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Management of Endodontic Complications

From Diagnosis to Prognosis

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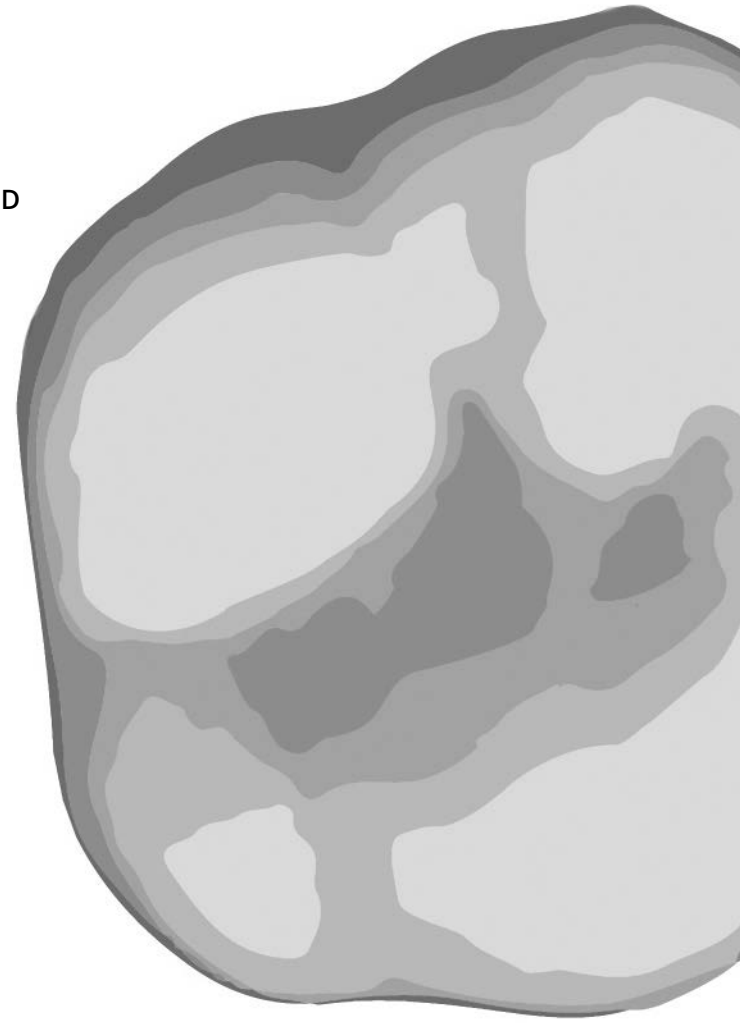

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Preface

Endodontics is a field of dentistry that deals with the biologic and technical aspects of root canal treatment. Root canal treatment is a well-established procedure that has provided pain relief, function, and esthetics to patients for decades. The main goal of this discipline is to preserve the natural dentition.

Like other dental and medical specialties, the practice of endodontics consists of two inseparable components: science and art. The science of endodontics covers the didactic and clinical aspects of this field as they relate to the biologic and pathologic conditions. The art of endodontics deals with proper execution of the technical aspects of this field.

Similar to other fields of dentistry, root canal treatment can have unwanted or unforeseen challenges that can affect its prognosis. These unwanted and unforeseen challenges are collectively termed *procedural accidents or errors*. The procedural accidents can occur during diagnosis, access preparation, shaping and cleaning, obturation, restoration, surgical and nonsurgical retreatments, and assessment of outcomes of root canal treatment. The principal objective of *Management of Endodontic Complications: From Diagnosis to Prognosis* is to discuss the etiology, prevention, and treatment of procedural errors before, during, and after root canal treatment.

This book presents clear and concise guidance on all aspects of both minor and major complications encountered in endodontic practice. Each chapter provides complete descriptions of the etiologic factors, explains the prevention of complications, and recommends treatment options associated with these complications. The main features of this book include learning objectives and key references; a systematic approach to each complication, including prevention, recognition, and management; and more than 500 high-quality clinical and radiographic images that demonstrate the discussed concepts.

During the writing and editing of this book, we noticed there are many areas within the field of endodontics that continue to need to be researched and investigated. We believe practitioners should be up to date regarding the latest scientific evidence in the field and know how to contribute their own research. As a result, we put together an online chapter that explains the proper methods to write and publish research protocols and focuses on the common errors in various steps of writing and publishing research findings.

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Having knowledge regarding the etiologic factors involved in procedural accidents and the methods to prevent and treat them properly should save millions of teeth throughout the world. We firmly believe most procedural errors can be avoided by adhering to the basic principles of diagnosis, case selection, treatment planning, access preparation, shaping and cleaning, obturation, restoration, nonsurgical and surgical retreatments, and outcomes assessment.

We would like to thank sincerely our contributing authors for sharing their valuable knowledge and experiences with us and our readers as well as the Quintessence staff for their assistance with the publication of this book.

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1

Complications During Diagnosis and Treatment Planning

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Objectives

After reading this chapter, the reader should be able to:

1. Differentiate between pulpal pain and other pains.
2. Identify the characteristics of pain with or without periapical pathology.
3. Describe the characteristics of nonpulpal pain with or without periapical pathology.
4. Discuss mishaps during the following:
   - Patient interview
   - Addressing the chief complaint
   - Recording medical history
   - Recording dental history
   - Clinical examination:
     - Extraoral examination
     - Intraoral examination
     - Clinical tests
     - Percussion
     - Palpation
     - Pulp sensitivity tests
     - Probing
     - Mobility
   - Radiographic examination
     - Radiolucencies simulating periapical pathosis
   - Additional diagnostic tests

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Introduction

The discipline of endodontics deals with the biologic aspects of the human dental pulp and periapical tissues as well as treatment of diseases related to these tissues. Additionally, the scope of endodontics includes diagnosis and treatment of pulpal pain with or without periapical pathology, vital pulp therapy, regenerative endodontic procedures, nonsurgical root canal treatment, and surgical and nonsurgical retreatment of cases with persistent disease. When indicated and properly performed, root canal treatment is safe, alleviates pain and suffering, and preserves natural dentition with a favorable and predictable outcome.[1] Like other medical and dental procedures, the practice of endodontics has two components: art and science. The *art* of endodontics consists of executing technical procedures for root canal treatment, which is often subjective. The *science* of endodontics is objective and includes an understanding of the biologic and pathologic conditions related to the art of endodontics through the principles and methods of evidence-based treatment. One of the most important parts of the application of both the art and science is the accurate diagnosis of pulpal and periapical diseases. Lack of attention to detail in application of the science of endodontics can easily result in diagnostic mishaps and subsequent inappropriate treatment.

Mishaps can often occur outside of the technical components of root canal treatment—during diagnosis. Mistakes during diagnosis can result in improper and unnecessary treatment and increased costs, creating unsatisfied patients and leading to legal action against a provider. Furthermore, misdiagnosis can result in serious consequences to the systemic health of the patient and may affect the prognosis of future treatment(s). In short, an unnecessary—although well-executed—root canal treatment should be avoided because it can cause frustration for both the patient and the clinician. There are a number of clinical and radiographic normal and pathologic conditions that mimic endodontic pathosis.[2] To avoid misdiagnosis, the clinician should use a systematic approach to gather pertinent medical and dental information, perform necessary tests, and analyze the gathered information to develop a differential diagnosis, definitive diagnosis, and subsequent treatment plan. Most misdiagnoses can be avoided by adhering to the basic principles of diagnosis and case selection. This chapter will focus on appropriate steps to obtain information during a patient's interview regarding their medical and dental histories, clinical and radiographic signs and symptoms, and the implications of the gathered data in treatment planning.

Pulpal pain vs other pains

Several types of nonpulpal pain with or without periapical pathology simulate clinical features of pulpal and/or periapical diseases. Because of the similarities of these conditions, dentists must perform clinical tests in a systematic manner to avoid misdiagnosis and subsequent incorrect treatment. To arrive at the correct diagnosis, a provider must review all relevant patient history, clinical signs and

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symptoms, pulp tests, and radiographic examination. Dentists are usually the first clinicians involved in diagnosis and treatment of these conditions.[3] In order to be successful in treating these patients, it is important to have a clear understanding of the many different ways in which the patient may experience nonodontogenic versus odontogenic pain. Within the dental field, the most useful pain consultants are dentists trained in orofacial pain, endodontists, and oral and maxillofacial surgeons.[2] Pain may be acute or chronic. Acute pain arises from inflammation or injury to the pulp and periapical tissues. Chronic pain is continuous in nature and lingers long after an injury has healed or may not even be associated with an injury. Despite apparent similarities of odontogenic and nonodontogenic pain, there are some subtle but key differences in the characteristics of these conditions. Paying close attention to these differences often reduces the chance of misdiagnosis.

Characteristics of pulpal pain with or without periapical pathology

Odontogenic pain is often acute and can awaken a patient from sleep or prevent the patient from sleeping. Sleep disturbance is an important part of the differential diagnosis. It is important to ask the patient very specific questions about the impact of pain on sleep patterns.[2] Pulpal pain with or without periapical tissue pathology is easily localized initially by the patient or by the practitioner. An affected tooth is typically painful to palpation or percussion. As the pain becomes chronic, it may spread to other teeth, and it may be more difficult for the patient to identify the offending tooth or teeth. Odontogenic pain has apparent etiologic factors such as caries, leaky restorations, trauma, or fracture. Depending on the condition of the pulp, it may be very sensitive to temperature changes, or in the case of pulpal necrosis, it can have no response to thermal changes. Absence of clinical and/or radiographic signs and symptoms of pulpal or periapical disease may indicate the presence of nonodontogenic pain. Pulpal pain is usually localized and usually limited to a single tooth. This type of pain is relieved by administering local anesthetic and performing dental treatment.

Characteristics of nonpulpal pain with or without periapical pathology

Nonodontogenic pain has several accompanying features that are different from those seen in odontogenic pain.[2] Most patients who have nonodontogenic pain are extremely distressed and frequently have jumped from one provider to another as treatment failures continue to mount. A history of unsuccessful root canal treatments on a number of teeth or different procedures performed by numerous providers is a good indication for the clinician to explore the possibility of nonodontogenic pain. In contrast to odontogenic pain, patients experiencing nonodontogenic pain cannot localize the source of their discomfort and have little or no clinical or radiographic signs and symptoms of pulpal disease with or without periapical pathology. Nonodontogenic pain has no apparent etiologic factors like those for odontogenic pain. The pain does not consistently

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subside by administration of local anesthetic. It can be bilateral but is generally unilateral. The first group of nonodontogenic conditions that simulate odontogenic pain includes pain related to the maxillary premolars and molars adjacent to the maxillary sinuses, musculoskeletal pain, temporomandibular disorders, neuropathic pain, neurovascular pain, atypical odontalgia, neuromas, neuritis, intracranial pain, headaches, and psychologic disturbances.[2] The second group of conditions that may cause referral of pain to the teeth and simulate pulpal pain with or without periapical pathology are pain from other teeth, maxillary sinus or nasal cavities, the cervical spine, vascular structures, the heart, tumors, and other neoplasms in the head and neck.[2] The most common misdiagnosis in the first group occurs from pain in the maxillary sinus, muscles of mastication, and the temporomandibular joint (TMJ).

Patients who have maxillary sinus pain describe it as constant pressure and fullness in the region. The pain may be referred to the maxillary premolar and molar teeth. Head position or movement can often exacerbate the discomfort.[4,5] These patients usually do not have decay or restorations in the region to indicate presence of pulpal and/or periapical diseases. Consultation and referral to an ear, nose, and throat (ENT) specialist is the right course of action for these patients.

Myofascial pain is the most common muscle pain disorder of the orofacial region. The most common symptoms associated with muscle problems are pain with palpation, movement anomalies, and referred pain. These patients usually do not have decay or restorations indicating presence of pulpal or periapical disease; however, it is not uncommon to see many failed endodontic treatments as a result of misdiagnosis of this condition as pulpal and/or periapical diseases.[6] Joint disorders are identified as a major cause of nondental pain in the orofacial region and are considered a subclassification of musculoskeletal disorders.[7]

Temporomandibular joint disorders (TMDs) are one of the major causes of nonodontogenic pain. Trauma from tooth grinding or jaw clenching or trauma from external forces such as automobile accidents has been implicated as an etiology of TMD.[4,5,8] Hyperextension of temporomandibular structures during long dental procedures is another possible etiology for TMD.[2] With TMDs, palpation of the TMJ and the muscles of mastication results in pain or discomfort. During examination of the TMJ, clicking or popping in the joint can be noticed. Similar to patients with sinus pain, these patients also generally do not have decay or restorations in the region to indicate presence of pulpal and/or periapical disease. Treatment of TMD includes wearing a nightguard and taking a muscle relaxant.

Trigeminal neuralgia affects the fifth cranial nerve and can cause another common pain that can be mistaken for odontogenic pain. The etiology of trigeminal neuralgia is unknown, but demyelination, vascular malformations and the presence of pathologic cavities at the site of previous tooth extraction, periodontal lesions, and previous endodontic therapy have been implicated for this condition.[5] It is usually unilateral and involves the maxillary or mandibular branch of the fifth cranial nerve. Because of the location of the symptoms of trigeminal neuralgia

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relative to teeth, many of these patients are referred for root canal treatment. Patients describe their high-intensity pain as an electric-like shock with a trigger zone associated with activities such as eating, talking, or even breathing cold air.[9] The intensity of the pain is very severe and can occur for short or extended periods of time.[9] Despite the severity and intensity of pain, it usually does not awaken the patient, which helps to differentiate this type of pain from pulpal and/or periapical pain.[2]

The second group of nonodontogenic conditions that simulates odontogenic pain is referred pain. When neurons from several teeth or other structures converge on a second-order neuron that is sensitized, the potential for referred pain increases. In referred pain, the pain originating in a tooth can seem to come from another tooth or another area, even outside the mouth.[10–15] These include pain referred from one tooth to another tooth or to the ear, from the maxillary sinus to the maxillary teeth, from vascular structures to teeth, and even from cardiac muscle to teeth.

One of the most common mishaps during diagnosis is the misdiagnosis and treatment of a normal tooth instead of the offending tooth. The pain from irreversible pulpitis in a tooth can be referred to another tooth in the same quadrant or the opposite dental arch. Pain in the mandibular arch can also be referred to the ENT specialist. Careful examination of the clinical and radiographic data can prevent these mishaps.

Another common mistake is when problems in the maxillary sinuses and/or paranasal mucosa refer pain to the maxillary premolar and molar teeth. This type of pain is usually dull and increases with coughing or sneezing. In addition, lowering the head can increase pressure over the sinuses, thus exacerbating this pain.[2] Pulp testing with cold and percussion may increase the pain from the sinus. A history of upper respiratory infection, nasal congestion, or sinus problems is a good indicator of the presence of sinus problems rather than a toothache. These patients usually do not have decay or restorations in the region to indicate presence of pulpal and/or periapical diseases. Sinus radiographs, CBCT images, or a magnetic resonance imaging (MRI) can greatly help in the diagnosis of these conditions and thus prevent mishaps. Referral to an ENT specialist is indicated when these conditions are suspected.

Arteritis of the carotid or temporal arteries can present with pain in and around teeth, jaws, and related structures. Palpation of these specific anatomical locations can assist in the diagnostic process.[4,5,8] Similar to patients with sinus pain, these patients also do not have decay or restorations in the region to indicate the presence of pulpal and/or periapical diseases.

Another nonodontogenic pain that is commonly misdiagnosed is cardiac pain. Cardiac problems such as angina pectoris or acute myocardial infarction refer pain to the shoulder, to the arm, and even to the mandibular teeth, which is why these patients seek dental treatment. The dentist must be aware of the fact that this type of pain may be associated with chest pain, but occasionally they do not

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occur together.[2] When a toothache has a cardiac origin, it usually increases with exercise and decreases with medication such as nitroglycerin tablets. The role of the dentist in this situation is to rule out any pulpal or periapical diseases and to immediately refer the patient to a physician for treatment of the underlying cardiac problem.

Mishaps During Patient Interview

Mishaps during a patient's interview can relate to information regarding the chief complaint, health and medical history, or dental history.

Chief complaint

Recording information about why the patient is seeking care starts with their chief complaint and is the first encounter between the patient and the provider or his/her staff members. The chief complaint should be listened to very carefully and be recorded in the patient's own words. Remember, this is why the patient is seeking help. Patients usually judge the character of the provider and staff based on the outcome of treatment and how well their chief complaint was addressed. Patients want to know that your priority as a clinician is their well-being rather than the knowledge that you possess. Ignoring or not paying enough attention to the patient's chief complaint not only results in missing valuable diagnostic information, but it may also cause a lack of trust between the patient and the provider.

Health and medical history

Recording an accurate and complete medical history with vital signs is important for a thorough endodontic evaluation and subsequent diagnosis. The relationship between systemic disease and apical periodontitis has been a subject of great interest for many years.[2] This relationship is an intricate one, because both conditions share many common bioburdens and risk factors.[16–19] The common diseases that may influence endodontic pathosis, treatments, and outcomes are cardiovascular disease (CVD), diabetes, hematologic disorders, cancer, kidney disease, and neurologic disorders. Osteoresorptive agents and medications that are known to increase the risk of osteonecrosis of the jaw (bisphosphonate, denosumab, and angiogenic drugs) should be avoided when considering endodontic surgical intervention.

Cardiovascular diseases

CVDs include a group of heart and vascular systemic diseases. Some of the most common CVDs among a population might include endocarditis, myocardial infarction, hypertension, dysrhythmias, and ischemic heart disease. Systematic reviews and epidemiologic data have reported the association between endodontics and CVD, which underscores the common mechanisms and immunomodulatory effects that link these two types of diseases.[18,20] This association occurs primarily from the bacterial byproducts shared by both of these chronic diseases, resulting

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in inflammatory reactions, increasing C-reactive protein, interleukins, matrix metalloproteinases, and immunoglobulins, which result in NF-kB pro-inflammation gene induction.[21,22]

Endocarditis

The American Dental Association (ADA) and the American Heart Association (AHA) updated a scientific statement in 2021 to support antibiotic prophylaxis only for the highest risk patients who have recurrent episodes of native or prosthetic valve infective endocarditis.[23] The statement highlights the importance of prophylaxis for all dental procedures that involve manipulation of gingival or periapical regions.

Myocardial infarction

Nonsteroidal anti-inflammatory drugs (NSAIDs) are not recommended for patients with myocardial infarction (MI).[24] A recent MI, defined as within the past 6 months, dictates that elective dental treatment should be postponed and, if urgently needed, should be provided in consultation with the patient's physician.[25] For stress reduction, oral sedative premedication may be indicated. Vital signs should be monitored, while nitroglycerin and aspirin 81 mg should be available. An emergency container should contain additional paraphernalia. An oral and maxillofacial surgery text should be consulted for the contents of this container.

Vasoconstrictors

Epinephrine should be limited to 0.04 mg for this population. The appointment should be terminated if blood pressure readings are > 180/110. In general, vasoconstrictors are contraindicated for the following patients: recent MI, unstable angina, recent coronary artery bypass surgery (within 3 months), uncontrolled or untreated hypertension, refractory arrhythmias, uncontrolled hyperthyroidism, or uncontrolled diabetes.[25]

Nonselective beta-blockers and vasoconstrictors might result in dangerous elevation in blood pressure. Thus, it is recommended to either avoid administration of epinephrine or closely monitor blood pressure after administration of 0.017 mg epinephrine.

Anticoagulant and antiplatelet agents

Patients taking antithrombic medications may be at high risk of excessive bleeding during an endodontic surgical procedure.[26] Due to the many complications associated with Coumadin, many patients are now taking direct oral anticoagulants (DOACs). Examples of DOACs include apixaban (factor Xa inhibitor), dabigatran (factor IIa inhibitor), edoxaban (factor Xa inhibitor), and rivaroxaban (factor Xa inhibitor). Care must be taken in treating these patients, particularly when performing incision and drainage, surgical treatment, or perforation repair,

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because excessive bleeding may occur. Local measures to control bleeding are recommended, and discontinuation of anticoagulant medication is not advised.[26] Patients on Coumadin should not receive fluconazole or metronidazole because both drugs increase the concentration of Coumadin.

Digoxin

Patients on digoxin should not receive epinephrine, because it would increase the risk for arrhythmia.

Diabetes mellitus

Diabetes is a metabolic disorder that is caused by either a deficiency or a resistance to insulin, which results in poor circulation, healing, and outcomes.[17,27] The microangiopathies from diabetes can cause problems with eyes, kidneys, extremities, and any other area where small arteries are located. A high prevalence of periapical radiolucencies within the type 2 diabetes population has been reported.[28] The authors suggested that controlling the disease with medications (insulin, metformin, statin) was associated with lower prevalence of apical periodontitis. This indicates that when treating these patients, the astute provider should know the patient's current hemoglobin A1c status (HbA1c).

Hematologic diseases

Sickle-cell anemia

Patients with sickle cell anemia have a high prevalence of orofacial pain and pulp necrosis.[29,30]

Hemophilia

Congenital bleeding disorders should be identified and treated appropriately. NSAIDs should be avoided as these patients are at great risk of bleeding from invasive dental procedures. Patients with hemophilia and von Willebrand disease may be managed with desmopressin and aminocaproic acid. Factor VIII replacement might be required prior to the treatment for hemophilia A, and Factor IX replacement may be required prior to an invasive treatment for hemophilia B. Local hemostatic agents should be used to control bleeding.

White blood cell disorders

White blood cells (WBCs) constitute three groups: granulocytes, lymphocytes, and monocytes. Because WBCs are responsible for defense against microbial invasion, defects in WBCs can result in infection and delayed healing. Bisphosphonates and denosumab are anti-resorptive drugs that are used for treatment of myeloma.[31,32] Though similar in their anti-resorptive action, the two drugs work differently: Denosumab acts by binding to and inhibiting RANKL, and bisphosphonates inhibit osteoclasts.[33] Both of these medications and another group of

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drugs, angiogenesis inhibitors, have been associated with medication-related osteonecrosis of the jaw (MRONJ).[34] These drugs are also used for osteoporosis, multiple myeloma, and/or cancer therapy.[35] As such, care must be used in treating these patients when manipulating hard tissues. Denosumab belongs to a group of anti-cancer drugs called *monoclonal antibodies*. These drugs have also been associated with external cervical resorption.[36]

Chronic kidney disease

Chronic kidney disease (CKD) and end-stage renal disease (ESRD) are conditions where renal osteodystrophy can occur secondary to high levels of parathyroid hormone. A clinician must not confuse the lesions with a periapical radiolucency. These patients should not receive NSAIDs, tetracycline, high doses of acyclovir, or high doses of amoxicillin or cephalexin.[37] They may be on immunosuppressant drugs and anticoagulant agents.

Neurologic diseases

Lyme disease

Lyme disease can mimic orofacial pain. As such, a clinician must ensure that all clinical signs and symptoms come together to form an accurate and logical diagnosis.

Multiple sclerosis

Multiple sclerosis is a common autoimmune disease where demyelination of the corticospinal tract neurons takes place. It can mimic trigeminal neuralgia and should be included in a differential diagnosis. Trigeminal neuralgia can occur secondary to multiple sclerosis and can mimic orofacial pain.[38]

Cancer

Chemotherapy drugs cause immunosuppression. Additionally, antiresorptive agents—such as bisphosphonates and denosumab—and angiogenesis inhibitors may be administered to these patients.[39] These drugs are also used for osteoporosis.[40] As discussed previously, these medications may result in MRONJ. For this reason, the clinician should be completely familiar with the patient's medical history and medications and know when to request the patient's complete blood count (CBC) with differentials.

Consultation with the patient's physician is highly recommended for surgical interventions. Occasionally, antibiotics may be required for patients whose WBC count is outside of the norm (normal value may be in the range of 4,000–10,000/mL and neutrophil should be 50% cell/mL).

Patients with radiation > 60 Gy to the head or throat have an 11-fold increased risk of osteoradionecrosis.[41] Thus, surgical interventions should be avoided.

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Pregnancy

According to the joint statement by the ADA and the American College of Obstetricians and Gynecologists, endodontic therapy can be safely performed without delay at any time during pregnancy.[42] Class B pregnancy drugs, which include lidocaine and prilocaine, acetaminophen, cephalosporins, clindamycin, and azithromycin, are preferred,[43] though acetaminophen should be used sparingly.[44] Caution should be exercised when using epinephrine because it contracts the uterine and vascular walls, resulting in reduced blood flow to the fetus.[45]

Smoking

Smoking is related to high prevalence of pulpal necrosis and apical periodontitis.[28,46] However, it is unknown if it would be associated with worse endodontic outcomes.[46]

Dental history

Recent visit(s) to other provider(s) might provide valuable information regarding the etiology of the patient's chief complaint. Information regarding recent trauma or restorations and previous treatment for temporomandibular dysfunction may indicate the type of treatment that would be most appropriate for a patient. When taking dental history, the clinician should ask about the presence and the nature of the pain, any swelling, broken or loose teeth, tooth discoloration, and/or a bad taste. Missing this information while recording a dental history can easily result in misdiagnosis and inappropriate treatment.

If there are two or more concurrent complaints, the history of each complaint must be obtained.[47] When pain is the chief complaint of the patient, the following questions should be asked regarding the characteristics and the nature of the existing pain: the location, onset, cause, and character of the pain (short, sharp, long lasting, dull, throbbing, continuous, occasional); if there is interference of sleep or work; if there is any worsening of the condition in the morning or evening; whether there is spontaneity (nonspontaneous or spontaneous); if any postural changes affect the pain; and if anything makes the pain better or worse (hot, cold, biting). Quantification of the amount of pain (on a Likert scale of 0 to 10) not only gives the practitioner an idea about the severity of the pain; it also allows comparison of the pain from visit to visit, particularly if there is residual pain after treatment.[47]

Mishaps During Clinical Examination

A clinical examination consists of careful observation and diagnostic testing of extraoral and intraoral tissues to compare them with other normal structures without apparent pathosis.

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Fig 1-1 Extraoral sinus tract. *(a)* This facial skin lesion was misdiagnosed and treated unsuccessfully by a dermatologist for several months. Fortunately, the patient's dentist then recognized it to be a draining sinus tract with its source being a maxillary cuspid tooth. *(b)* The pulp was necrotic with a previous root canal treatment. *(c)* The tooth was treated surgically. *(d)* A 7-year recall shows that the sinus tract and surface lesion resolved completely. *(e)* The periapical lesion also resolved completely. (Courtesy of Dr C.J. Hong.)

Fig 1-2 Intraoral sinus tract. Presence of a stoma usually indicates existence of a necrotic pulp and a chronic apical abscess.

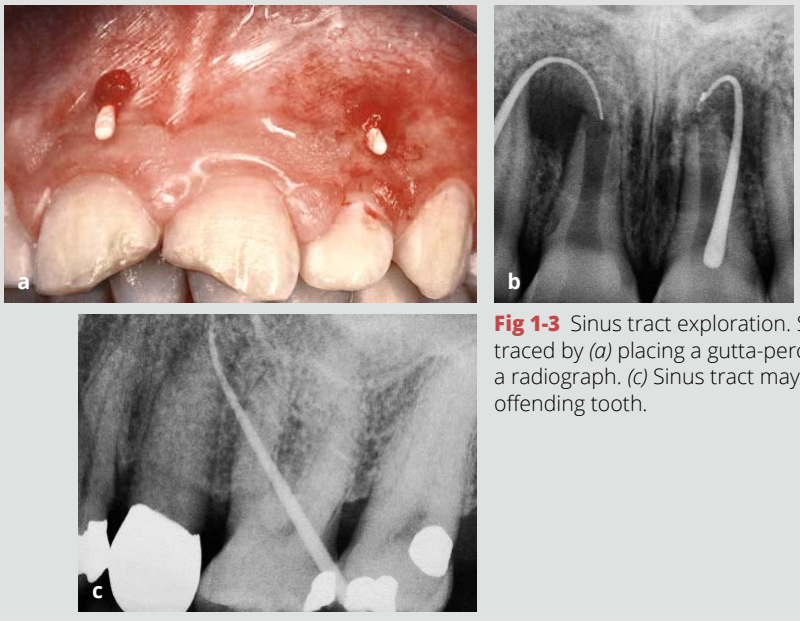

Fig 1-3 Sinus tract exploration. Sinus tracts should always be traced by *(a)* placing a gutta-percha in them and *(b)* exposing a radiograph. *(c)* Sinus tract may appear far away from the offending tooth.

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Extraoral examination

During extraoral examination of a patient, the general appearance, skin tone, and facial asymmetry are evaluated. The presence or absence of swelling, discoloration, redness, extraoral scars, sinus tracts, and lymphadenopathies should also be evaluated. A careful extraoral examination can identify the cause of the patient's chief complaint and may help to reveal the cause of intraoral pathosis. A good example of this condition is the presence of an extraoral fistula related to a mandibular or maxillary tooth (Fig 1-1). A common mishap is misdiagnosis of these conditions as skin infections and subsequently treating them with medications and multiple surgeries.

Intraoral examination

Intraoral examination consists of close observation and testing of soft and hard tissues of the oral cavity. A soft tissue examination includes a careful visual evaluation and digital evaluation of the lips, oral mucosa, cheeks, tongue, periodontium, palate, and muscles of mastication. The alveolar mucosa and gingiva are examined for the presence of inflammation, ulceration, discoloration, and sinus tract formation. The presence of a stoma usually indicates a necrotic pulp, while a chronic apical abscess might indicate a periodontal abscess (Fig 1-2). Sinus tracts should always be traced by placing a gutta-percha in them and then confirming with a radiograph. A common mishap is the assumption of some clinicians that the sinus tracts appear adjacent to the offending tooth. That is not always true. A sinus tract may appear far away from the offending tooth (Fig 1-3). When swelling is present, questions must be asked regarding when the swelling began, how quickly the swelling increased in size, the nature of the swelling (fluctuant, indurated, tender), if there is drainage from the swelling, and if the swelling is associated with an excessively mobile or tender tooth.[47] Answers to these questions can determine whether the swelling is from a periapical abscess or a periodontal abscess. This information may help prevent misdiagnosis and mistreatment.

Before performing clinical tests, the teeth should be examined with a mirror and an explorer for discolorations, fractures, abrasions, erosions, caries, failing restorations, or other abnormalities.[2,47] A discolored crown is often pathognomonic of pulpal pathosis or the sequela of past root canal treatment (Fig 1-4).

Fig 1-4 A discolored incisor may indicate the presence of a tooth with necrotic pulp, calcified pulp chamber, or inadequate previous root canal treatment.

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Clinical tests

Clinical tests include several methods to determine the presence or absence of pathologic changes in the dentition. The reason for using a number of tests is that each test has its inherent limitations and must be interpreted carefully in conjunction with all other information available. In order to improve the outcome of these diagnostic tests, each test should be explained in simple terms to the patient. It is important to include a control (comparison) tooth of a similar type to the suspected tooth or teeth. A common mistake during performing clinical tests is the exclusion of control teeth for comparison, but a control tooth provides vital information for the clinician to compare the patient's baseline responses. The clinical tests used during diagnosis include percussion, palpation, probing, vitality tests, and radiographic examination.

Percussion

Percussion is performed either by using the end of a mirror handle held parallel or perpendicular to the crown or by applying gentle digital pressure on a very tender tooth to identify the offending tooth with pulpal or periapical disease. When a painful response is obtained, it only indicates the presence of inflammation somewhere in the periodontal ligament of the tooth. Repetitive strain of the periodontal ligament through clenching, presence of gross malocclusion, or traumatic injury to teeth can cause inflammation of the periodontal ligament without pulpal and/or periapical disease.[2] A common mistake during a percussion test is the assumption that the tenderness of a tooth to percussion is due to the presence of a tooth with periapical inflammation. To avoid this mistake, the presence of other etiologies should be considered, such as deep decay and/or restorations in teeth with sensitivity to percussion.

Palpation

Palpation sensitivity indicates the presence of inflammation in the periapical tissues of a tooth and is more reliable than percussion sensitivity testing. A painful response to palpation usually indicates presence of periapical inflammation in a tooth with pulpal and/or periapical disease.

Pulp sensitivity tests

Currently, there are three methods to determine pulp response: cold, hot, and electrical tests. These tests do not determine the *vitality* of the dental pulp; they only determine the level of *sensitivity* of the dental pulp to these stimuli. Selection of the appropriate test is based on the patient's chief complaint to check for reproducibility of the symptoms that simulate the patient's complaint. If a patient's chief complaint is sensitivity to cold, the results of hot or electrical tests for that patient are generally irrelevant.

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The cold test is the most reliable method to determine the presence or absence of vital tissue in a tooth. After the tooth is dried and isolated with cotton rolls, a cold stimulus is applied to the buccal or lingual surface of the tooth close to the cementoenamel junction (CEJ). Presence of prolonged pain after application of cold to a tooth usually is an indication of irreversible pulpitis. However, absence of a response to cold does not necessarily mean the presence of a necrotic pulp. There are patients who present with very little or no response to thermal changes without having pulpal pathosis. A false negative response is often obtained when cold is applied to teeth with calcific metamorphosis, whereas a false positive response may result if cold contacts gingiva or is transferred to adjacent teeth with vital pulps. Gingival recession and attachment loss decrease sensitivity to cold testing.[48] Common errors for this test are lack of isolation of a test tooth, lack of a control tooth for comparison, and misunderstandings regarding the possibilities for false positive and negative responses.

An electric pulp test determines the sensitivity of the pulp to this stimulus. After the tooth is dried and isolated with cotton rolls, an electric stimulus is applied to the buccal or lingual surface of the tooth with a small amount of toothpaste on the electrode of the pulp tester as a conduction agent. False positive and false negative results can be the main problems with this test.[49] Small canals or pulp-canal obliteration may lead to false negative responses.[50] Some clinicians use the exact readings during this test as an indication of pulpal status. However, the exact number of the reading is not significant because it does not detect subtle degrees of pulpal vitality.[51] Additionally, this test does not indicate if there is partial necrosis, particularly in a multirooted tooth. The common errors for electric testing are lack of proper isolation of the test tooth, absence of control tooth for comparison, and lack of knowledge regarding the shortcomings of this test.

The heat test is the least reliable, and it should only be used in patients who complain about heat sensitivity.[52] After isolating the tooth with a rubber dam to prevent false positive responses from adjacent teeth, heat is applied to the buccal or lingual surface of the suspected tooth. As with cold, the presence of prolonged pain after application of heat to a tooth usually is an indication of the presence of irreversible pulpitis. Like cold and electric pulp testing, the common errors for this test are lack of proper isolation of the suspect tooth, the absence of a control tooth for comparison, and lack of knowledge regarding the shortcomings of this test.

Currently, a single diagnostic device capable of applying thermal and electrical stimuli and transillumination is not available. The convenience of having a single diagnostic test is overlooked because the current gold standard for testing requires different materials and techniques. Figure 1-5 shows the current devices used for pulp sensitivity tests. A single diagnostic device capable of providing cold, heat, electricity, and light in one comprehensive setting would increase diagnostic accuracy of pulp testing.

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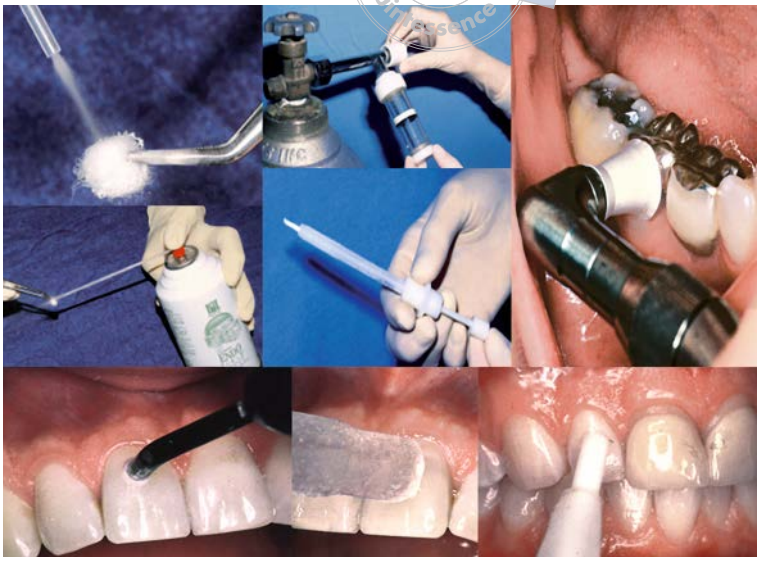

Fig 1-5 The current devices for pulp sensitity tests.

Probing

Probing is an important clinical test but, unfortunately, is the least used test for diagnosis and treatment planning. Periapical and periodontal lesions both destroy periradicular tissues and may mimic each other. Probing is a diagnostic tool that can accurately differentiate between these two problems. Periodontal defects have been classified into three major categories.[53–55] They are either of pulpal origin (endodontic), periodontal origin, or both endodontic and periodontic origin (true combined lesions).

Primary periodontal defects of endodontic origin

A periodontal defect of endodontic origin is usually associated with a tooth with pulpal necrosis (Fig 1-6a). Periodontal probing usually indicates normal sulci around the tooth except in one area with a narrow defect. This defect is not a true periodontal pocket because adequate cleaning, shaping, and obturation of the root canal system usually leads to complete resolution (Figs 1-6b and 1-6c). A common mishap is inadequate probing to determine the etiology of the periodontal pocket.

Primary periodontal defects of periodontal origin

A periodontal defect of periodontal origin is usually associated with generalized gingivitis and/or periodontitis resulting from the accumulation of plaque and/or calculus formation (Fig 1-7). Teeth with these defects respond normally to pulp sensitivity testing. When probing, the crest is within normal limits. Then, in a "step-down" fashion, the probe reaches deeper. The pocket depth decreases in a "step-up" manner and reaches the normal depth on the other side of the pocket.[53] A common mishap in this situation is a false assumption that these lesions are of pulpal origin and that the tooth or teeth will respond positively to root canal treatment.

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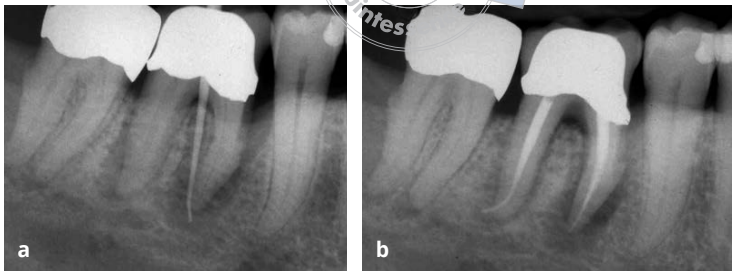


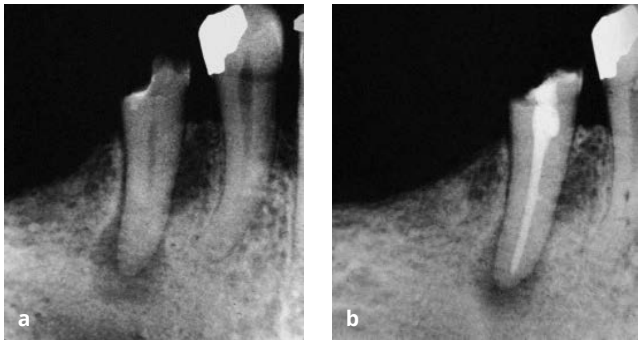
Fig 1-6 *(a)* A necrotic pulp has developed a periodontal lesion and a sinus tract traceable by gutta-percha. *(b)* Complete cleaning, shaping, and obturation of the root canal system with gutta-percha and sealer. *(c)* Complete resolution of this lesion after 3 years. (Courtesy of Dr Samuel O. Dorn.)

Fig 1-7 Periapical radiograph of left maxillary premolar region reveals the presence of severe periodontal lesions in this area with generalized vertical and horizontal bone loss along the root surfaces.

Primary periodontal defects of endodontic-periodontic origin (true combined lesions)

These defects have two concurrent components: a periodontal component and a periapical component (Fig 1-8a). A true combined defect is usually associated with clinical signs and symptoms of generalized gingivitis and/or periodontitis. A tooth with a true combined lesion is unresponsive to pulp vitality tests. Similar to a lesion of periodontal origin, a defect of this type is wide and V-shaped.[56] True combined lesions require endodontic and periodontal treatments (Fig 1-8b). A common mishap in this situation is a false assumption that these lesions will respond positively to exclusively endodontic or periodontal treatment.

Fig 1-8 *(a)* A true combined endodontic-periodontic lesion is observed in the second mandibular premolar. *(b)* Endodontic and periodontal treatments of this tooth have resulted in the decrease of these lesions in 6 months.



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Mobility

Like periodontal probing, the mobility test is underused and overlooked in many cases, and it is often not correctly recorded.[57] The mobility test can possibly determine the etiology of the disease and its prognosis. Teeth with extreme mobility as a result of periodontal disease have little periodontal support and usually a poor prognosis. A severe periapical abscess can cause excessive mobility, which usually decreases dramatically after successful root canal treatment. A common mishap is a false assumption that all teeth with severe mobility, regardless of their etiology, have a poor prognosis and need extraction.

Mishaps During Radiographic Examination

Radiographic examinations are essential for the evaluation of hard tissues (see chapter 2). However, their value is overestimated by some clinicians who often rely more on radiographic findings than clinical findings. This attitude is a mistake and can lead to misdiagnosis and incorrect treatment. Radiographic examinations reveal the relationship between teeth and the adjacent neurovascular bundle and maxillary sinuses as well as the presence or absence of carious lesions, defective restorations, previous endodontic treatment(s), abnormal pulpal and periapical appearances, impacted teeth, and bone loss from periapical and periodontal diseases.[58] They may also reveal structural changes and bony disease unrelated to the pulp. However, radiographs are two-dimensional (2D) images and may not reveal the full picture of a clinical problem. Exposing more than one radiograph from different angles may minimize this shortcoming.

CBCT provides 3D images and dramatically aids in the diagnosis of complex cases. CBCT imaging eliminates the anatomical noise that is present in 2D imaging, particularly in areas of structural overlap such as the posterior region of the maxilla.[59] CBCT images can detect periapical pathosis in an earlier stage of disease than 2D imaging techniques.[60] CBCT was reported to have twice the odds of detecting a periapical lesion than traditional 2D periapical radiography.[61] The disadvantages of using CBCT imaging are increased radiation exposure, high cost, and lack of availability in all dental offices. Exposing CBCT images is recommended for difficult diagnoses, complex anatomy, evaluation of prior treatment complications, assessment of potential surgical cases, and evaluation of cases with traumatic injuries or resorption.[62,63]

A number of radiolucent lesions of nondental origin simulate the radiographic appearance of endodontic lesions. Because of their similarities, dentists must use their knowledge and perform clinical tests in a systematic manner to arrive at a diagnosis and avoid critical mistakes. Pulp responsive tests are the most important aids in differentiating between endodontic and non-endodontic lesions. Teeth associated with radiolucent periradicular lesions have necrotic pulps and therefore generally do not respond to pulp tests. In contrast, lesions of non-pulpal origin usually do not affect the blood or nerve supply to an adjacent tooth pulp;

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therefore, their responsiveness to various stimuli remains unaffected. Unfortunately, some clinicians use only radiographs for diagnosis without taking a complete history of the signs and symptoms and performing clinical tests. To avoid mistakes, all relevant pulp tests, radiographic examinations, clinical signs and symptoms, and details of the patient history should be used for diagnosis and treatment planning. Most radiographic changes are, in fact, endodontic and arise from pathologic changes in the pulp. However, some radiographic variations, such as anatomical variations as well as benign and malignant lesions, may simulate the appearance of periradicular lesions.[2]

Anatomical entities simulating periapical lesions of pulpal origin include large marrow spaces adjacent to the apices of teeth, submandibular fossae, maxillary sinus, apical dental papillae of developing teeth, nasopalatine foramen, mental foramen (Fig 1-9), and lingual depressions in the mandible. Associated teeth respond to vitality tests and show no clinical signs or symptoms of any disease process. Additionally, changing the cone angulation, the location of these radiolucent lesions can be moved relative to their original positions and to the root apices (see Fig 1-9b).

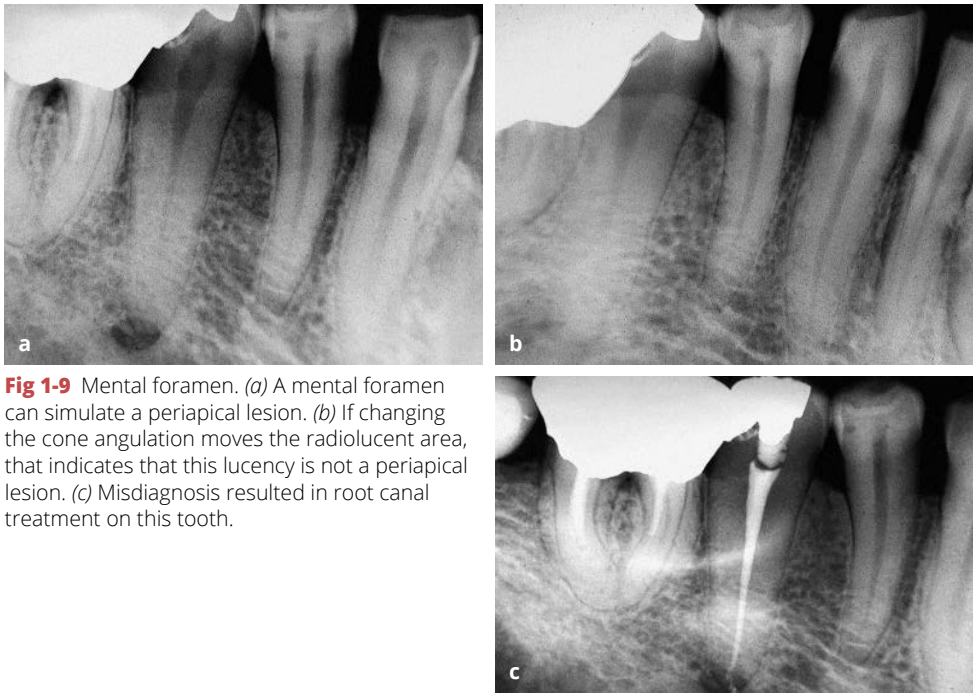

Fig 1-9 Mental foramen. *(a)* A mental foramen can simulate a periapical lesion. *(b)* If changing the cone angulation moves the radiolucent area, that indicates that this lucency is not a periapical lesion. *(c)* Misdiagnosis resulted in root canal treatment on this tooth.

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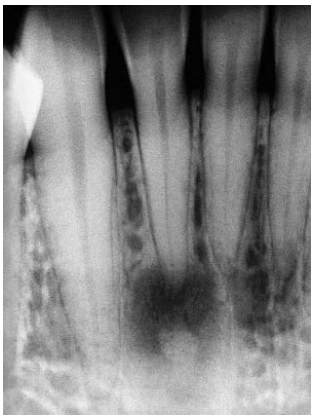

Fig 1-10 Cemental dysplasia. The initial stage of periradicular cemental dysplasia can be mistaken for a periapical lesion of pulpal origin.

Some benign lesions with radiographic appearances similar to odontogenic periradicular lesions include the initial stages of periradicular cemental dysplasia (Fig 1-10), early stages of monostotic fibrous dysplasia, ossifying fibroma, primordial cyst, lateral periodontal cyst, dentigerous cyst, nasopalatine duct cyst, solitary bone cyst, central giant cell granuloma, central hemangioma, hyperparathyroidism, myxoma, and ameloblastoma. The lamina dura around the apices of teeth associated with these lesions is usually intact, and pulp tests of these teeth respond within normal limits. To confirm the final diagnosis of these lesions, a surgical biopsy and histopathologic examination are needed.[64]

Malignant lesions that may simulate odontogenic periradicular lesions are metastatic lymphoma, squamous cell carcinoma, osteogenic sarcoma, chondrosarcoma, and multiple myeloma. Unlike endodontic lesions of pulpal origin, these lesions are usually associated with rapid and extensive hard tissue destruction (Fig 1-11). The teeth in the affected region usually remain responsive to vitality tests, but occasionally, the pulps or sensory nerves are disrupted and nonresponsive. For a more complete list as well as clinical and radiographic descriptions of these lesions, an oral and maxillofacial pathology text should be consulted.[65]

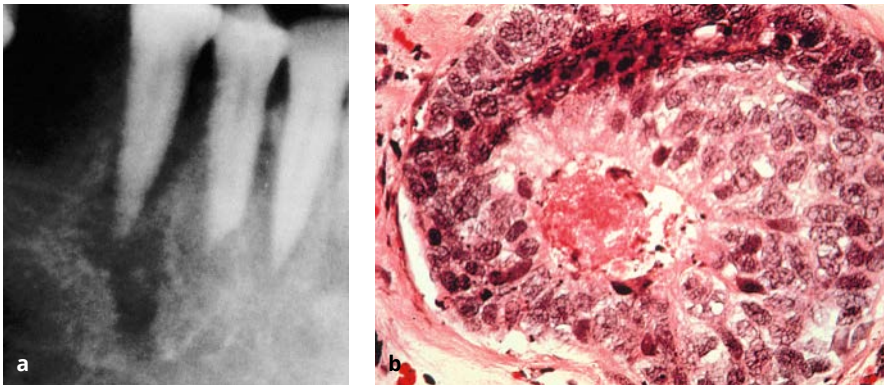

Fig 1-11 Adenocarcinoma. *(a)* Despite the presence of a lesion in the mandibular premolar, all the teeth in the region were responding within normal limits. *(b)* The lesion was fast growing, and the biopsy showed presence of an adenocarcinoma.

Mishaps During Additional Diagnostic Procedures

After systematically performing clinical and radiographic tests, it is usually possible to establish an accurate diagnosis and subsequent treatment plan. However, if the clinician is unable to make a definitive diagnosis, additional tests such as a cavity test, selective anesthesia, and transillumination might be helpful.

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Test cavity

When the results of cold, heat, or electrical tests are inconclusive and the clinician cannot determine the presence of a necrotic pulp in a suspected tooth, dentin stimulation using a test cavity is the most reliable test. After careful explanation of the nature of the test to the patient, an access preparation, without anesthesia, is performed. If the pulp is vital, a pain sensation will be felt by the patient when the dentin is reached. If the pulp is necrotic, no discomfort will be felt upon entering the dentin or the pulp chamber. Unfortunately, most clinicians are not aware of the value of this test to determine the presence of a necrotic pulp in a suspected tooth. Additionally, an inadequate explanation to the patient before testing may result in a false positive response.

Selective anesthesia

Selective anesthesia is a useful test in localizing pain when the patient cannot identify the offending tooth. If a mandibular tooth is the suspect, a mandibular block could help confirm the diagnosis if the pain disappears after the injection. If a maxillary tooth is the suspect, infiltration anesthesia in an anterior to posterior fashion can help identify the suspected tooth. A common mistake in performing this test is administration of infiltration anesthetic in posterior to anterior regions. Another common mistake is the assumption that the intraligament injection identifies the offending tooth in the mandible. Intraligament injection often anesthetizes several teeth and should not be used as a diagnostic method to identify the source of pain in mandibular teeth.[66] However, using this technique for maxillary teeth is more reliable.

Bite and transillumination tests

Bite and transillumination tests are helpful methods to identify the presence or absence of cracks or fractures in teeth.[67] A common mistake in using these tests is accepting craze lines as cracks or fractures without digital examination of the involved teeth.[68]

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