Common Complications in Endodontics

Prevention and Management

Priyanka R Jain
Editor

Second Edition

Springer

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To my father, whose guiding presence I feel with me always.

Preface

Since the publication of the first edition, I have been overwhelmed and deeply gratified by the reception this book has received. The feedback from readers, both critical and complimentary, has not only reinforced the original purpose of this book but also provided insights for its improvement.

The second edition aims to share three more chapters in addition to refining the existing chapters. While the core objective remains the same—providing practical solutions and preventive strategies for endodontic complications—this edition introduces new chapters that reflect current trends and interdisciplinary approaches:

The chapter "Harmonizing Endodontics and Orthodontics," authored by Dr. Sanjay Miglani and Dr. Neha, explores the intricate relationship between these two specialties, focusing on the impact of orthodontic treatment on endodontic health and vice versa. It provides a comprehensive guide to managing cases that require collaboration between orthodontists and endodontists.

The chapter "Mechanical Failure After Root Canal Shaping: Strategies for Prevention, authored by Dr. Kim, delves into the mechanical principles, design considerations, and potential pitfalls associated with their use, given the critical role of instruments in endodontic procedures. Understanding these factors can help clinicians minimize procedural errors and improve outcomes.

The chapter "Legal Considerations in Endodontics," authored by Dr. Annalie and myself, addresses documentation, informed consent, and strategies for mitigating legal risks while delivering quality care. It also gives two fictitious case examples of dental litigation cases.

I hope this second edition continues to serve as a reliable guide for addressing complications in endodontics and inspires confidence in managing even the most challenging cases. Thank you for your trust and interest in this work.

Sincerely,
Priyanka R Jain

Metro Manila, Philippines

Acknowledgement

This new edition would not have been possible without the invaluable support of my colleagues and the readers who have shared their insights and experiences. I would like to extend my heartfelt gratitude to them and to the publishers for their unwavering commitment to this project.

I would like to begin by thanking all my contributing authors from the first edition, without whose support this project would not have been possible. I am also grateful to Dr. Sanjay Miglani, Dr. Neha, Dr. Hyeon-Cheol Kim, and Dr. Annalie De Lemos for their contributions toward the new edition.

To those returning to this book, I hope you find the changes enriching and relevant. For new readers, I trust this edition provides a thorough and engaging introduction to endodontics.

I would also like to thank Alison for her faith in me and giving me the opportunity to write the second edition. My sincere thanks go to Ms. Pinky Satishkumar and her team for their professional expertise in making this book a reality.

Most importantly, thanks to my husband, my children, and all my family members for constantly encouraging me and putting up with me when I am completely absorbed in my work.

Thank you for your continued interest and support.

Priyanka R Jain

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1.1 Introduction

Establishing an accurate diagnosis (both pulpal and periapical) is the most important step in determining the appropriate treatment [1, 2]. If an incorrect diagnosis/assessment of the clinical findings is made, improper management may result often leading to confusion, for example, performing endodontic treatment when it is not needed or providing some other treatment when root canal treatment is indicated. Tooth pain is usually considered the worst and least tolerable kind of pain. It usually originates in dentine, pulp, or periapical tissue and is thus considered of endodontic origin. Therefore, 90% of all patients with orofacial pain require a thorough endodontic assessment and diagnosis, and 60% of them may require endodontic treatment. A proper diagnosis is only possible following the subjective description of complaints by the patient coupled with objective clinical findings. Identification of a coronal or radicular fracture is also important. Although this is not specifically a pulpal or periradicular diagnosis, but it is important to note that fractures may change the proposed treatment plan. Temporomandibular joint (TMJ) dysfunctions may also present as dental pain, so we should keep in mind the clinical presentation of patients with those symptoms as well.

Following a definitive diagnosis of the need for root canal treatment, the treatment planning stage should be straightforward. The goal of endodontic treatment is to preserve the tooth as a functional unit within a functioning dentition. Therefore, the endodontic treatment must be integrated into a comprehensive treatment plan that includes both restorative and periodontal management.

This chapter will talk about the various endodontic diagnosis and describe each condition typical of clinical and radiographic characteristics supported by clinical cases. But we as clinicians have to recognize the fact that diseases of the pulp and periapical tissues are dynamic and their signs and symptoms may vary between

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patients. A simple and practical system which uses terms related to clinical findings is essential and will help clinicians understand the progressive nature of pulpal and periapical disease, directing them to the most appropriate treatment approach for each condition. The proposed endodontic treatment should be part of an agreed, comprehensive treatment plan that includes the patient's participation in the treatment decisions. The author will also discuss the various treatment planning considerations to be kept in mind. Pulpal obliteration and its management are also discussed in brief.

In 2008, the American Association of Endodontists proposed universal recommendations regarding endodontic diagnoses and developed a standardized definition of key diagnostic terms that will be generally accepted by endodontists, educators, test construction experts, third parties, generalists and other specialists, and students [3]. This will help in the interpretation of results and determine the radiographic criteria and clinical criteria needed to validate these.

1.2 Examination

Endodontic diagnosis cannot be made from a single complaint. The clinician must gather all the data presented to him to be able to make a probable diagnosis (Table 1.1).

1.2.1 History of Chief Complaint

The initial step for an exact endodontic diagnosis involves taking the patient's past and present medical history and any current medication. The relationship between the medical conditions and endodontic treatment are discussed later in the book. The medical case history is followed by a dental history, with particular emphasis on the current history. This should be clearly structured and suggestive questions must always be avoided.

Table 1.1 Examination procedures required to make an endodontic diagnosis

Medical/dental history	Past/recent treatment, drugs
Chief complaint (if any)	How long, symptoms, duration of pain, location, onset, stimuli, relief, referred, medications
Clinical exam	Facial symmetry, sinus tract, soft tissue, periodontal status (probing, mobility), caries, restorations (defective, newly placed?)
Clinical testing	
Pulp tests	Cold, electric pulp test, heat
Periapical tests	Percussion, palpation, tooth sloth (biting)
Radiographic analysis	New periapicals (at least 2), bitewing, cone beam computed tomography
Additional tests	Transillumination, selective anesthesia, test cavity

Possible questions for a detailed dental history:

1. Reason for consultation of dentist?
   If the patient indicates pain as a reason, a differentiated history of pain is required.
   (a) When did the pain start?
   (b) Kind of pain: spontaneous, constant, intermittent, continuously worsening, or improving periodically?
   (c) Does the pain radiate?
   (d) Can you localize it?
   (e) Pain during the night? Is it worse in the morning?
   (f) Any aggravating or relieving factors like heat/cold?
   (g) How long does it last?
   (h) Quality of the pain: dragging, stabbing, and throbbing?
2. Is there any swelling, and if so, where?
3. Is there a sensitivity to temperature? If so, describe the nature of it.
4. Has there been a need to take pain medication for this tooth? Does it help in controlling the pain?
5. Has there been any sinus problem lately?
6. Is the tooth sensitive to chewing or pressure?
7. Have you had any recent dental work?

It is important to recreate the patient's chief complaint during the clinical examination. This reduces the chance that you will miss an important piece of evidence. Also note that antibiotics and pain medications can make the diagnostic process more challenging and less reliable.

The clinical and radiographic examinations must be always combined with a thorough periodontal evaluation and clinical testing (pulp and periapical tests) before arriving at a preliminary diagnosis. In case the findings are inconclusive and a definitive pulpal and periapical diagnoses cannot be made, it is better that treatment should not be rendered at this stage. The patient may have to wait and be reassessed at a later date.

Endodontic diagnosis is composed of two parts: pulpal diagnosis and the periapical diagnosis. Pulpal diagnosis indicates the status of the pulp (nerve and connective tissue inside the tooth) and can be accomplished by using thermal and electric pulp tests. The periapical diagnosis indicates the status of the periapex (tissues around the root of the tooth) and, according to the *American Association of Endodontists*, is based upon pain and swelling. Diagnostic terminology used in this chapter is approved by the American Association of Endodontists and the American Board of Endodontics [4–6].

For clarification, the acute classifications refer to recent symptomatology. The chronic classifications refer to a situation that is long standing and can be viewed on a radiograph. Suppurative periradicular periodontitis is used when a sinus tract or drainage area is present. An acute periradicular abscess occurs when there is acute swelling, pus formation, tenderness, and eventual swelling with or without radiographic pathology.

1.2.2 Pulpal Diagnosis [7–12]

1.2.2.1 Normal Pulp

In this case, the pulp is symptom-free and usually responsive to pulp testing normally. A "clinically" normal pulp results in a mild or transient response to thermal and cold testing, lasting for few seconds after the stimulus is removed. The response should always be compared with adjacent and contralateral teeth.

1.2.2.2 Reversible Pulpitis

This is based upon both subjective and objective findings indicating that the pulp will return to normal following appropriate management of the cause. Pain is experienced when a stimulus such as cold or sweet is applied but goes away quickly (within a couple of seconds) following the removal of the stimulus. Etiological factors may include exposed dentin (dentinal sensitivity), caries, or deep restorations. There are no significant radiographic changes in the periapical area of the affected tooth. Pain elicited is not spontaneous but is usually hypersensitive. After the management of the etiology, the tooth requires further evaluation to determine whether the "reversible pulpitis" has returned to a normal status. Symptoms of dentinal sensitivity mimic those of a reversible pulpitis.

1.2.2.3 Symptomatic Irreversible Pulpitis (SIP)

This scenario is based on subjective and objective findings that the vital inflamed pulp is incapable of healing (returning to normal status) and that root canal treatment is indicated. Characteristics may include sharp pain upon thermal stimulus which lingers (often 30 s or longer after stimulus removal), spontaneous pain (unprovoked pain), and referred pain. At times, the pain may be accentuated by postural changes such as lying down or bending over, and over-the-counter analgesics are typically ineffective. Common factors include deep caries, extensive restorations, or fractures exposing the pulpal tissues. Such teeth may be difficult to diagnose because the inflammation has not yet reached the periapical tissues, thus resulting in no pain or discomfort to percussion. In such cases, detailed dental history and careful examination in conjunction with thermal testing are the primary tools for assessing pulpal status (Fig. 1.1).

1.2.2.4 Asymptomatic Irreversible Pulpitis

This is a clinical diagnosis also based on subjective and objective findings and root canal treatment is indicated. These cases have no clinical symptoms and usually respond normally to thermal testing but may have deep caries that would likely result in exposure during removal.

1.2.2.5 Pulp Necrosis

This is a clinical diagnostic category indicating death of the dental pulp, necessitating root canal treatment. The pulp is nonresponsive to pulp testing and is asymptomatic. Pulp necrosis by itself does not cause apical periodontitis (pain to percussion or any radiographic changes) unless the canal is infected. Some teeth may be nonresponsive

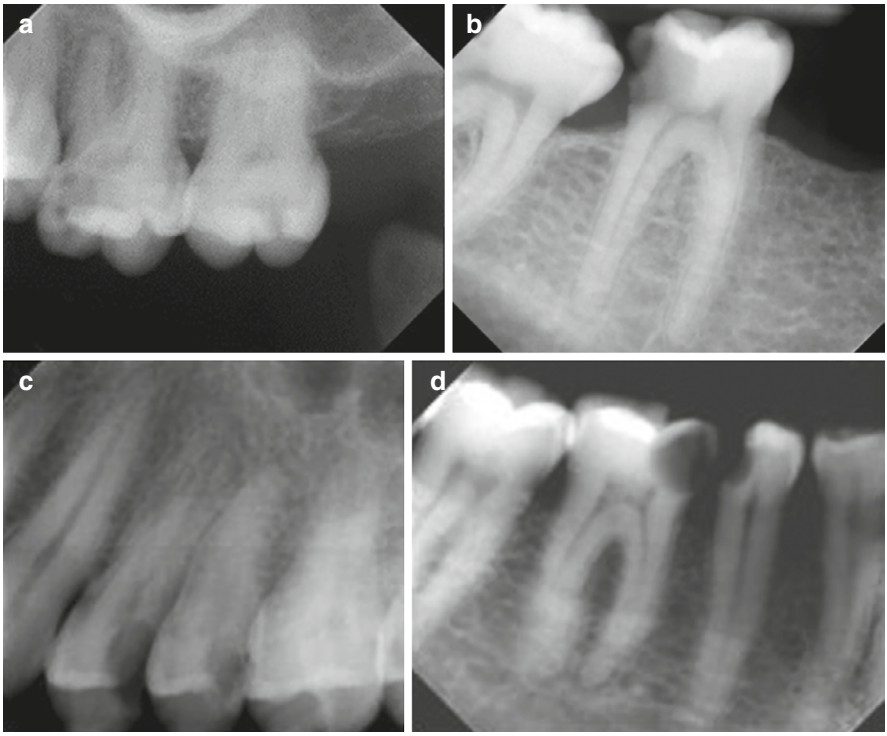


Fig. 1.1 (**a**, **b**) Symptomatic irreversible pulpitis. (**c**) Irreversible pulpitis on tooth 24, 25. (**d**) Irreversible pulpitis and widening of PDL on tooth 45, 46

to pulp testing due of calcification or recent history of trauma. Therefore, vitality testing must be comparative in nature with the adjacent teeth (Fig. 1.2).

If the pulp necrosis is asymptomatic, there:

1. May or may not be an observable radiographic lesion. If there is no observable lesion radiographically, caution is advised. If the tooth requires a new crown and there is evidence that the pulp is necrotic, it is optimal to perform endodontic therapy before placing the crown. If the tooth was once symptomatic with clear signs of irreversible pulpitis (especially spontaneous pain) and later became asymptomatic with or without a lesion, the tooth should be treated.
2. May be a lack of response to thermal pulp testing.

1.2.3 Apical Diagnoses [7–12]

1.2.3.1 Normal Apical Tissues

In teeth which are not sensitive to percussion or palpation during testing and radiographically, the lamina dura surrounding the root is intact with the periodontal

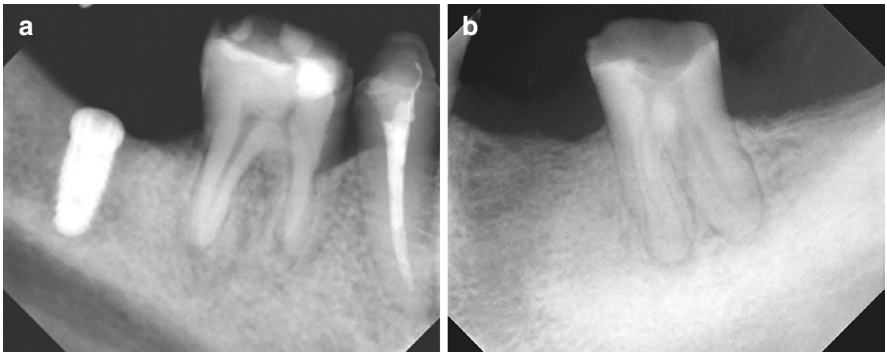


Fig. 1.2 (**a**) Partial pulp necrosis with root resorption (tooth 46). (**b**) Pulpal necrosis with uncertain periapical status

Table 1.2 Clinical findings used to differentiate between SIP and SAP

Criteria	Symptomatic irreversible pulpitis (SIP)	Symptomatic apical periodontitis (SAP)
Sensitivity to cold (carbon dioxide snow)	+	–
Radiographically widened ligament space	±	+
Swelling or sinus tract	–	–
Periapical radiolucency	–	±

ligament space as uniform. As with pulp testing, comparative testing for percussion and palpation should always begin with normal teeth as a baseline for the patient.

1.2.3.2 Symptomatic Apical Periodontitis (SAP)

This represents inflammation, usually of the apical periodontium. Clinical symptoms include a painful response to biting and/or percussion or palpation. This may or may not be accompanied by radiographic changes (i.e., depending upon the stage of the disease, there may be normal width of the periodontal ligament or there may be a periapical radiolucency). Severe pain to percussion and/or palpation is highly indicative of a degenerating pulp, and root canal treatment is needed (Table 1.2) (Fig. 1.3a, b).

1.2.3.3 Asymptomatic Apical Periodontitis

In this case, inflammation of the apical periodontium is of pulpal origin. It manifests as an apical radiolucency and does not present clinical symptoms (no pain on percussion or palpation) (Fig. 1.4a–c).

1.2.3.4 Chronic Apical Abscess

This is an inflammatory reaction to pulpal infection and necrosis characterized by gradual onset, little or no discomfort, and an intermittent discharge of pus through an associated sinus tract. Radiographically, there are signs of a radiolucency.

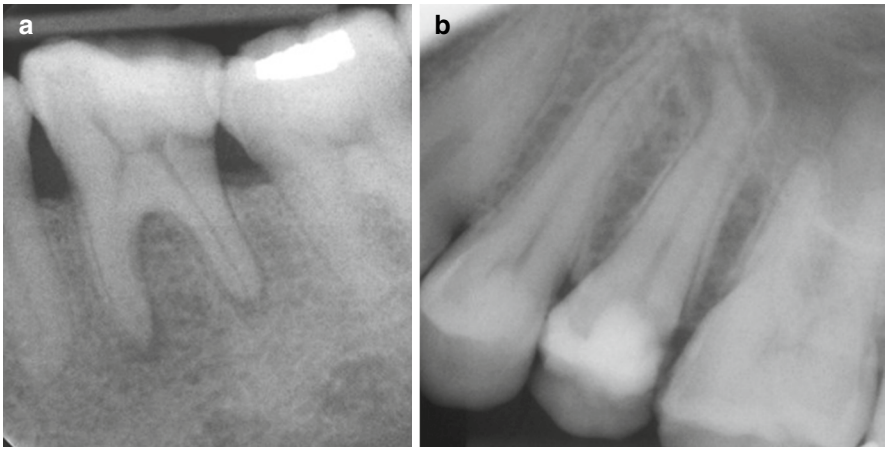


Fig. 1.3 (**a**, **b**) Pulpal necrosis with symptomatic apical periodontitis

1.2.3.5 Acute Apical Abscess (AAA)

This is necrosis characterized by rapid onset, spontaneous pain, and extreme tenderness of the tooth to pressure, pus formation, and swelling of associated tissues. There may be no radiographic changes, and the patient often experiences malaise, fever, and lymphadenopathy (Fig. 1.5).

1.2.4 Condensing Osteitis

This is a diffuse radiopaque lesion representing a localized bony reaction to a low-grade inflammatory stimulus usually seen at the apex of the tooth.

Symptomatic clinical conditions such as symptomatic irreversible pulpitis (SIP), symptomatic apical periodontitis (SAP), and acute apical abscess (AAA) can be extremely painful [13, 14]. Unfortunately, the current diagnostic nomenclature of the American Association of Endodontists (AAE; [15]) does not differentiate between teeth that cause significant enough pain to require the patient to seek emergency care from those that merely show an increased reaction to diagnostic tests [16].

Due to the obvious clinical symptom of edema (swelling) associated with the diagnosis of AAA, this diagnosis poses no challenge. In contrast, clear-cut symptoms have not been identified to differentiate between SAP and SIP. While SIP is merely painful, SAP is the beginning of the spread of infection with a possibility of untoward systemic consequences [17]. The emergency treatment for SIP and SAP differs [18, 19]. With SIP, simply removing the coronal pulp is sufficient for relief [20], while with SAP the disinfection of the entire root canal system is needed.

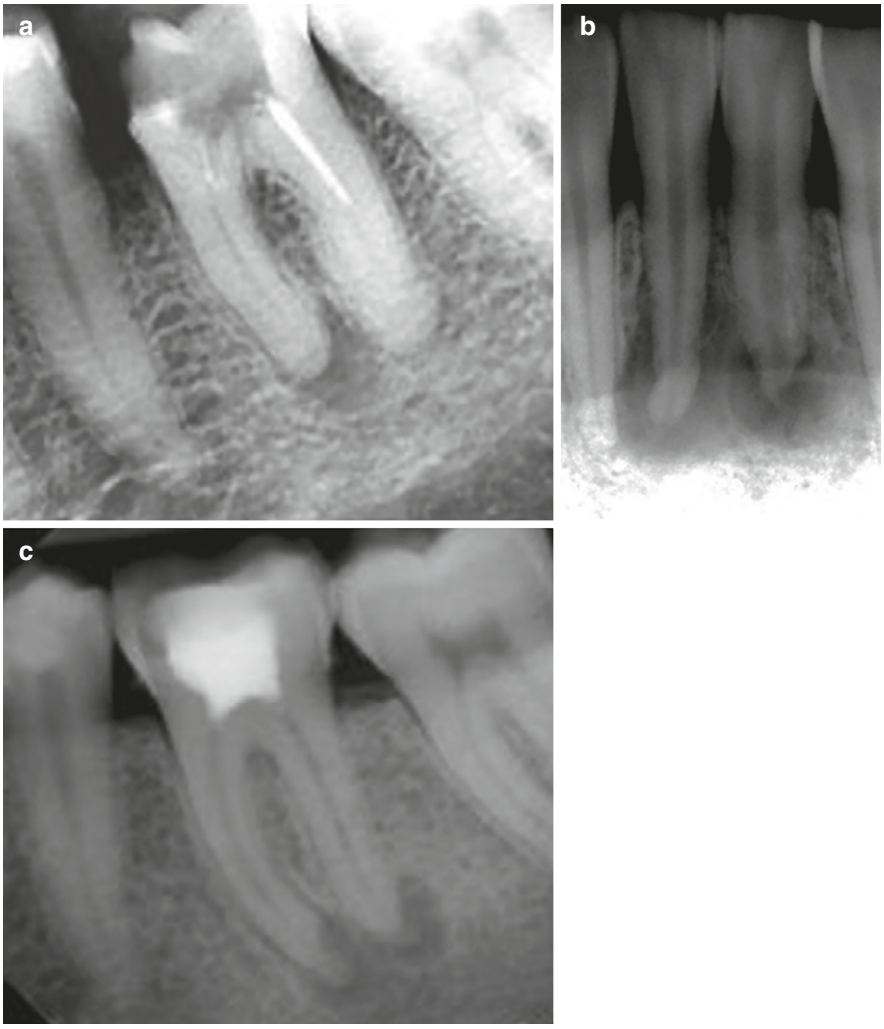


Fig. 1.4 (**a**) Post-treatment asymptomatic apical periodontitis on lower left first molar. (**b**) History of trauma 15 years ago—pulp necrosis with asymptomatic apical periodontitis with grade 2 mobility and pocket depth of 8 mm. (**c**) Asymptomatic apical periodontitis and root resorption

Fig. 1.5 Pulp necrosis with acute apical abscess

1.3 Clinical Evaluation

The clinical evaluation consists of several tests including but not limited to palpation, percussion, periodontal probing, thermal/electrical testing, biting, and release (Tables 1.3 and 1.4). For a comparative result to help in establishing a diagnosis, all tests should be performed on the tooth in question and the contralateral/adjacent teeth as well.

1.3.1 Palpation, Percussion, and Periodontal Probing

The first step in the examination is to do a visual evaluation by looking at the patient straight on to check if there is any visible swelling or asymmetry. Both extraoral and intraoral digital palpation should be performed, including palpating the lymph nodes on the affected side. Make sure to palpate the buccal and lingual/palatal surfaces of the affected tooth and ask the patient if the areas are sensitive.

Percussion testing is a short and indirect mechanical irritation of the tooth or the periodontium in order to obtain information about the condition of pulp or periodontium from the patient's reaction. It is a very reliable means for diagnosing irreversible pulpitis or apical periodontitis. Percussion should be performed carefully, especially in patients who have the chief complaint of biting, chewing, or pressure sensitivity. A finger, "Tooth Slooth," or the blunt end of any plastic instrument may be used to elicit symptoms. Start gently and increase the intensity slowly. Testing the adjacent teeth first is a good way to gauge the patient's reaction. If he responds strongly with a healthy tooth, be extra gentle when testing the tooth in question.

Periodontal probing is important, especially in diagnosis of suspected root fractures or combined periodontic-endodontic problems. Always examine the gingiva

Table 1.3 Pulpal diagnosis

Clinical classification	Signs and symptoms	Diagnostic tests	Endodontic treatment needed or not
Reversible pulpitis	*Pain*—no history of pain, pain is non-spontaneous *Radiographically*—no radiographic evidence of internal resorption or periapical change	*EPT*—response is normal and within range *Thermal tests*—moderate to sharp response to thermal, sweet; response subsides when stimulus is removed *Percussion and palpation*—negative, no response	**NOT** needed
Irreversible pulpitis (with or without apical pathosis) *Etiology* Deep caries and/or restorations, exposed dentin (attrition, abrasion, and erosion), traumatic injuries, orthodontic forces	*Pain* • May have acute or chronic symptoms • Pain may be spontaneous/continuous; previous repeated episodes of pain • Pain with mastication (on biting) *Radiology* • Radiographic evidence may reveal normal pulp, narrow pulp chamber, "calcified" canals, or condensing osteitis • An enlarged PDL may also be present	*EPT* Tooth may test within normal limits, but response may be markedly different from control; rapid/delayed onset, may be persistent, and may be of severe intensity *Thermal test* A key factor in making a diagnosis. Sharp, exaggerated, painful response to thermal stimulus; pain lingers after stimulus is removed *Percussion test* May or may not be positive *Palpation* May or may not be positive	**IS** needed
Necrotic pulp (with or without apical pathosis) *Etiology* Deep caries and/or restorations, exposed dentin (attrition, abrasion, and erosion), traumatic injuries, orthodontic forces	*Pain* • May have acute or chronic symptoms • Pain may be spontaneous/continuous; previous repeated episodes of pain, often dull and throbbing • Pain on biting *Radiology* • May be normal • Enlarged PDL maybe evident • Periapical or lateral lesions maybe evident	*EPT* No response/may have false positives *Thermal test* No response *Palpation/percussion test* May or may not be positive	**IS** needed

Table 1.4 Periapical diagnosis

Clinical classification	Signs and symptoms	Diagnostic tests	Endodontic treatment needed or not
Acute apical periodontitis *Etiology* Irreversible pulpitis, traumatic injuries, Periodontal disease, orthodontic forces, restoration in hyperocclusion	*Pain* Sharp, intermittent pain of pulpal origin (moderate to severe intensity), aggravating factors are usually present	*EPT and thermal tests* may be normal, or similar to irreversible pulpitis or pulpal necrosis *Palpation/percussion* Moderate to severe pain *Radiology* Usually thickening of PDL, may have periapical or lateral radiolucency	**MAY** need endodontic treatment
Chronic apical periodontitis (etiology—same as above)	*Pain* • Slight intensity to no pain, pain may be absent or constant • Periapical pain can be spontaneous • Pain is dull throbbing • Pain can occur with mastication	*EPT and thermal tests* may be normal, or similar to irreversible pulpitis or pulpal necrosis *Percussion* Moderate to none *Palpation* Moderate to none. May be swelling *Radiology* Periapical or lateral radiolucency	**MAY** need endodontic treatment
Chronic suppurative apical periodontitis *Etiology* Irreversible pulpitis, traumatic injuries, periodontal disease, orthodontic forces, restoration in hyperocclusion	*Pain* • Usually no pain present • A draining sinus tract or other evidence of suppuration is evident	*EPT and thermal tests* may be normal, or similar to irreversible pulpitis or pulpal necrosis *Percussion* None to slight pain *Palpation* Slightly tender *Radiology* Periapical or lateral radiolucency	**IS** needed
Acute alveolar abscess (acute apical abscess) *Etiology* The result of coronal apical progression of pulpal necrosis into the periapical tissues	*Pain* • Severe pain which is constant and spontaneous • Pain is pulsing and throbbing • Pain can occur with mastication	*Pulp tests* No response *Percussion* Moderate to severe *Palpation* Moderate to severe, swelling probable *Radiology* PDL thickening, periapical or lateral radiolucency	**IS** needed

A pulpal diagnosis is required for a definitive determination

for inflammation and exudate. Documentation of all relevant periodontal findings such as pocket probing depth, probing for furcation involvement, and tooth mobility should be done.

If a sinus tract is present, always trace it by inserting the tip of a small gutta-percha point into the sinus tract and taking a radiograph with the point in place. It acts like an arrow directing you to the root of the problem.

1.3.2 Sensitivity Testing

Sensitivity testing is required prior to any kind of root canal treatment and the result must be documented. The pulpal diagnosis is obtained by using thermal or electrical tests. Thermal tests may be hot or cold, depending on the chief complaint. Sensitivity testing will only determine the ability of pulpal tissue for nervous conduction but will not give any information on the vascular supply of the pulp. *Therefore, the tests used are referred to as sensitivity tests and not vitality tests*. As stated before, any thermal or electrical sensitivity testing should always be compared with the adjacent teeth or its counterpart in the other quadrant.

1.3.2.1 Thermal Tests

Cold Test

The pulpal diagnosis is obtained by using thermal or electrical tests. Thermal tests may be hot or cold, depending on the chief complaint.

There are several ways to reproduce the sensation of cold. These include a skin refrigerant (such as Endo Ice®), ice pellets, or a CO_2 stick. The simplest thermal test is the cold test which is performed using ethyl chloride spray (Fig. 1.6), dichlorodifluoromethane (CCl2F2—Frigen®, Freon®, Arcton®), a propane-butane mixture, or carbon dioxide snow. A cold test is usually a very reliable means for diagnosis of a pulpless (devitalized) tooth (the reason for majority of negative cold tests is pulpal necrosis), but a lack of response to a cold test does not always necessarily mean a pulpal necrosis. In this case, additional electrical sensitivity testing is required. Reversible pulpitis can also be diagnosed using the cold test.

Heat Test

Heat test can be very helpful to establish a provisional diagnosis of suppurative pulpitis. This kind of pulpitis reacts with a clear sensation of pain even at slight temperature increase of only 2–3 °C. The most effective way to heat test the teeth is to isolate each tooth using a rubber dam and flood the area with water with similar temperature to that of a warm or hot beverage. Warn the patient that there will be some pressure/sensation. Heat testing should never be performed with a melted stick of wax or an electrically or flame-heated instrument. This type of heat is difficult to control and may cause pulpal damage in healthy teeth. As soon as the patient feels any type of sensation, remove the stimulus and ask him to report his feelings: Is the sensation painful? Does it linger? Is this what he feels when he drinks or eats something hot or cold?

Fig. 1.6 Refrigerant spray for cold vitality testing

Suppurative pulpitis, however, will cause a feeling of pain described by the patient. Heat test must never be used for routine testing—in order to obtain any reaction from healthy pulp, the temperature within the pulp cavity would have to be raised such that this would result in denaturation of pulpal tissue protein.

Electrical Sensitivity Test

The electrical pulp test is helpful when natural tooth structure is available and the results of the thermal tests are inconclusive. It is not suitable, however, for the control of teeth with metallic or ceramic crowns or dental bridges and is not reliable when placed too close to the gingiva. Electrical pulp testing devices should not be used on patients with cardiac pacemakers. Ideally, the area should be isolated and the tooth dry. Conducting medium, such as topical anesthetic or toothpaste, should be used. Testing a normal tooth first is good to give the patient a baseline of what the test feels like, even if it is not an adjacent tooth (Fig. 1.7a, b).

Although the results are given numerically, usually from a scale of 1 to 80, it is impossible to know how "alive" the tooth is. A response before the scale is at its maximum means that there is some vital tissue inside the tooth; no response at the maximum number means that there is not.

Fig. 1.7 (**a**) Electric pulp tester (**b**) Clinical Pulp testing

1.3.3 Biting and Release

This test is useful for the diagnosis of a coronal fracture. It is best to have a Tooth Slooth for testing cusps individually. When using the Slooth, ask the patient to bite down on his teeth together and open quickly. Instruct him to note if the pain is upon biting or release. Pain upon release from biting with the absence of any other symptoms and normal responses to the other diagnostic tests is frequently correlated to a coronal fracture. This is usually effectively treated with a full-coverage restoration.

1.4 Radiographic Evaluation and Diagnosis

Radiological diagnosis is a valuable additional method in clinical examination. It will not inform about the condition of the pulp or different types of pulpitis but can give various other bits of information such as carious lesions not identified in clinical examination, root resorption, internal resorption, width of the periodontal

ligament space, condition of the periapical tissue, and root fractures. Radiological diagnosis of the affected tooth is important prior to any root canal treatment.

The clinical evaluation is the most important part of the diagnostic process because there is often a lack of radiographic pathology associated with an endodontic problem. To view radiographic bone destruction, there must be erosion of one of the cortical plates. There can be extensive loss of cancellous bone without any radiographic pathology.

1.5 Treatment Planning and Considerations

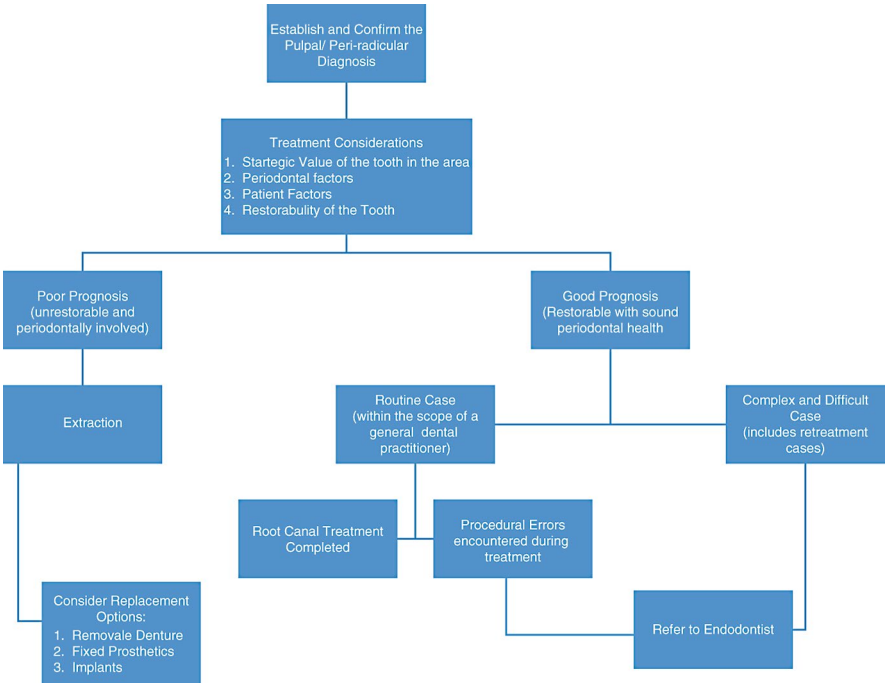
Endodontic diagnosis can be challenging. Understanding both the pulpal and periradicular diagnoses and how to obtain them is crucial. Although it can be frustrating for the patient and the provider, sometimes no treatment until the symptoms localize is the best option.

An ideal treatment plan should address the chief complaints of the patient, provide long-lasting and cost-effective treatment, and at the same time meet the patient's expectations. Treatment should always be patient centered and based on scientific and clinical evidence and should preserve the biological environment while maintaining comfort and function. The selection of cases for endodontic therapy should take into consideration the prognosis of the endodontic, restorative, and periodontal procedures [21, 22]. Although certain teeth are endodontically treatable, the amount of tooth structure remaining may not be readily restorable, and a durable coronal restoration is not achievable [23]. The periodontal condition of the tooth must be assessed prior to endodontic therapy because optimal periodontal health is critical to the long-term success of teeth that are endodontically treated [24]. At the same time, it is essential to consider the patient's needs, attitude, and willingness to accept treatment [25].

Factors which help in deciding whether the tooth concerned has a good or poor prognosis include:

1. Strategic value of the tooth.
2. Periodontal factors.
3. Patient factors (systemic and oral health).
4. Restorability of the tooth.

The clinician should also take into account the patient's medical condition and motivation to maintain oral health [26]. The above considerations will aid the dentist in determining whether a tooth can be preserved via endodontic therapy or whether it is in the best interests of the patient to consider extraction and possibly a prosthetic replacement [27]. Both the dentist and patient must agree on the definitive plan. The dentist should consider whether he or she possesses the necessary skills and knowledge to perform endodontic treatment for this particular tooth to a high standard. The components of the treatment planning are summarized in Flow Chart 1.1.



Flow Chart 1.1 Treatment Planning

1.5.1 Strategic Value of the Tooth

The primary concern is the long-term preservation of a healthy functional dentition. The dentist should consider the strategic value of the tooth to be endodontically treated in relation to the overall function of the dentition. For example, a second or third molar is generally considered to be of little strategic value, unless it is required to support a prosthesis. This is because a denture is more stable if it has a posterior abutment tooth to retain and support it [28].

Other strategic considerations may include the structural integrity, remaining sound tooth structure, morphology and dimensions of the root, the level of surrounding bone, amount of periodontal support, and whether the tooth is in the esthetic zone [27]. Endodontic treatment is contraindicated when there is limited remaining tooth structure, and the definitive crown will not be able to engage at least 1.5–2.0 mm of tooth structure with a cervical ferrule [29, 30]. Retaining a tooth with a poor long-term prognosis via endodontic treatment, particularly a cracked tooth, can lead to substantial bone loss by the time the tooth is eventually removed. The resulting bone defect can substantially affect the esthetic result.

Endodontic treatment is associated with procedural accidents occasionally. These mishaps can occur during access preparation, cleaning and shaping, and obturation (discussed later in the book) as well as during preparation of the post

space [31]. Some of these errors can have a negative effect on the outcomes and subsequent prognosis of endodontic treatment [32–34].

A number of adjunctive procedures affect the comparison of complicated and/or high-risk endodontic treatment with tooth extraction and placement of an implant and a crown. For instance, retaining some teeth via endodontic therapy may require treatment for periodontal disease, crown lengthening through surgery or orthodontic extrusion, a core buildup or a post and core, or a crown. Each of these procedures adds complexity to the treatment plan and can present additional complications and risks. It also increases the overall cost of treatment and makes it more difficult for patients to comprehend and accept a treatment plan.

1.5.2 Periodontal Factors

The health of the periodontium needs to be assessed because in a compromised dentition, the long-term prognosis for retaining a single tooth may be poor [35]. Approximately, one-third of endodontically treated teeth requiring extraction are lost because of periodontal problems [36]. Periodontal management of patients is important to the long-term success of any treatment plan.

1.5.3 Patient Factors

The dentist should be aware and prepared that some patients will opt to have an extraction of a tooth on the grounds of time involved in treatment, fear of treatment, or the financial cost [28]. A patient's previous positive or negative experiences with either treatment may also affect his or her decision as to which treatment modality should be pursued.

Although medical conditions (e.g., diabetes or habitual tobacco smoking) may complicate or delay healing, but in general, medical reasons are not a contraindication to root canal therapy. Endodontic considerations in patients with underlying medical condition are discussed later in the book. However, conditions which limit a patient's ability to lie supine (e.g., spinal arthritis), to open the mouth wide for a prolonged period (e.g., rheumatoid arthritis), or to have anxiety disorders [35] may make endodontic treatment more difficult but not impossible. Things to consider before starting a root canal treatment are [28].

- Is endodontic treatment in the patient's best interest?
- What are the patient's expectations?
- Will the patient be able to afford the treatment planned?

1.5.4 Restorability of the Tooth in the Arch

Extraction of the tooth is a viable treatment if endodontic therapy is not applicable or where successful completion of the treatment plan is impossible because of

periodontal or restorative concerns [24]. The tooth in question must be assessed for any restorative challenges before the start of the treatment that would compromise the restorability following root canal treatment.

The prognosis for endodontic treatment of the tooth or teeth in question must take into account the treatment planning. Although we, as dentists, would like to give the patient as accurate a prognosis as possible before the start of an endodontic treatment, a less than ideal technical standard provided or procedural errors and/or an inadequate coronal restoration will lead to a reduced prognosis for the tooth.

1.5.5 Other Considerations

1.5.5.1 When to Refer and When to Perform Endodontic Retreatment

Dentists should be able to assess when the difficulty of the treatment exceeds their skill and be able to refer the patient to an endodontist as necessary [27]. Sometimes, the technical difficulty of the case dictates that the patient be referred to a specialist for treatment and management [26]. Other factors that may complicate and increase the difficulty of an endodontic case include [23]:

- Calcifications.
- Inability to isolate the tooth with a rubber dam.
- Resorptive defects.
- Extra roots and canals.
- Retreatment cases.
- Presence of a post.
- Ledges and perforations.

Referring the patient before commencement of endodontic treatment is better than after the problem has been created because the error will compromise the prognosis of the tooth [26]. Retreatment is acceptable only after an acceptable observation period with no signs of radiographic improvement. In some cases where the extra-radicular infection is the source of ongoing disease, apical surgery is considered the treatment of choice [37]. Dentists must be aware of their level of clinical skill, knowledge, and experience.

The treatment plan should be divided into various stages such as

- Initial relief of pain, e.g., emergency pulp extirpation.
- Corrective treatments, e.g., complete root canal treatment and restorative treatment.
- Maintenance, e.g., measures to prevent the disease recurrence [35].

Treatment plans can also be divided into “simple” and “complex.” A plan may be considered simple if only one tooth is involved and the overall status of the dentition is acceptable [26]. A complex treatment plan is required for patients who have not attended for some time or where there is a need for a major reassessment of the

entire dentition. In such a case, it is important to manage the acute pain and swelling associated with a tooth that requires root canal treatment before offering a definitive treatment plan.

1.5.5.2 Post-Endodontic Restoration

The choice of the final coronal restoration will influence the outcome of endodontic treatment. It should provide adequate coverage to protect the endodontically treated tooth against fracture [26]. Other potential problems associated with the final restoration playing a role in the breakdown of root canal treatment include a permanent restoration with marginal breakdown or bacterial penetration due to restorative procedures such as post space preparation [38].

Research has suggested that both root canal filling and the coronal restoration serve as a barrier against fluid and bacterial penetration into the periapical area [39]. In reality, there are no available materials or obturation techniques that can confidently assure an impervious seal of the complex root canal system [40]. Fractures of endodontically treated teeth could lead to infection of the root canal system or extraction of the tooth.

The difficulty of a case should be balanced with the skill and experience of the dentist in deciding whether to manage the case in general practice or to refer the patient to an endodontist [26]. The overall treatment planning in endodontics should be in agreement with the overall dental management of the patient.

1.6 Pulp Canal Obliteration

Pulp canal obliteration, also known as calcific metamorphosis, is defined as a pulpal response to trauma that is characterized by the loss of root canal space due to the deposition of hard tissue along the root canal walls and the pulp space proper [5] (Fig. 1.8). It is also referred to as dystrophic calcification, diffuse calcification, and calcific degeneration. Calcified canals may pose diagnostic challenge. In spite of improved magnification methods like the dental operating microscope, it may still be difficult to locate and negotiate them. In the process, excessive tooth structure may be removed, and the tooth or a root may be at risk of untoward sequelae of perforation. The new imaging technologies such as cone beam computed tomography (CBCT) are very useful and can help to ascertain if the root canal lumen is present in a tooth that appears calcified on periapical radiograph and if the tooth is amenable to conventional endodontic treatment [41].

Teeth with calcification provide an endodontic treatment challenge. Traumatized teeth frequently develop partial or total pulpal obliteration characterized evidently by loss of the pulp space radiographically and a yellow discoloration of the clinical crown. Since only a small percentage of such teeth develop pulp necrosis with radiographic signs of apical periodontitis, it is difficult to decide whether to treat these teeth immediately upon detection of the pulpal obliteration or to wait until signs and symptoms of pulp and/or apical periodontitis occur.

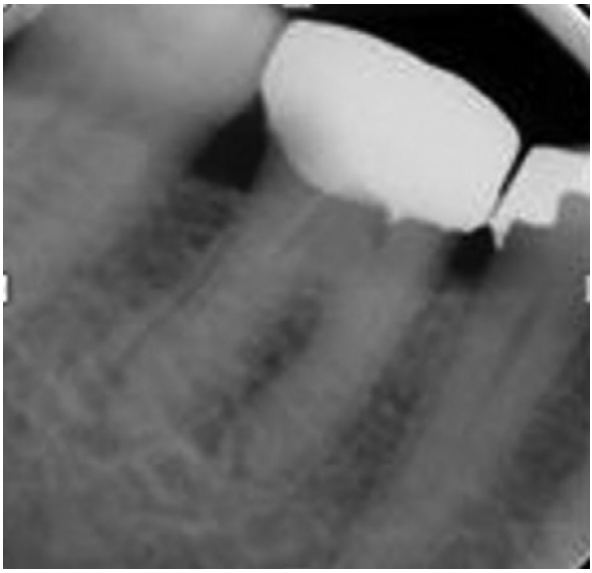


Fig. 1.8 Pulp canal obliteration

1.6.1 Clinical Picture

The calcification of the pulp chamber results in a darker hue than the adjacent and the loss of translucency due to a greater thickness of dentin under the enamel. Some teeth also have a gray/yellowish appearance of the crown of the tooth [42]. The affected teeth do not always react to sensibility tests, and generally there is no sensitivity to percussion [43]. Pulp necrosis is most frequently a complication with ranges varying from 1% to 16% [44, 45].

Research shows that tooth discoloration has no diagnostic value. Not all teeth with radiographic signs of pulpal obliteration undergo a color change [46]. Furthermore, more than two-thirds of teeth with pulpal obliteration are asymptomatic. These teeth are often an incidental finding following clinical or radiographic investigations. As the pulp calcification becomes more pronounced, there is a progressive decrease in the response to thermal and electrical pulp testing. But, partially obliterated teeth can give positive results; hence, in the presence of pulpal obliteration, it is generally accepted that sensibility tests are unreliable [46].

1.6.2 Radiographic Appearance

The radiographic appearance is partial or total obliteration of the pulp canal space with a normal periodontal ligament space and intact lamina dura. A thickening of the periodontal ligament space or periapical radiolucency may sometimes be observed with or without subjective symptoms. Complete radiographic obliteration of the root canal space does not necessarily mean the absence of the pulp or canal space; in the majority of these cases, there is a pulp canal space with pulpal tissue.