

Chapter 1

Introduction to endodontology

John Whitworth, Lise-Lotte Kirkevang, and Lars Bjørndal

Endodontology

The word “endodontology” derives from the Greek language and can be translated as “the knowledge of what is inside the tooth.” Thus, endodontology concerns all structures and processes within the tooth, with particular reference to the dental pulp and the space it occupies. But what about “knowledge”? What does it actually mean to “know” things? Most people would probably say that knowledge has something to do with truth and being able to provide reasons for things. It is often believed that dental and medical knowledge is simply scientific knowledge—truth that is supported by scientific research to provide reasons for disease processes and justification for clinical actions. But as practicing dentists, scientific knowledge is not always sufficient, and although it is important to know about the anatomy of the pulp space and the fatigue failure of engine-driven endodontic files, we must also develop sound judgment and the ability to make correct clinical decisions, often in the face of uncertainty. The knowledge required by dental practitioners is therefore complex and multi-dimensional and can be considered within Aristotle’s domains of “episteme,” “techne,” and “phronesis” [1].

Episteme

Episteme is the word for theoretical, scientifically supported knowledge, the opposite being *doxa*, which refers to common beliefs or opinions that may not be so grounded in “hard” evidence. The body of epistemic knowledge in endodontology is enormous, spanning from fundamental pulp biology to the clinical risk factors associated with root canal treatment failure. The knowledge generated by science, however, is often less certain than we would wish, and subject to the weakness of study design, the bias of conflicting interests, and a lack of obvious translation to the realities of

“wet-fingered” dentistry. Nevertheless, efforts are made to present scientific knowledge in a balanced way through lectures, articles, and textbooks, so from a student’s point of view, learning requires ample time for reading and opportunities for discussion and reflection. This book, in large part, is composed of epistemic knowledge.

Techne

A substantial element of learning endodontology must be characterized as *techne*, or “knowing how,” which embraces elements of practical skill, craft, and artistry. It is not always possible to explain every detail of how we perform technical acts, such as negotiating a challenging root canal with delicate tactile sense or riding a bicycle around a corner without falling off. In this way, it is not sufficient to teach students how to shape a root canal solely by asking them to read a book or attend a lecture. Their knowledge must be supplemented with practical experiences, both observing and doing, and by discussion and personal reflection to understand the challenges they encounter, develop cognitive and practical strategies to overcome them, and to help them do better next time.

It is not possible to learn all about the procedures in endodontology by studying a textbook. Observing a good clinical instructor, watching other dentists at work, performing the procedures oneself, and reflecting on what has been learnt are all important. The preclinical simulation laboratory provides an essential environment in which to embed new factual knowledge and translate it into practical reality.

Phronesis

According to Aristotle, *phronesis* is the ability to think about practical matters and then acquire the ability to act

2 Introduction to endodontology

in the “right” way in any given circumstance. The practice of clinical dentistry demands that wisdom is exercised, “to do the right thing at the right moment,” acting in the best interest of the patient, even if it is difficult or costly for the dentist to do so. Examples might include the use of rubber dam to control asepsis in all endodontic procedures, or being honest with patients and seeking a practical solution when things have gone wrong. Again, this cannot be fully developed by reading a book; the essence of phronesis must be learnt from practice.

Concepts of endodontology

It can be concluded that endodontology encompasses not only theoretical thinking but also the practical skills of a craftsperson and the practical thinking needed for clinical and moral judgment. The serious student of endodontology must investigate all three aspects, and although this textbook will contain many pointers to the development of technical skills and clinical judgment, there are understandable limits to what can be achieved without hands-on experience combined with diligent reflection.

The objective of endodontic treatment

The consequences of inflammatory lesions in the dental pulp and periapical tissues have tormented humankind for thousands of years (Fig. 1.1) and historically, the main task of endodontic treatment was to cure toothache caused by inflammation in the pulp (pulpitis) and the periapical tissues (apical periodontitis). For a long time, this was achieved by cauterizing pulp tissues with hot wires, applying toxic chemicals such as arsenic or



Fig. 1.1 A medieval skull found in Denmark showing teeth with serious attrition. In the mandibular left first molar the pulp chamber is exposed and the alveolar bone is resorbed around the root apices, indicating that this person had been suffering from periapical inflammation caused by an infected, necrotic dental pulp.

formaldehyde, or by incising soft tissues to drain pus; all extremely painful in the era before local anesthetic.

Although the relief of pain is still a primary goal of endodontic treatment, much of the pulpal and periapical disease that we encounter is painless, and the emphasis should be on managing the cause of disease, invariably microbial infection, and promoting conditions that are compatible with the healing and repair of tissues. This means that all steps of the endodontic procedures described in this book, ranging from caries management and vital pulp therapies to surgical retreatment and the final coronal restoration, should be guided by efforts to eliminate and exclude microorganisms from the pulp space, the periapical tissues, and, by extension, from other parts of the body. With meticulous infection control, the treatments described should allow predictable tissue healing and the preservation of functional teeth in the large majority of cases.

Clinical problems and solutions

Core concepts 1.1 and 1.2 provide a summary of common pulpal and periapical conditions and the treatment procedures to manage them.

The vital pulp

Under normal physiological conditions, the dental pulp is sterile and well protected from injury by hard tissues and an intact periodontium. But when the integrity of these tissue barriers is breached for any reason, microorganisms and the substances they produce may enter the pulp and adversely affect its health. The most common microbial challenge is from dental caries. Even at an early stage of caries progression, the immunocompetent pulp is aware, because substances from the cariogenic biofilm may reach the dental pulp and its odontoblast cells along patent dentinal tubules. Like any connective tissue, the pulp responds with innate and adaptive immunity, which has an important role in neutralizing and eliminating the noxious agents. Inflammation within the pulp can be seen as a two-edged sword, with the early stages providing a “necessary” defensive response, contributing to hard-tissue deposition and to the repair of damaged soft tissues. Thus, the pulp may react in a manner that allows it to sustain the irritation and remain in a functional state. Yet when caries has actively progressed to the vicinity of the pulp, the response may take a destructive course leading to tissue necrosis followed by large-scale microbial invasion. These processes may or may not be painful. In an ideal world, it would be possible to control all risk factors for caries, but caries remains highly prevalent, and if damage is to be limited, practitioners should recognize

Core concept 1.1 Recommended diagnostic terminology and synonyms for endodontic conditions

Pulpal

- **Normal pulp:** A clinically asymptomatic pulp that responds within normal limits to pulp sensibility testing (synonym: healthy pulp).
- **Pulpitis:** Inflammation of the dental pulp.
- **Reversible pulpitis:** Inflammation of the pulp that if treated should allow the pulp to return to normal.
- **Irreversible pulpitis:** Inflammation of the pulp that is incapable of healing. *Symptomatic* (painful) and *asymptomatic* (painless) forms are recognized.
- **Pulp necrosis:** Pulp death. The pulp chamber is devoid of functional pulp tissue with varying degrees of pulp breakdown within the root canals.

Additional terms to denote teeth that have already received treatment: although these terms do not denote the presence of a pathological condition, they are widely adopted to describe the state of teeth that commonly present to treatment providers in practice.

- **Previously initiated treatment:** A tooth that presents with evidence of emergency treatment for pain relief, but without the completion of a permanent root filling.
- **Previously treated:** A tooth containing a permanent root canal filling (synonym: root-filled).

Periapical

- **Normal apical tissues:** Teeth presenting with no clinical symptoms or clinical/radiographic signs of periapical disease.
- **Apical periodontitis:** Inflammatory reaction in the tissues surrounding the root of a tooth, usually caused by pulp space infection, but

sometimes perpetuated by infection or foreign bodies that have become established within the periapical tissues. Inflammation of the periapical tissues can also be caused by traumatic injuries, but this is often sterile and short lived (transient).

- **Symptomatic apical periodontitis:** Inflammation producing clinical symptoms, and usually accompanied by clinical and/or radiographic signs that indicate the presence of disease or traumatic injury (synonym: acute apical periodontitis). The term *acute apical periodontitis* may also refer to the very painful first stages of the periapical inflammatory reaction where bone destruction has not yet occurred and there is no evidence of a periapical radiolucency.
- **Asymptomatic apical periodontitis:** Inflammation producing no clinical symptoms but with clinical and/or radiographic signs that indicate the presence of disease (synonym: chronic apical periodontitis).
- **Condensing osteitis:** A form of apical periodontitis characterized by the slow deposition of bone, usually around the apex of a tooth and associated with low-grade inflammation (synonym: periapical osteosclerosis).
- **Apical abscess:** A purulent lesion associated with an infected, necrotic pulp.
- **Acute apical abscess:** An inflammatory reaction characterized by the rapid onset of painful periapical symptoms, pus formation, and swelling of associated tissues (synonyms: suppurative apical periodontitis, phoenix abscess).
- **Chronic apical abscess:** An inflammatory reaction characterized by gradual onset, little or no discomfort, and the intermittent discharge of pus through an associated sinus tract (synonym: apical periodontitis with fistula).

Core concept 1.2 Common treatment procedures to manage endodontic disease conditions

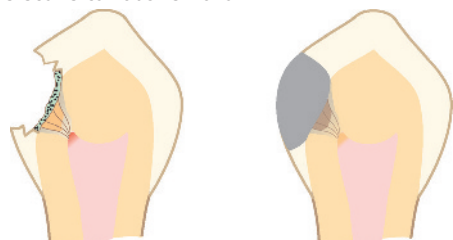
- **Deep caries management:** Treatment procedure that aims to preserve vital pulp functions by avoiding direct exposure of pulp tissue to the oral environment. Recognized approaches include:
 - selective carious tissue removal (one visit) (synonym: partial caries removal) and
 - stepwise carious tissue removal (two visits) (synonym: stepwise excavation).
- **Pulp capping:** Treatment procedure that aims to preserve vital pulp functions after direct exposure of pulp tissue to the oral environment (direct pulp cap).
- **Pulpotomy:** Treatment procedure that aims to preserve vital pulp functions by surgically removing superficial pulp tissue (partial pulpotomy) or the entire coronal pulp (pulp chamber pulpotomy).
- **Pulpectomy:** Treatment procedure in which a vital pulp is removed, the root canal system is instrumented and cleaned, and a permanent

root canal filling is placed (synonym: root canal treatment of a tooth containing vital pulp tissue).

- **Root canal disinfection:** Treatment procedure in which a necrotic/infected pulp is removed, the root canal system is instrumented, cleaned, and disinfected, and a permanent root canal filling is placed (synonym: root canal treatment of a tooth containing necrotic/infected pulp tissue).
- **Nonsurgical retreatment:** Treatment of a previously treated tooth with clinical and/or radiographic signs of root canal infection, where root filling materials are removed to facilitate the disinfection and refilling of the pulp space. Also undertaken to improve the technical quality of previous treatment.
- **Surgical retreatment:** Treatment of a previously treated tooth by surgical means to manage infection or other pathology that has not responded to nonsurgical management.

4 Introduction to endodontology

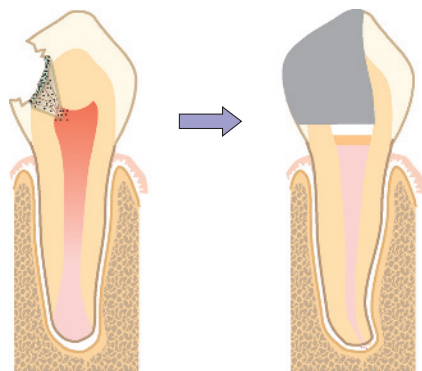
(a) Selective carious removal



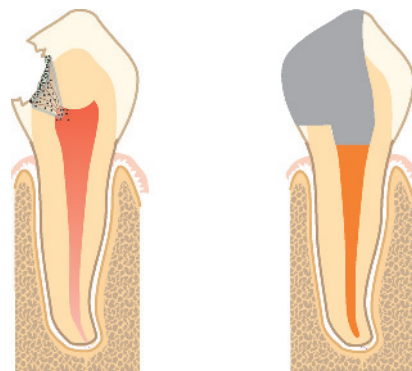
(b) Pulp capping



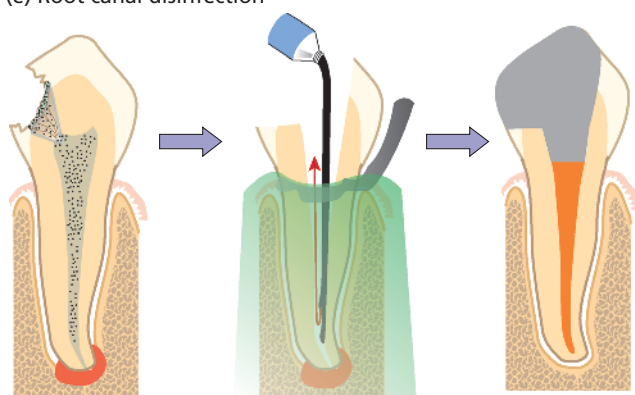
(c) Pulpotomy



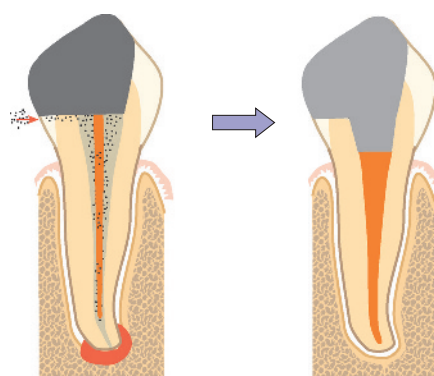
(d) Pulpectomy



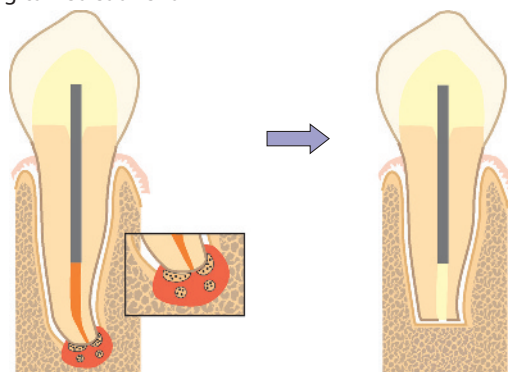
(e) Root canal disinfection



(f) Non-surgical retreatment



(g) Surgical retreatment



and treat precavitated carious lesions without operative intervention, and approach the operative treatment of lesions that have progressed more extensively in a way that will avoid direct pulp exposure to the mouth (Fig. 1.2a). Even in the case of frank pulp exposure after traumatic injury or during operative dentistry, especially in the young, it may be possible to preserve vital pulp functions by *pulp-capping* or *pulpotomy* procedures (Fig. 1.2b,c).

When the dental pulp is judged to be irreversibly inflamed or if the pulp is likely to be compromised by a restorative procedure (e.g., decoronation of a tooth as an overdenture abutment), pulp tissue may be removed and replaced with a root filling—a procedure termed *pulpectomy* (Fig. 1.2d). Clinically, pulp tissue is aseptically removed under local anesthesia, canals are shaped with instruments to accommodate a root canal filling, the pulp space is irrigated to remove residual pulp tissue and microorganisms, and the canal is filled before restoring the cavity. Pulpectomy is highly successful and aims to prevent significant infection from establishing within the pulp space, which would inevitably lead to the extension of inflammatory changes into the periapical tissues. It is easy to become complacent about the predictability of pulpectomy, yet in common with all endodontic procedures, failure to exercise stringent asepsis may result in established pulp space infection and the development of apical periodontitis in the long term. All of these technically exacting and often minimally invasive procedures are greatly assisted by magnification and enhanced illumination, ideally from an operating microscope.

The necrotic or infected pulp space associated with apical periodontitis

Pulp tissue may become necrotic after traumatic disruption of its blood supply, or as a consequence of microbial

infection. Necrotic pulp tissue is defenseless against microbial invasion and the entry of oral microorganisms after frank pulpal exposure or through dentinal tubules as a consequence of extremely deep caries, sudden cracks, and fractures, as well as operative dentistry or periodontal disease/instrumentation, will soon result in pulp space infection. Established infections are typically in biofilm formation and colonize canal walls, pulp space irregularities, and dentinal tubules. They are also frequently interspersed with residual necrotic tissue. The host has no means of eliminating infection from the avascular pulp space, and the percolation of microbial components into the periapical tissues leads inevitably to the extension of inflammatory disease into the tissues surrounding the tooth. Although localized periapical inflammation (apical periodontitis) is the most commonly studied, serious and potentially life-threatening extension is possible (acute apical abscess; spreading cellulitis), as is the potential for more widespread effects on general health. Apical periodontitis can remain undetected and untreated for long periods of time, particularly if there are no symptoms, and may expand significantly, discharge to the mouth through a sinus tract, or undergo cystic change.

Although the treatment of a necrotic/infected pulp space or *root canal disinfection* (Fig. 1.2e) is an aseptic procedure with much in common with pulpectomy, the aim is not just to eliminate necrotic tissue but to disrupt and remove biofilm infection from the complexities of the pulp space. The emphasis on disinfection is thus highlighted, and only in the presence of a clean canal can a well-executed root filling and coronal restoration preserve favorable conditions for periapical healing.

The endodontically treated tooth

Although the treatment of pulpitis and apical periodontitis is usually successful, painful symptoms are

Fig. 1.2 (a) *Conservative deep caries management*. Selective caries excavation avoids the risk of pulp exposure and microbial infection. A sealing coronal restoration prevents new infection, arrests caries, promotes the deposition of tertiary reactionary dentin and allows the pulp to return to normal. (b) *Pulp capping*. A traumatic injury exposes previously normal pulp tissue to the oral environment. Working under aseptic conditions, hemostasis is secured before applying a pulp-capping agent and a well-sealing coronal restoration. In favorable circumstances, the pulp lays down tertiary reparative dentin and remains in a normal, uninfamed state. (c) *Pulpotomy*. In an effort to preserve vital pulp functions and allow continued root development, the infected and inflamed coronal pulp of an immature tooth with an extremely deep carious lesion is aseptically amputated at the floor of the pulp chamber and dressed with a capping agent before sealing the tooth against infection. In favorable conditions, the remaining pulp tissue remains vital, completes root formation and lays down a protective layer of tertiary reparative dentin beneath the capping material. (d) *Pulpectomy*. The removal of an irreversibly inflamed pulp and its aseptic replacement with a root canal filling and sound coronal restoration prevents root canal infection and the development of periapical inflammation. (e) *Root canal disinfection*. Infection of the necrotic pulp causes inflammation in the periapical tissues and is treated by shaping, disinfecting and filling the pulp space under strict asepsis and sealing the crown to prevent new infection. The central image shows the tooth with complete caries excavation, isolated with rubber dam and the canal being irrigated with sodium hypochlorite solution to eliminate microorganisms and necrotic pulp tissue. Healing of apical periodontitis is predictable if infection can be adequately managed. (f) *Nonsurgical retreatment*. A poorly conducted endodontic treatment, coupled with leakage of the coronal restoration promoted infection of the root canal system and the failure of apical periodontitis to heal. Disinfection of the pulp space, followed by root canal filling and a sound coronal restoration predictably results in periapical healing. (g) *Surgical retreatment*. A tooth with a satisfactory root canal treatment and sound coronal restoration presents with persistent apical periodontitis. The cause in this case is extraradicular infection associated with biofilm formation on the external root surface and established infection in the periapical tissues. Disinfection of the root canal will not eliminate the infection, which must be approached surgically. Resection of the root end, followed by the preparation and sealing of an apical cavity, eliminates infection and allows periapical healing without disturbing the coronal restoration.

6 Introduction to endodontology

not always controlled and the periapical tissues do not always heal. This is often associated with imperfections in the initial treatment, including suboptimal infection control, missed anatomy, or other technical challenges that might have been identified by more careful diagnosis, more advanced imaging of the tooth, or greater attention to detail during the initial endodontic treatment or final restoration. In these circumstances, *retreatment* may be considered. In *nonsurgical retreatment* (Fig. 1.2f), the root canal system is re-entered from the mouth under aseptic conditions, the causes of treatment failure are identified and managed, the canal system is disinfected, and the root canal densely filled before providing a sealing coronal restoration to promote periapical healing. In *surgical retreatment* (Fig. 1.2g) persistent infections are approached surgically, usually by resecting the root tip, and managing and pulp space infection by creating a root-end cavity and sealing it tightly with a root-end filling. Retreatment procedures are technically demanding and are made easier and more predictable with magnification and enhanced illumination.

The diagnostic dilemma

To many, the process of endodontic diagnosis is as much an art as a science. Dentists are often confronted by disease processes in the pulp and periapical tissues that have few or no symptoms, or by symptoms referred to or from adjacent teeth or other structures. There are no laboratory investigations, such as blood tests, that can provide objective insights, and the tissues under investigation are generally hidden from view. Clinicians must therefore rely on imperfect, indirect tests, such as the application of cold or an electronic stimulus to the teeth, or the interpretation of two-dimensional radiographic images to diagnose pulp and periapical conditions and select an appropriate treatment. Throughout this textbook, considerable attention is given to the process of pulp and periapical diagnosis, the dilemmas that may arise, and the care that must be exercised in reaching conclusions.

The outcome dilemma

The meaning of “success” also demands some introduction. To some, the elimination of painful symptoms and the preservation of a tooth in comfortable function is a key measure of success. For others, the slightest radiographic evidence of periapical inflammation, even in the absence of clinical symptoms and signs, suggests an uncertain outcome or treatment failure. The outcome dilemma is highlighted by the widespread use of three-dimensional imaging with its potential to detect persistent lesions that would not have been identified by

traditional radiographic methods. As healthcare professionals, we should strive to control inflammatory disease by managing the cause, which is invariably microbial infection. Throughout this textbook, an optimal treatment outcome will be defined by the absence of clinical signs and symptoms of inflammatory disease, and by the radiographic preservation or re-establishment of a lamina dura and normal periapical bony structure.

The tools of treatment

To many dentists, endodontic procedures can be described by Winston Churchill’s words on golf: “An impossible game with impossible tools.” The complexity of root canal anatomy, the relative stiffness of many instruments, the inability to visualize the area of work properly, and the lack of space in the mouth provide substantial challenges to the skill and patience of the dentist. Intracanal work is exceptionally demanding and this is clearly demonstrated by numerous radiographically based epidemiological surveys, which repeatedly show that many root canal fillings fall below acceptable technical standards. Because clinical outcome is strongly related to the quality of treatment, the high frequency of suboptimal treatment is a subject of great concern to the profession.

The last 15–20 years have seen tremendous technological developments that facilitate endodontic treatment and enhance the potential to improve standards [2]. Many of these have made the previously impossible possible, by broadening the scope of teeth that can be successfully treated, by empowering dentists who do not have specialist skills, and by making procedures more efficient and enjoyable for dentists and patients alike. The widespread adoption of ultra-flexible engine-driven instruments for shaping root canals is a prime example, though one danger of this technological focus and the ability to instrument and root-fill teeth quickly is that the

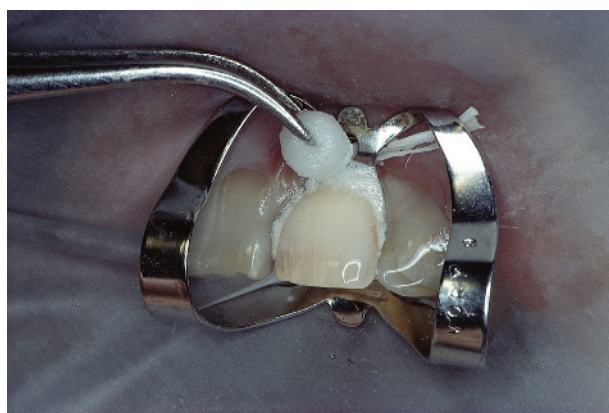


Fig. 1.3 Rubber dam-isolated tooth in the process of being disinfected prior to pulp access.

focus on asepsis and the stringent management of infection may have been undermined.

Luckily, there are few medical treatments that can be carried out as aseptically as endodontic procedures and shielding the tooth with a rubber dam is the oldest and still the most effective way to ensure that the operation field remains sterile (Fig. 1.3). It is this, combined with a range of infection-controlling measures to be implemented at each stage of endodontic treatment, that helps to preserve teeth damaged by disease or trauma and that will return them to long-term health and function [3].

References

1. Aristotle. *Nicomachean Ethics* (Iruin T, ed.). London: Hackett, 1988.
2. Molander A, Caplan D, Bergenholtz G, Reit C. Improved root-filling quality among general dental practitioners educated in nickel titanium rotary instrumentation. *Int. Endod. J.* 2007; 40: 254–60.
3. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. *J. Endod.* 2004; 30: 846–50.

