary filling material is placed. This would also be the method of choice in the case of a tooth with prepared post space, in which the post could not be permanently cemented immediately. The choice of temporary materials could still include a zinc oxide eugenol cement if the interval between appointments will be short. If the interval will be extended, or if the tooth is under heavy occlusal loading, composite resins or amalgam would provide better sealing under function. In the experience of the authors, glass ionomer cements have not been durable under occlusion, especially when placed in the access opening that has been made in a metallorceramic crown.

A second complication that may arise with the use of temporary filling materials over long periods of time is the presence of unrestored post space.54 If coronal leakage occurs, the significantly shorter gutta-percha fillings have been shown to leak much more rapidly than fully filled canals.12,26,87 In these situations, the use of a calcium hydroxide/2% chlorhexidine dressing in the post space would seem to be advantageous.100 At the time of restoration, removal of the dressing and rinsing of the post space with additional antimicrobial solutions such as 2% chlorhexidine would be of benefit.117

Regarding the use of intermediate restorative material (IRM, Dentsply Caulk, York, PA, USA) as a temporary material, the issue of a eugenol-based material is controversial relative to the ultimate use of a bonded restoration, composite, or core material for the final restoration.42,150 Since dentinal tubules account for only ±15% of the material retention,33 the dentinal surface, in particular the collagen matrix in the intertubular dentin, will influence the bulk of the ultimate retention.101,129,130 Eugenol-contaminated dentin will lessen the adhesiveness of the bonded restorations, whether by stopping the polymerization reaction or interfering with the actual bonding mechanism,96 and therefore the surfaces must be etched and rinsed to regain full bonding capability.102,148 Various approaches have been advocated to achieve this goal, such as air abrasion techniques (EtchMaster [Gorman Dental, Ann Arbor, MI, USA]) and etch-and-rinse management.

There are other problem-solving concepts that must be addressed when using composites to restore access openings in root-treated teeth. First, while there are multiple generation bonding systems available for this purpose, the three-step adhesives (fourth generation) seem to work the best and are the most durable.116 They might be the best materials to use with eugenol-contaminated surfaces.100,102,148 Secondly, dentin bonding agents will lose bond strength as early as 3 months, followed by the potential for leakage over time.23 Finally, self-etching materials may not fare well with intact enamel rods around the margins; therefore, the margins must be beveled.

Postoperatively, the very best solution is to restore the tooth immediately and avoid temporization completely. If this approach is not possible, the treatment plan should seek to accomplish as much permanent closure of the root canal system as possible. The pulp chamber should be permanently restored immediately if a post is not required. If the tooth requires a post and core, it would be best to proceed to these procedures immediately on completion of the root canal treatment. The crown could be completed at a later time. An alternative would be temporary closure of the pulp chamber and immediate crown preparation so that the integrity of the root canal procedures and the internal anatomy could be further protected with a temporary crown. The important goal is the preservation of all the efforts made to clean, disinfect, and obturate the root canal system.

## Restoring Access Openings

Root canal procedures are commonly required for teeth that have satisfactory existing restorations, primarily crowns that have good margins and no evidence or deterioration (if metallorceramic no obvious craze lines or fractures). In doing so, potential weakening of the restoration or the tooth structure supporting the restoration is a valid concern.3 A number of studies have addressed the clinical scenario.34,92,136-139,151 For this reason, conservative access cavities are always preferable to generous and often excessive preparations. Keep in mind, however, that when crowns have been placed on rotated teeth or roots and canals exit the coronal part of the tooth at unusual angles, access openings may have to be enlarged or altered in shape significantly in order to find the entire canal system (see Chapter 8).

The crowns of many teeth are frequently reconstructed entirely of amalgam or composite resin filling materials. Following root canal treatment, it is common to repair the access cavities with restorations of the same material. Nevertheless, research has demonstrated that routine access through large, multiple surface amalgam restorations significantly compromises the fracture strength of the repaired restoration post-operatively.34 For this reason, the placement of a full crown is worthy of consideration because the prognosis of this type of restoration will enhance tooth retention.2 The effect of access preparations through coronal reconstructions with composite resin is an unknown entity, and good restorative principles must be applied based on individual case demands. If any area of exposed enamel exists during the access opening preparation, beveling of the enamel margin followed by a self-etching adhesive system would be favored38 to protect the weaker dentin bonding beneath the surface.36
BOX 20-1 Case Study Highlighting the Problems Encountered With Failure to Restore Endodontically Treated Teeth in a Timely and Appropriate Manner

Case Study:
A 49-year-old female was referred for evaluation of the mandibular right posterior teeth. She had a recent history of spontaneous pain episodes in the area and was now experiencing prolonged pain to heat. Clinical examination revealed a large carious lesion on the distal surface below the margin of the full gold crown of the mandibular right first molar (Fig. 20-1, A). Pulp sensibility testing indicated tooth number 30 was abnormally responsive to heat stimulation. The crown was removed, the caries was excavated, and complete root canal treatment was performed. The distal root was prepared for an intraradicular post, and the tooth was temporized with IRM. The patient was dismissed with the expectation that the tooth would be restored as soon as possible.

Two months later, the patient called with the complaint that the temporary filling had come out. Upon examination, the IRM was found to be intact over the mesial orifices, but the distal canal was exposed to saliva (see Fig. 20-1, B). The distal canal was immediately recleansed and reobturated, again leaving space for a post. The patient was urged to have the tooth restored immediately.

Seventeen months later, the patient was referred for evaluation of a draining sinus tract lateral to the mandibular right first molar. The tooth was now restored, and a radiograph indicated that a post had been placed in the distal canal. A large periapical lesion was identified on the same root (see Fig. 20-1, C), but there was no apparent pathosis associated with the mesial root apices. The patient recalled that again there had been a delay of several weeks before she was able to get an appointment for the restoration. Periapical surgery was performed on the distal root only (see Fig. 20-1, D), which upon 8-month reexamination appeared to have healed completely (see Fig. 20-1, E).

Nearly 9 years after the original treatment, the patient was referred again for reevaluation of the mandibular right first molar, as the referring dentist had discovered another draining tract in the buccal vestibule. The radiograph indicated that there was a periapical lesion at the apex of the mesial root which extended coronally to the furcation (see Fig. 20-1, F). Clinically, the restoration was in excellent condition without evidence of caries or marginal leakage. The mesial canals were revised nonsurgically through the existing restoration (see Fig. 20-1, G) and on reexamination 9 months later, the lesion on the mesial root appeared to be healing normally (see Fig. 20-1, H).

Problem-Solving Analysis:
In retrospect, the most obvious etiology for the multiple postoperative problems was coronal leakage that occurred before the final restoration of the tooth initially. This could be attributed to an inadequate temporary restoration and prolonged delays before permanent placement of the post and crown. Leakage into the prepared post space most likely accelerated the failure of the root canal treatment in the distal root. The most reasonable explanation for the eventual failure of the root treatment of the mesial canals was residual bacteria in the pulp chamber from the original leakage problem. If the tooth had been restored immediately and periods of temporization had been avoided, none of the subsequent problems would likely have occurred. These problems are identified daily in private practice and can be prevented with a cognizant approach to the protection of all root-treated teeth with immediate attention to proper restoration.

For onlays and full crown restorations, the structural integrity of the underlying tooth structure and restorative materials is more of a concern than the structure of the crown itself. Therefore, the clinician should use a caries detector upon entry to ensure that there are no hidden carious pathways that have undermined the restoration.17,116 This examination is also enhanced with magnification (i.e., loupes or microscope). Access openings made through an intraradicular post, and the tooth was temporized with IRM. The patient was dismissed with the expectation that the tooth would be restored as soon as possible.

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For onlays and full crown restorations, the structural integrity of the underlying tooth structure and restorative materials is more of a concern than the structure of the crown itself. Therefore, the clinician should use a caries detector upon entry to ensure that there are no hidden carious pathways that have undermined the restoration.17,116 This examination is also enhanced with magnification (i.e., loupes or microscope). Access openings made through an existing restoration result in loss of retention92,151 and strength.54 When the access opening is restored, loss of retention is reversed,92,151 and if a post is added, additional retention can be gained.151

The most significant structural consideration in making access though full crowns is the presence of ceramic material. As discussed in Chapter 8, access cavities can be safely made through metalloceramic and full ceramic crowns without serious risk of fracture, although craze lines have been noted.139 Once the root canal procedures have been completed, the restoration of the access cavity must be completed. Bonding to dentin deeper in the access opening is not as effective as bonding to enamel.56 In these cases, however, there is a metalloceramic or ceramic margin. Etched ceramic materials can form a strong and durable bond with resin.67

A micromechanical bond can be obtained by roughening the porcelain with a bur, air abrasion, or etching with hydrofluoric acid,128 but acid etching appears to be the most effective method.8,89,124,133 This acid is provided in a 10% concentration in a syringe, and adherence to the manufacturer’s instructions is essential to prevent problems.8 Adhesion between a resin and porcelain may be enhanced by the use of a silane coupling agent.120 Some systems can bond well to both composites and amalgams, thereby reducing leakage with either material.31 This could provide direction for restoring a root-treated tooth that is not in a load-bearing area or has little contact in function, such as opposing a removable denture or partially edentulous space.

The metallic ring in the metalloceramic crowns is usually not significant when restoring an access opening. However, if the occlusal boundaries of the access opening are all metal, then some type of mechanical adhesion is necessary.89 The
use of burs or air-abrasion techniques is indicated; chemical adhesion is also possible with metals that form an oxide layer, but silane has no effect on bonding to metal.142

Traditionally it has been common in restorative dentistry to place a cement base for deeper preparations. A more contemporary evolution of this concept is the intracoronal barrier as discussed above. Research has recently shown the effectiveness of sealing the canal orifices against coronal leakage with a 3-mm layer of glass ionomer cement, flowable composite resin, compomer, or MTA.* Following placement of the intracoronal barrier, the remainder of the access cavity may be restored as discussed earlier, depending on the nature of the coronal material. The technique for composite repair of the access cavity made through a gold three-quarter crown is seen in Fig. 20-2. The intracoronal barrier would be

*References 4, 14, 45, 63, 78, 141, 148, and 152.

indicated even if the final restoration of the occlusal surface were amalgam or gold.

Problem-Solving Key Factors That Influence Restorative Choices in Anterior and Posterior Teeth

Multiple factors that must be considered in choosing the final restoration include:

- Amount of remaining sound tooth structure
- Occlusal function and the use of cuspal coverage in posterior teeth
- Nature of the opposing dentition
- Position of the tooth in the arch
- Length, width, and curvature of the roots
- Alterations in the tooth architecture caused by removal of the roof of the pulp chamber and the loss of cusps and marginal ridges
- Changes that occur in the dentin of endodontically treated teeth, and the ability of the tooth to function under stress
- The need for crown lengthening (see Chapter 17)
- The need for a ferrule to retain and stabilize the restoration
- Preservation of cervical tooth structure
- Use of agents (eugenol-based) that impact on bonding posts in the root canal and on coronal tooth structure

Alterations in the tooth that result in the potential for structural weakness are not attributable to changes in moisture content, but rather these changes are attributable to architectural changes in the remaining compromised dentin, both on a macroscopic and microscopic basis. Studies in the biomechanical properties of root-treated teeth and their contralateral vital pairs indicate that teeth do not become brittle after root canal treatment, as was previously thought. However, the strongest tooth will always be the one in which sound dentin and enamel can be retained and used to rebuild the tooth. Multiple restorative options are available to best serve the patient’s needs; these options must be chosen carefully for each particular situation.

Restoration of Anterior Teeth

The use of a composite resin in combination with dentinal bonding systems is the restorative material of choice in teeth that have intact marginal ridges, cingulum, and incisal edges. Additionally, prevention of coronal leakage is a primary concern. When restorations are placed without sufficient adherence to restorative protocols, failure is likely to result (Fig. 20-3). Because most anterior teeth experience fewer functional forces than posterior teeth do, the routine removal of sound tooth structure in favor of extensive post-core restorations is rarely warranted. In this regard, many root-treated and discolored teeth may be bleached to an esthetically acceptable color by use of a chemical or “walking bleach” technique without placement of a veneer or ceramic crown.

Some root-treated anterior teeth require complete coronal coverage. The most common indications are loss of tooth structure in the incisal half of the crown from trauma or from fracture associated with large or multiple restorations. Such heavily restored teeth often become unaesthetic as well through staining and wear. Full coverage is both aesthetic and durable and should be considered routinely in these situations.

The retention of a sound cingulum in anterior teeth also appears to be a major consideration, especially as it relates to the “ferrule effect” to be discussed later in this chapter. Often, removal or undermining of the cingulum has been encouraged in anterior teeth that have the propensity to have two canals, such as mandibular anterior teeth. The lingual canal is usually located beneath the cingulum, and failure to find it has led to many failures in these teeth. Ironically, the destruction of the cingulum in an attempt to find the canals may adversely affect the ultimate retention of an artificial crown on these teeth. Of greater importance, however, may be the concerns that come with treatment planning the retention of these teeth in the presence of significant lingual decay or, more frequently seen, lingual resorption that destroys the integrity of the cingulum.

Restoration of Posterior Teeth

Primarily because of the loss of structural integrity and the amount of occlusal force during function, these teeth have a different set of restorative needs. Contemporary thought in research, clinical practice, and outcomes studies supports the placement of a restoration with full cuspal protection. Restorations of this nature are essential to prevent fracture when occlusal forces from the opposing cusps tend to wedge and separate cusp tips during function. Retrospective evaluation of endodontically treated teeth up to 8 years has shown that 85% of the teeth that were lost were not protected with full-coverage restorations. Furthermore, studies have shown that endodontically treated posterior teeth that do not receive full, protective coverage fail as much as six times more than those restored with full coverage. In cases of posterior teeth opposing a partial or complete denture, the forces of mastication and cuspal interdigitation may be reduced significantly, and tooth restoration with complete coronal coverage may or may not be warranted.

Of initial restorative concern is the seal of the pulp chamber. A separate intracoronal barrier should be placed before the construction of the final restoration begins. During core construction, care must be taken to ensure that areas of deep excavation or fracture near the future crown margins are well sealed to prevent possible marginal leakage. When there is substantial remaining coronal tooth structure, any
restorative material can be used for the core as the support for the crown is derived principally from dentin. However, if the coronal preparation would eliminate or reduce the remaining dentin thickness to where it is of no value, then a bonded composite or core paste-type material is indicated. If the final preparation will be in sound dentin, even a glass ionomer would be appropriate as a core buildup material, however, it lacks sufficient strength as a free-standing restoration.46

Bonded composite resin cores, sometimes supported by intraradicular posts, are indicated in cases with loss of up to half of the clinical crown (Fig. 20-4).89 In cases missing more than half of the clinical crown, the physical properties of the core material become crucial to long-term survival.72 For maximum strength, bonded amalgams, composites, and core paste materials are preferred.46,60,72,103,104 Again, glass ionomers are not considered strong enough for this purpose. From the endodontic perspective, however, direct core


FIGURE 20-4 Root-treated molar indicated for core build up.
construction without posts should be confined to the pulp chamber; occasionally, careful extension into the coronal 2 to 3 mm of the canal space may be indicated. Overzealous enlargement and extension into the canal spaces, however, can result in weakening, fracture, or perforation of the root (Fig. 20-5).

In treatment planning the restoration of posterior teeth with significant loss of coronal tooth structure, it is important to consider the amount of crown preparation that will be required once the core is placed. Although the tooth may have a satisfactory core buildup, there may be insufficient tooth structure after preparation to retain it. The result is frequently a complete fracture of the crown at the level of the gingival margin. Neither dentinal bonding nor retentive pins appear to be a solution for the retention of large cores in teeth with minimal coronal dentin (Fig. 20-6).

**Intraradicular Posts**

Both anterior and posterior teeth that lack sufficient remaining coronal dentin to place a direct core must be evaluated carefully for restorability. Crown lengthening and orthodontic extrusion (see Chapter 17) are useful adjuncts for many compromised teeth, but some limitations exist. For example, crown lengthening cannot be effectively carried out below the level of the furcation. Consider the example depicted in Fig. 20-7. To provide a restorable clinical crown and facilitate a “ferrule effect” for such (see below), a minimum of 2 mm of crown exposure above the free gingival margin would be required. On the mesial, there is only 1 mm of tooth structure remaining above crestal bone. Resecting another millimeter of crestal bone would immediately infringe on the furcation, but that is not all. Crown lengthening requires the restoration of biologic width (see Chapter 17). Biologic width is the normal physiologic distance from the gingival attachment to the margin of the free gingival. This would require an additional 2.5 mm of crestal bone reduction, which for this tooth is entirely unfeasible. A third consideration is relatively short root length. There would be a compromise between the root canal seal and post length. The treatment plan for this tooth would favor extraction (Fig. 20-7).

Although the majority of structurally compromised teeth are restored with an intraradicular post, this philosophy and clinical approach does not necessarily reinforce teeth as was once widely believed. In the short term, posts may be of benefit, with bonded posts having an impact on root strengthening initially. Over time, their value may be lost because of the loss of adhesion due to thermal, chemical, and mechanical stresses from the oral cavity. The routine use of posts is now believed to have a negative impact over time on the retention of teeth. Therefore, there is no value in placing posts in otherwise intact root-treated teeth that do not need core retention (Fig. 20-8).

The principal function of the post is retention of the core. There are a number of considerations in determining the indications for a post, the choice of a post, and the technique for its placement. These considerations fall into two categories, restorative and endodontic.

**Restorative Considerations for Post Placement**

Posts should be selected or designed to preserve as much coronal tooth structure as possible. Therefore, the preparation in the canal should remove as little dentin as possible. Cast posts by their very nature cannot be given a specific design because they represent the shape of the prepared root

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**FIGURE 20-5** Amalgam core overzealously extended into canal orifices, resulting in weakening of tooth structure and fracture of the distal root.

**FIGURE 20-6** A, A prosthetic crown fractured off due to insufficient remaining tooth structure. B, The addition of retentive pins fails to compensate for lack of coronal tooth structure. C, Fracture of thin palatal tooth structure led to failure of entire crown.
The choice of a post system can also be greatly influenced by the installation stresses. Cement viscosity, cement type, the option of intracanal bonding, canal cleanliness, and general fit of the post must be considered in treatment planning the final restoration (see Table 20-1). Parallel-threaded post systems have relatively low installation and functional stresses compared with the tapered, self-threading systems. Other systems have similar characteristics depending on their use.

Bonded carbon fiber (no longer black), glass fiber, quartz fiber, and silicon fiber posts have also been advocated. The chief benefit is that they are white and do not detract from the esthetics of full ceramic crowns. The purported structural benefit of these post types is a modulus of elasticity that is similar to dentin. However, long-term randomized clinical trials assessing the efficacy and outcomes of using these types of posts are lacking, as the use of fiber posts in endodontically treated teeth with full crowns has been studied primarily in vitro.
Fracture resistance was shown to be improved, and the fractured tooth was judged to be restorable more often in teeth with fiber posts.\(^{111}\) On the other hand, the value of flexibility is questionable with respect to cement or bonding seals at the interface of dentin and core material.\(^{32}\) As with all methods of restoring root-treated teeth, preservation of as much coronal tooth structure as possible would be an important adjunct to the success of these posts. When removal is necessary, the ultrasonic instrument has been found to be effective.\(^{37,117}\)

Zirconium and ceramic posts are also available. Although similar in esthetic application to fiber posts, these materials have less tensile strength; consequently, more bulk is required. They are also weaker than metal posts, so along with an increase in diameter comes more removal of sound dentin in the root than a corresponding metal or fiber design. A second disadvantage is that they are extremely difficult to remove if a fracture occurs. The posts cannot be etched and therefore cannot be bonded, which may impact negatively on core retention.\(^{24}\) While it might be possible to grind the remaining ceramic material from the canal, at very best, the post preparation will inevitably become larger as a result. Zirconium is virtually impossible to grind. A fractured zirconium post would most likely result in extraction of the tooth.

From a restorative viewpoint, recommendations for post length were empirically derived from clinical experience. While numerous clinicians believed that the post should roughly equal the length of the crown,\(^*\) there are abundant guidelines for post length, each having its own research or empirical support.\(^{47}\) In an effort to arrive at a consensus, a table of average measurements of crowns and roots was devised almost 30 years ago.\(^{115}\) Crowns of maxillary anterior teeth are around 10 mm, while the mandibular teeth measured around 9 mm. The posterior teeth have crowns averaging around 7.5 mm. If these measurements were used, this would result in post lengths of 7.5 to 10 mm. Ratios of half, two-thirds, or three-quarters the length of the root have also been advocated.\(^{47}\) If the average root lengths were considered within these ratios, it would provide a post length similar to the two-thirds ratio recommendation.

A number of studies have confirmed the relationship between post length and retention. A sampling of four of these studies indicates that by increasing post length from 5 mm to 8 mm, retention increased by 33% to 47%.* Therefore post lengths around 9 to 10 mm for anterior teeth and 8 mm for posterior teeth would appear to be adequate and effective when a post is needed to restore the tooth (Fig. 20-10).


*References 26, 30, 70, 73, 110, 125, and 126.
Clinical experience indicates that short posts tend to become easily dislodged (Fig. 20-11). Moreover, there is evidence to conclude that a short post may contribute to vertical root fracture during the period of loosening and dislodgement. The often insurmountable problem is the anatomically short tooth and how to restore it based on remaining tooth structure and patient function. Again, preservation of coronal tooth structure is one important strategy. Less stress would be put on the post core if crown retention depended on the remaining dentin of the clinical crown. Therefore, teeth with roots need to be assessed fully during treatment planning, and in this case extraction may be in the patient’s best interest.

In vitro studies on the luting of posts do not present a clear preference for a cement type, although any of the cements can be used if the proper principles are followed. Zinc phosphate and glass ionomer cements have been used for many years with a good deal of clinical success; one caution, however, with glass ionomer cement is the setting time, which may take days for a complete set. Continued buildup and preparation on the day of cementation may permanently weaken the cement.

Presently there appears to be a trend toward the use of resin-modified glass ionomer and resin cements. These materials provide initial increased retention and tend to leak less than other cements, but they are more technique sensitive, requiring extra steps in the preparation of the canal walls and efficiency in placement and cementation. While it is thought that eugenol-based root canal sealers would inhibit resin polymerization, intracanal dentinal bonding may actually increase retention, strengthen roots, and prevent coronal leakage. However, this technique requires extra steps in cleaning and preconditioning of the dentinal wall. Failure of the pretreatment agents to reach all areas of the preparation or contamination of either the post or the canal will prevent bonding. Self-curing resins would be preferred over light-cured varieties because of the lack of light penetration. There is also the question of the durability of the bond. Additionally, degradation over time may characterize intracanal bonding procedures. The disadvantages of this approach may defeat the theoretical benefits.

The eugenol-containing cements used for root canal obturation are thought to inhibit polymerization of resin cements that are used to cement posts, and for that matter seal an access opening. Therefore the walls of the canal and coronal portion of the tooth must be cleaned. The use of chlorhexidine to rinse the canal space prior to post and core placement will assist in bacterial control and enhance the bonding that is desired. Chlorhexidine may leave some surface debris, but it does not appear to effect the shear bond strength.

Clinically, the adaptation of the post to the canal wall is important. Grossly undersized posts cannot possibly provide retention for the core (Fig. 20-12). In large canals, there may be no effective way to place a post (Fig. 20-13). This is especially true in mandibular second molars that exhibit a C-shaped canal system or any molar that has ribbon-shaped canals (see Chapter 13). When the attempt is made to place a post in a very large canal, it often occurs that the post is cemented to gutta-percha and nothing else. There is no

**FIGURE 20-11** Maxillary canine restored with a post of inadequate length.

**FIGURE 20-12** A grossly undersized post fails to provide retention.
increased with crown margins placed on ferrules of 1 to 2 mm in width. As discussed in the earlier section on core buildups without posts, the coronal tooth structure must be assessed before placing the post and core to envision how much will remain after crown preparation. Although the crown preparation may appear to have the desired ferrule effect, in actuality, the observed dentin may now be very thin and weak, contributing very little to the structural integrity of the completed restoration. Post failures are common once the dentin fractures (Fig. 20-16).

The ferrule also protects against coronal leakage. In teeth restored without a ferrule, occlusal loading will cause failure of the cement seal between the core and the dentinal wall. Experimentally, this has been found to be visually undetectable and results in coronal leakage into the post space over time. These cases are usually discovered clinically, when the entire post-core-crown becomes loose (Fig. 20-17; see Fig. 20-16, A and B) or there is a root fracture (Fig. 20-18). A second disastrous form of failure is metal fatigue and fracture of the post itself (Fig. 20-19). A common denominator in examining the core inside the crown is the lack of adequate extension over tooth structure identical to the failures of cores alone (see Fig. 20-6) and post cores (see Figs. 20-16 and 20-17). Fortunately, most post fragments can be removed, but unless more tooth structure can be included under the next restoration, a recurrence of post fracture is likely. In cases where there is little remaining clinical crown, surgical crown lengthening is recommended. The restoration could also include the use of multiple posts (Fig. 20-20) if appropriate to support the large core that is needed.

Endodontic Considerations for Post Placement

Although many teeth cannot be restored by any means other than the use of an intraradicular post, there are a number of significant risks and prognostic concerns even with their use, although the restorative requirements are satisfied. The key
FIGURE 20-16 A, Failed post core restoration. An intraradicular post cannot compensate for lack of sufficient coronal tooth structure. B, Loss of bridge abutment due to fracture of dentin (arrow) below the crown that caused the posts to loosen in the tooth.

FIGURE 20-17 A, Right mandibular first molar restored with a post, core, and full gold crown. B, Marginal leakage extended to the post space causing failure of the luting cement. C, Examination of crown and the post core indicates the lack of sufficient ferrule circumferentially.

FIGURE 20-18 Radiograph that verifies the nature of the fracture abutment, again on a mandibular premolar bridge abutment. Multiple issues are involved with these occurrences: namely, length of bridge span, lack of ferrule, poor root length, improper occlusal forces (especially during function), improper use of posts, and failure to consider double abutments.

FIGURE 20-19 A fractured intraradicular post in a maxillary left lateral incisor. The restoration had no ferrule.
problem-solving concept in this area is prevention. Most of the problems described in this section will seriously affect prognosis or require immediate extraction of the tooth.

The discussion of coronal leakage in the section on temporary fillings applies to permanent restorations as well. Timely if not immediate restoration of any prepared post space is one of the best ways to prevent coronal leakage, the effects of which may not appear for a considerable time after treatment. In the same manner, any avenue of leakage that might remain or develop postoperatively will result in failure of the root canal procedures, with predictable evidence for persistent of or a new periapical pathosis. Likewise, coronal leakage to the site of a lateral canal must always be suspected when a lesion develops laterally at the level of the terminus of a post, and this finding may be misdiagnosed as being due to a post perforation or a periodontal pocket (Fig. 20-21).

The amount of filling in the root canal that is left after post space preparation is critical to the prognosis of treatment. Most authors have concluded that 4 to 5 mm of root filling material is sufficient to maintain the apical seal (Fig. 20-22). Every effort must be made to resist the temptation to extend the post preparation beyond a radiographically predetermined level as the seal of the root canal filling may be compromised (Fig. 20-23). In these cases, if the root canal treatment fails, revision is difficult and demanding. There are only two options, nonsurgical or surgical revision. When a post is present, removal is difficult, and many cases either require or result in the removal of a satisfactory restoration.
just to remove the post. Periapical surgery, on the other hand, is compromised because of the difficulty in preparing the apex for a root-end filling (Fig. 20-24).

In the anatomically short-rooted tooth, a conflict arises between adequacy of post length for core retention and adequacy of root canal filling to ensure the integrity of the seal. The root canal seal cannot be compromised, and therefore if there are no alternatives for core retention or exposure of more clinical crown, extraction should be considered as was discussed with Fig. 20-7.

A recent clinical study has confirmed what many clinicians have observed empirically. Unfilled root canal space that might be left between the post and the residual gutta-percha filling material may negatively affect the long-term prognosis of the tooth.91 In this study, 94 root-treated teeth were restored with post and cores and followed for 5 years. Teeth with no gap were found to be 83% successful. Teeth with a gap of over 2 mm were found to be 29% successful. Although the cause of failure was not the object of this study, a number of causes can be identified or at least suspected. The first is leakage into the canal. As was discussed earlier in the section on temporary fillings, studies indicate that canals with less gutta-percha filling materials, such as those prepared for intraradicular posts, are more susceptible to leakage.1,86

Secondly, lateral canals are not uncommon at the midroot levels of teeth. This is usually about the level that

**FIGURE 20-21** A radiolucency associated with a lateral canal is likely communicating with unfilled canal space.

**FIGURE 20-22** A completed post core restoration with appropriate post length and preservation of root canal fillings.

**FIGURE 20-23** A and B, Overzealous extension of the post that resulted in perforation of the apex. Note complete displacement of the minimal apical gutta-percha in the maxillary left lateral incisor. Apical surgery complicated by the difficulty of removing the metallic post material to reseal the apical foramina. (B, Courtesy Dr. Rachel Hogan.)
intragradicular post preparations terminate (Fig. 20-25). Occasional lateral abscesses are found to be caused by the bacteria and tissue debris that emanates from lateral canals that communicate with unfilled and probably contaminated spaces in the main canal (Fig. 20-26).

A study of the timing of post space preparation relative to completion of the root canal treatment indicates that immediate preparation has no effect on the newly created apical filling and its seal. This supports the treatment plan of immediate restoration and avoids any period of temporary that could invite coronal leakage. Prior to initiating any treatment, an accurate radiograph of the tooth should be measured to determine an approximate depth to which the post should extend. Any root curvature should be noted so that the preparation will stop before exiting the canal space. Similarly, the general anatomy of the root should be noted to look for possible indications of lateral fluting, lateral canals, or generally thin root structure. These factors
Problem Solving the Challenges Faced in the Restoration of Endodontically Treated Teeth

Removing the gutta-percha prior to the use of rotary instruments to enlarge the canal space has always been a safe approach to creating post space. The various techniques described in Chapter 14 for the removal of root filling materials in the process of treatment revision will apply to preparation for posts as well. A hot endodontic plugger or heating device (System B or Touch 'N Heat [SybronKerr, Orange, CA, USA]; BeeFill 2in1 [VDS, Munich, Germany]; CalamusDual 3D Obturation System [Dentsply Tulsa Dental Specialties, Tulsa, OK, USA]) are ideal for this purpose. This can be followed by Gates-Glidden burs, Peeso burs, and solvents, depending on the root shape and canal size. Once the canal space is free from most of the filling materials, larger burs that come with the prefabricated post kits or drills that can be used safely will follow the prepared space with much less risk of perforation. Before their use, make sure the canal is clean and dry and the drill will be centered in the canal. The gutta-percha should remain visible and centered at the base of the preparation throughout the process.

Unfortunately, perforation of the root during post space preparation occurs and is a disastrous event that diminishes the prognosis for tooth retention. Posts and post preparations will not follow curvatures in the root, so preoperative assessments should prevent continued penetration past the point where straight-line enlargement is possible (Fig. 20-27). For example, in the palatal canal of maxillary molars, it is not possible to appreciate buccal-palatal curvature radiographically. As a consequence, it is extremely important to remove the gutta-percha filling and either visualize the direction of the canal or use an endodontic file to explore the curvature before beginning post preparation. Perforations will usually occur on the furcation side of the palatal root (Fig. 20-28), which will not be evident on a film (Fig. 20-29, A). These lesions generally drain to the palatal surface around the mesial or distal aspect of the root (see Fig. 20-29, B), and probing will often identify the tract (see Fig. 20-29, C).

**Figure 20-27** A, A lateral perforation to the mesial of molar root. The operator failed to negotiate the root curvature. B, A lateral perforation in a maxillary incisor due to the use of an excessively large-diameter post for the root. C, A furcation perforation in the mesial root of a mandibular molar. Note the thin mesial-distal width and the curvature of the root. Post placement should have been confined to the distal root alone.

**Figure 20-28** A post perforation to the buccal surface of the palatal root of a maxillary molar.
radiographically, if the post space perforation is on the furcation or the palatal side of the root, it may not deviate with an angled film. if the perforation tends to go either to the distal or mesial, the post may appear to deviate from the direction of the canal (fig. 20-30). another possible clue to a furcation perforation of the palatal root is bone loss in the clinical absence of periodontal disease (fig. 20-31).

perforations can occur as a result of unanticipated anatomic variation, such as deep fluting on the mesial or distal surfaces of posterior teeth (fig. 20-32). strip perforations can also occur during an attempt to place a post that is too large for the root (fig. 20-33). it is also possible to perforate into the furcation of maxillary premolars, because the anatomy of that area cannot be visualized radiographically (fig. 20-34).

small perforations detected early can often be repaired with mta in the base of post preparation. however, the prognosis diminishes rapidly with increasing size of the
perforation. Irritating medicaments in the canal or coronal leakage resulting in infection of the adjacent periodontal tissues will also reduce the probability of successful repair.

Unfortunately, the majority of perforations occur through misalignment of post drills or beginning a post preparation without prior removal of the gutta-percha filling. If the resultant perforation is above or at crestal bone level, repair will generally be possible without a serious effect on the prognosis (Fig. 20-35). Deeper perforations that do not affect the marginal or sulcular attachment can also be repaired with an excellent long-term prognosis if the defect is small and accessible (Fig. 20-36). The techniques for repair of these types of defects are beyond the scope of this book, but other examples of this type of surgery can be found in Chapter 18.

Regardless of size, perforations into the furcation do not bode well for a positive outcome (Fig. 20-37). If small and repaired immediately, the prognosis may be good. Attempts at internal repair of older perforations that have become infected are not usually successful, most likely due to the difficulty of adequate cleaning and disinfection of the perforation site internally.

Similarly, surgical repair is difficult due to the inaccessibility of the defect and the destruction of the attachment in the process (see Chapter 8).

Occasionally, gross perforations are encountered for which extraction is the only option. Typically, at the point of discovery, irreversible destruction of the periodontium adjacent to the perforation has taken place, resulting in a permanent periodontal defect. Repair of the perforation at this point is futile (Fig. 20-38).
A midroot perforation to the labial. Probings are normal, indicating the perforation is located below the level of the marginal attachment. Repair with mineral trioxide aggregate (MTA) would have an excellent prognosis for healing. One-year reevaluation after perforation repair with MTA. The lesion has completely resolved clinically.

Perforations into the furcation are difficult to repair. With a post protruding through a perforation, repair is virtually impossible.
Exposed and Contaminated Root Fillings Due to Coronal Leakage

Occasionally, fractured or carious teeth that have had previous root canal treatment require reconstruction. There may be no symptoms, and the radiograph may give no evidence of apical pathosis, but the gutta-percha filling material has been exposed to saliva and bacteria, often for unknown time periods (Fig. 20-39). The dilemma is whether or not such a tooth can be restored without nonsurgical root canal revision (see Chapter 5). Even if the crown had come off the same day as the examination, it is entirely unknown if the tooth had been cracked or if the tooth-restorative margins had been leaking. Usually, most teeth will have clinical and radiographic signs of failure within months of a crown failure, but even this finding does not always occur (Fig. 20-40).

The weight of scientific evidence cited earlier concerning coronal leakage leaves little doubt that the case in question is in the process of failing. Placement of an intraradicular post...
would greatly complicate the eventual need for revision. Most likely, the treatment plan would be apical surgery. At the time of diagnosis, revision would be relatively simple, perhaps not even requiring anesthesia.

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