

Chapter 1

Introduction to endodontology

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Endodontology

The word “endodontology” is derived from the Greek language and can be translated as “the knowledge of what is inside the tooth”. Thus, endodontology concerns structures and processes within the pulp chamber. 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 providing reasons for things. It is often believed that dental and medical knowledge is simply scientific knowledge – science is based on research and deals with how things are constructed and work. But as practicing dentists we also need other types of knowledge. Although it is important to know about tooth anatomy and how to produce good root canal preparations for example, we must also develop good judgment and ability to make the “right” clinical decisions. There are at least three different forms of knowledge that the dental practitioner requires and, in a tradition that goes all the way back to Aristotle, we will refer to the Greek terms for these forms: *episteme*, *techne* and *phronesis* (1).

Episteme

Episteme is the word for theoretical–scientific knowledge. The opposite is *doxa*, which refers to “belief” or “opinion”. There is a massive body of epistemic knowledge within endodontology, for example on the biology of the pulp, the microorganisms that inhabit root canals, the procedures and materials used in the clinical practice of endodontology (endodontics) and the outcome of endodontic therapies. Science produces “facts”. It must be understood that modern science is an industry and is affected by many factors, both internal and external. Although this is not the place to discuss the philosophy of science, the concept of “truth” and the growth of scientific knowledge is not unproblematic. There has been substantial contemporary philosophical discussion reflecting on epistemic knowledge, and the interested reader is referred to one of the many good introductory texts that are available (3).

The results of science are presented in lectures, articles and textbooks. So from a student’s point of view the learning situation is rather straightforward, provided that the subject is structured well and ample time given for reading and reflection. This book, in large part, is composed of epistemic knowledge.

Techne

The first person to challenge the deeply entrenched theoretical concept of knowledge was the British philosopher Gilbert Ryle. In his book *The Concept of Mind* (10) he introduces “knowing-how” and distinguishes it from “knowing-that”. “Knowing-how” is practical in nature and concerns skills and the performance of certain actions. This concept of knowledge implies the ability not only to do things, but also to understand what you are doing. To say that you have practical knowledge, it is not enough to produce things out of mere routine or habit. You have to “know” what you are doing and be able to argue about it. Practice must be combined with reflection. The idea that there is a tacit or silent dimension of knowledge has had a great impact on the contemporary discussion. Michael Polanyi, for example, said that “We know more than we can tell” (9). When trying to explain how we master practical things such as riding a bicycle or recognizing a face, it is not possible to articulate verbally all the knowledge that we have. Certain important aspects are “tacit”. Likewise, it is not sufficient to teach students about root canal preparation simply by asking them to read a book or presenting the subject matter in a lecture. It has to be *demonstrated*. Knowledge is very often transmitted by the act of doing.

A substantial body of endodontic knowledge must be characterized as *techne*. 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 learned are all important.

Phronesis

According to Aristotle, *phronesis* is the ability to think about practical matters. This can be translated as “practical wisdom” (5) and is concerned with why we might decide to act in one way rather than in another. When thinking about the “right” action or making the “right” decision we enter the territory of moral philosophy. The person who has practical wisdom has good moral judgment. Modern ethical thinking has been influenced significantly by ideas that originated during the enlightenment. Morality is concerned with human actions and there are certain principles that can separate “right” from “wrong” decisions. Jeremy Bentham (2) and the utilitarians launched the utility principle and Immanuel Kant (6) invented the categorical imperative, each creating a tradition with great impact on today’s medical ethics and decision making.

Aristotle, on the other hand, believed that there are no explicit principles to guide us. He understood practical wisdom as a combination of understanding and experience and the ability to read individual situations correctly. He thought that *phronesis* could be learnt from one’s own experience and by imitating others who had already mastered the task. He stressed the cultivation of certain character traits and the habit of acting wisely.

The clinical situation demands that the dentist exercises practical wisdom, “to do the right thing at the right moment”. In order to develop *phronesis*, theoretical studies of moral theory and decision-making principles might be helpful. Neoaristotelians such as Martha Nussbaum (8) have suggested that reading literature should be part of any academic curriculum, the idea being that it increases our knowledge and understanding of other people. However, the essence of *phronesis* has to be learnt from practice.

Concepts of endodontology

From the above 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. Unfortunately, through the years, undue prestige has been given to theoretical–scientific thinking and this has hindered the development of a rational discussion of the other types of knowledge. The serious student of endodontology has to investigate all three aspects, but, as argued above, there are limits to what can be communicated within the covers of a textbook.

The dawn of modern endodontology

It all started with a speech at the McGill University in Montreal. In the morning of October 3, 1910, Dr William

Hunter gave a talk entitled “The role of sepsis and anti-sepsis in medicine”. Hunter said that:

“In my clinical experience septic infection is without exception the most prevalent infection operating in medicine, and a most important and prevalent cause and complication of many medical diseases. Its ill-effects are widespread and extend to all systems of the body. The relation between these effects and the sepsis that causes them is constantly overlooked, because the existence of the sepsis is itself overlooked. For the chief seat of that sepsis is the mouth; and the sepsis itself, when noted, is erroneously regarded as the result of various conditions of ill-health with which it is associated – not, as it really is, an important cause or complication.

“Gold fillings, gold caps, gold bridges, gold crowns, fixed dentures, built in, on, and around diseased teeth, form a veritable mausoleum of gold over a mass of sepsis to which there is no parallel in the whole realm of medicine or surgery. The whole constitutes a perfect gold trap of sepsis.”

The cited text was published in the *Lancet* in 1911. But Hunter’s words rapidly spread and were intensively discussed among laymen and given banner headlines in the newspapers. Essentially, Hunter proposed that microorganisms from a dental focus of infection can spread to other body compartments and cause serious systemic disease. The fear that illnesses and even those of chronic or of unknown origin were caused by oral infections, brought thousands of people to the waiting rooms of dentists with demands to have their teeth removed. As a result of the focal infection theory teeth were extracted in enormous numbers.

Although not directly stated by Hunter, teeth with necrotic pulps were seen as one of the main causes of “focal infection”. Laboratory studies had disclosed the presence of bacteria in the dead pulp tissue. In the 1920s, dental radiography came into general use and radiolucent patches around the apices of teeth with necrotic pulps indicating an inflammatory bone lesion were possible to detect. If such teeth were extracted and cultured, microorganisms were often recovered from the attached soft tissue. It became virtually incontestable that pulpally diseased teeth should be removed.

Reflecting on this period in the history of dentistry, Grossman (4) wrote: “The focal infection theory promulgated by William Hunter in 1910 gave dentistry in general, and root canal treatment in particular, a black eye from which it didn’t recover for about 30 years.” However, in hindsight, this period can also be regarded as the dawn of modern endodontology. Researchers started to question and oppose the clinical consequences of the focal infection theory. Microbiologists began mapping out the microflora of infected root canals. Pathologists

investigated the reaction patterns of the pulp and periapical tissues and came to understand the protective power of the host defense mechanisms. Clinicians invented aseptic methods to treat the root canal, and radiography made it possible to confine the procedures to within the root canal space. It was further demonstrated that root canal infections could be combated successfully and it became obvious that root canal infections were not such a serious threat to the human organism as once believed. Pulpally compromised teeth could therefore be spared and endodontic treatment became a necessary skill of the modern dentist.

The objective of endodontic treatment

The consequences of inflammatory lesions in the pulp and periapical tissue (Fig. 1.1) have tormented humankind for thousands of years. Historically, therefore, the main task of endodontic treatment has been to cure toothache due to inflammatory lesions in the pulp (pulpitis) and the periapical tissue (apical periodontitis). For a long period of time a commonly used method to remedy painful pulps was to cauterize the tissue with a red-hot wire or with chemicals such as acid. In 1836, arsenic was introduced to devitalize the pulp, a method that would be used for well over 100 years. Procedures to remove the pulp without toxic chemicals were introduced in the early part of the 19th century and small, hooked instruments were used. The advent of local anesthesia at the beginning of the 20th century made pulpectomy a painless procedure.

Signs of root canal infection, such as abscesses with fistulae, were also dealt with historically using highly toxic chemicals. These substances were introduced to the root canal, and forced through the foramen into the fistula. Often the treatment was more damaging than the



Fig. 1.1 A medieval skull found in Denmark showing teeth with serious attrition. In the first left molar the pulp chamber is exposed and the alveolar bone is resorbed around the root apices, indicating a once-present periapical inflammation due to necrosis of the pulp followed by root canal infection.

disease condition itself, and the tooth and parts of the surrounding bone were often lost in the process.

While relief of pain is still a primary goal of endodontic treatment, patients also may want to exclude the compromised tooth, as both a general and local health hazard. This means that intra- as well as extraradicular infections should be eradicated and that materials implanted in the root canal should be innocuous and not cause adverse tissue reactions or systemic complications. Using modern endodontic treatment procedures, these treatment objectives can be attained in the large majority of cases.

Clinical problems and solutions

The vital pulp

Under normal, physiological conditions the pulp is well protected from injury and injurious elements in the oral cavity by the outer hard tissue encasement of the tooth and an intact periodontium (Fig. 1.2). When the integrity of these tissue barriers is breached for any reason, microorganisms and the substances they produce may gain access to the pulp and adversely affect its healthy condition. The most common microbial challenge of the pulp derives from caries. Even in its early stages substances from caries-causing bacteria may enter the pulp along the exposed dentinal tubules. Like any connective tissue, the pulp responds to this with inflammation. Inflammation has an important aim to neutralize and eliminate the noxious agents. It also organizes subsequent repair of the damaged tissue. 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 extended to the vicinity of the pulp, the response may take a destructive course and result in severe pain and death (necrosis) of the tissue.

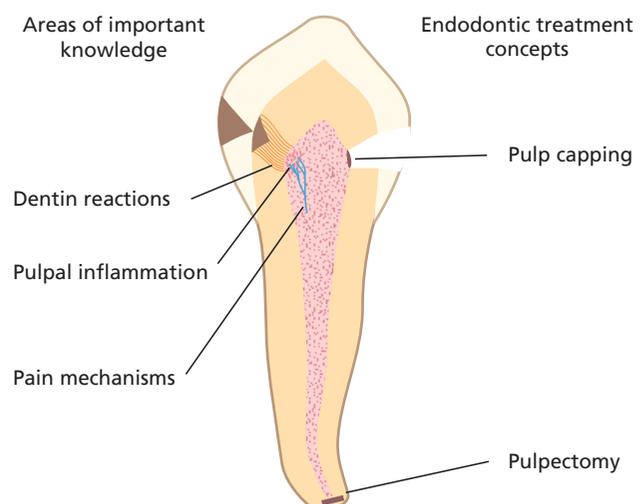


Fig. 1.2 The scope of endodontology: the vital pulp.

An inflamed or injured pulp may have to be removed and replaced with a root filling – a procedure termed pulpectomy. This measure is undertaken especially in cases when the condition of the pulp is such that an inflammatory breakdown is deemed imminent. A manifest infection may otherwise develop in the root canal system.

A pulpectomy procedure is carried out under local anesthesia and with the use of specially designed root canal instruments. These instruments remove the diseased pulp and prepare the canal system so that it can be filled properly. The purpose of the filling is to prevent microbial growth and multiplication in the pulpal chamber. Thus, pulpectomy is a measure primarily aimed at preventing the development of a manifest root canal infection and painful sequelae.

Pulpectomy may also be carried out any time a pulp is directly exposed to the oral environment. This may occur after clinical excavation of caries or after a traumatic insult or iatrogenic injury. If the exposure is fresh and the pulp judged not to be seriously inflamed it may not have to be removed. If the open wound is treated with a proper dressing and protected from the oral environment by *pulp capping*, healing and repair of the wound

are possible. For common terminologies used to specify the endodontic disease conditions and their treatments, see Core concept 1.1.

The necrotic pulp

As mentioned above, injury to the pulp may lead to necrosis of the tissue (Fig. 1.3). The necrotic pulp is defenseless against microbial invasion and will allow microorganisms indigenous to the oral cavity to reach the pulp chamber, either along an open direct exposure or through uncovered dentinal tubules or cracks in the enamel and dentin. Lateral canals exposed as a result of progressive marginal periodontitis may also serve as pathways for bacteria to reach the pulp. The specific environment in the root canal, characterized by the degrading pulp tissue and lack of oxygen, will favor a microbiota dominated by proteolytic, anaerobic bacteria. These microorganisms may organize themselves in clusters and in microbial communities attached to the root canal walls as well as inside the dentinal tubules of the root. In these positions microorganisms stay protected from host defense mechanisms and can therefore multiply rapidly to large numbers. Microorganisms attempt to

Core concept 1.1 Common terms and expressions used for endodontic disease conditions and treatment procedures

Pulpitis	Inflammation of the dental pulp. <i>Symptomatic</i> and <i>asymptomatic pulpitis</i> , as well as <i>irreversible</i> and <i>reversible pulpitis</i> , are commonly used terms to specify lesions with and without painful symptoms. The terms <i>total</i> and <i>partial pulpitis</i> are also in use.
Pulp necrosis	Pulp death. Pulp chamber is devoid of a functional pulp tissue. Necrosis can be more or less complete, i.e. partial or total.
Apical periodontitis	Inflammatory reaction of the tissues surrounding the root apex of a tooth. <i>Symptomatic</i> and <i>asymptomatic apical periodontitis</i> and <i>acute/chronic apical periodontitis</i> , respectively, are applied to indicate lesions with and without overt clinical symptoms such as pain, swelling and tenderness. <i>Dental</i> or <i>apical granuloma</i> is a histological term for an established lesion. <i>Apical</i> , <i>periapical</i> and <i>periradicular</i> are interchangeable terms to state the location of the process at or near the root tip.
Pulp capping	Treatment procedure aimed at preserving a dental pulp that has been exposed to the oral environment.
Partial pulpotomy	Treatment procedure by which the most (often inflamed) superficial portion (1–2 mm) of the coronal pulp is surgically removed with the aim of preserving the remaining tissue.
Pulpotomy	Treatment procedure by which the entire coronal pulp tissue is surgically removed with the aim of preserving the remaining tissue. The term pulpotomy is also used to describe a pain-relieving procedure in an emergency treatment of symptomatic pulpitis.
Pulpectomy	Treatment procedure by which pulp tissue (often inflamed) is surgically removed and replaced with a root filling.
Root canal treatment (RCT)	Treatment of teeth with necrotic pulps where root canals are often infected.
Non-surgical retreatment	Treatment of root filled teeth with clinical and/or radiographic signs of root canal infection, where root fillings are removed, canals disinfected and refilled. May also be carried out to improve the technical quality of previous root fillings.
Surgical retreatment	Treatment procedure by which the root apex of a tooth is surgically accessed to manage a root canal infection that has not been successfully treated by RCT. <i>Retrograde endodontics</i> or <i>surgical endodontics</i> are other terms for this procedure.

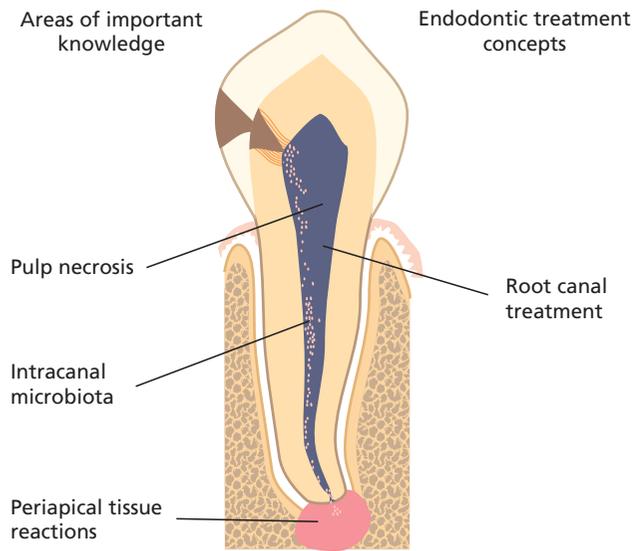


Fig. 1.3 The scope of endodontology: the necrotic pulp.

invade the periodontal tissues via the apical foramen or any other portal of exit from the root canal, and may do so before the host defense has been effectively organized. Once established, however, organisms will normally be held back but not eliminated from the root canal space. A chronic inflammatory lesion will ensue, normally around the root tip, and remain for as long as no treatment is initiated.

The periapical tissue reaction is often visible in a radiograph as a localized radiolucency because the adjacent bone has been resorbed in the course of the inflammatory process. The condition may or may not be associated with pain, tooth tenderness and various degrees of swelling.

Treatment of the necrotic pulp is by *root canal treatment* (RCT) and is aimed to combat the intracanal infection. The canal is cleaned with files in order to remove microbes as well as their growth substrate. Owing to the complex anatomy of the root, instruments cannot reach all parts of the canal system and therefore antimicrobial substances are added to disinfect the canal. In order to avoid reinfection and to prevent surviving microbes from growing, the canal is then sealed with a root filling.

The root filled tooth

Pulpectomy and RCT do not always lead to a successful clinical outcome. For example, a tooth may continue to be tender or periapical inflammation may persist. Such treatment “failures” are often associated with defective root fillings, which allow organisms from the initial microbiota to survive in the root canal or new bacteria to enter via leakage along the margins of the coronal restoration (Fig. 1.4).

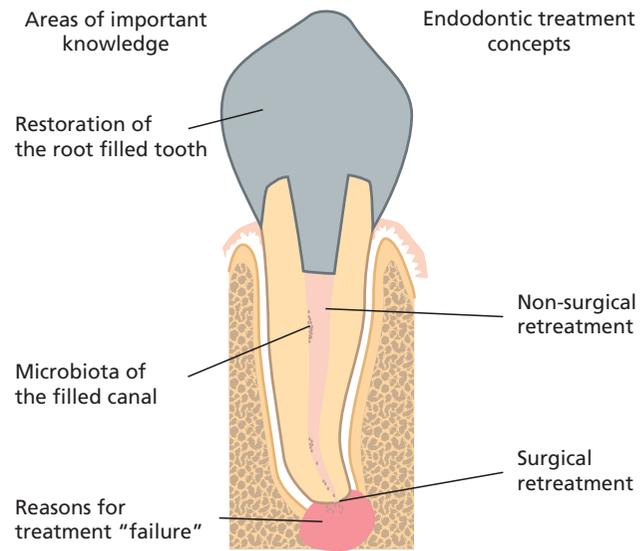


Fig. 1.4 The scope of endodontology: the root filled tooth.

The root canal in such cases may be retreated using either a non-surgical or a surgical approach. In *non-surgical retreatment* the root filling is removed and the canal is reinstrumented. Antimicrobial substances are applied to kill the microbes and the space is refilled. Crowns, bridges and posts may mean that it is sometimes not feasible to reach the root canal in a conventional way. In such cases, a *surgical retreatment* may be attempted. A mucoperiosteal flap is then raised and entrance to the apical part of the root made through the bone. Surgical retreatment often involves cutting of the root tip, instrumentation of the apical root portion and placement of a filling at the apical end.

The diagnostic dilemma

The disease processes in the pulp and periapical tissues take place in a concealed body compartment that normally is not available for direct inspection. Instead, the clinician has to rely on indirect information to assess the condition of the tissue and reach a diagnosis. The reliance on indirect signs and symptoms entails the risk of making false-positive and false-negative diagnoses. For example, the patient’s report of pain has been found to be an inaccurate sign because there is no exact relationship between the amount of tissue damage and level of pain encountered. Furthermore most inflammatory episodes within the pulp or periapical bone pass by without symptoms. Another factor is that the discriminatory ability of the intrapulpal nerves is not perfect, which means that if a patient has toothache due to pulpitis there is a high risk that he or she may “point out the wrong tooth”. Nevertheless a patient’s experience of pain and especially its character serve as important

indicators of an endodontic disease condition. Along with pulp vitality testing and radiographic examination, the disease history is a prime source of diagnostic data. Yet, to avoid erroneous diagnoses all data have to be interpreted with utmost care and with in-depth knowledge of possible errors and the factors that influence diagnostic accuracy.

The tools of treatment

To many dentists, RCT can best be described by using Winston Churchill's words on golf: "An impossible game with impossible tools". The complexity of root canal anatomy, the relative stiffness of root canal instruments, being unable, often, to visualize the area 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; this is clearly demonstrated by numerous radiographically based epidemiological surveys, which repeatedly report that many root fillings do not meet acceptable technical standards. Because clinical outcome is strongly related to the quality of treatment, the high frequency of substandard performances is a subject of great concern to the profession.

The last 10–15 years have seen a tremendous technological development that facilitates endodontic treatment and enhances the potential to increase its overall standard (7). For example, the advent of super-flexible nickel–titanium alloy has made it possible to fabricate instruments that are highly flexible and can follow the anatomy of the root canal and therefore produce good quality canal preparations. Furthermore, systems have been developed that allow the instruments to be maneuvered by machine rather than by hand, improving fine-scale manipulation and decreasing operator fatigue.

The surgical microscope has brought light and vision into the pulp chamber. Working under high magnification, it is now far easier to remove mineralizations, locate small root canal orifices and control intracanal procedures than with the naked eye or with loupes. However, high-quality microscopes are expensive and, thus far, the technology has found limited adoption by dentists other than those specialized in endodontics.

In the midst of this technological boom it must not be forgotten that endodontics is primarily about controlling infection. While the intracanal work is aimed to eliminate infectious elements and give space for the subsequent root filling, this effort would be futile if measures were not undertaken to prevent oral contaminants from entering the root canal space during the procedure. Luckily, there are few medical treatments that can be carried out as aseptically as endodontic therapy. Shielding the tooth with a rubber dam is the oldest and still the most effective way to ensure that the operation field remains

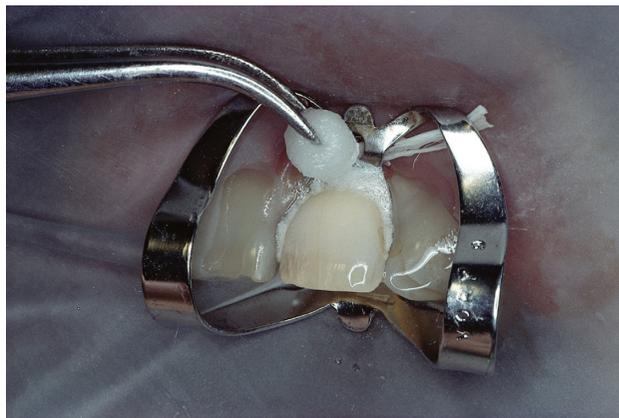


Fig. 1.5 Rubber dam isolated tooth, which is in the process of being disinfected.

sterile (Fig. 1.5). This measure also facilitates the procedure and is critically important to the clinical success of endodontic therapy.

Extraction and dental implant?

Extraction and placement of dental implants to replace endodontically compromised teeth has gained popularity in recent years. Such a measure can certainly be a valuable option in cases of severely damaged teeth that either have a hopeless prognosis or cannot be provided with a proper restoration. Yet, dental implants must not be overused or misused because an endodontic treatment, for example, may appear complicated. Clearly endodontic therapy represents a very realistic opportunity to restore most teeth with diseased pulps to a healthy state. Indeed endodontic therapy has reached a level of sophistication today that dentists, with proper knowledge and training, can carry out the procedures with a high rate of success. Epidemiological data have furthermore shown that endodontically treated teeth maintain a functional place in the oral cavity for long periods of time (11).

References

1. Aristotle (Iruin T, ed.). *Nicomachean Ethics*. London: Hackett Publishing, 1988.
2. Bentham J. *Introduction to the Principles of Morals and Legislation (1789)* (Burns JH, Hart DLA, eds). London: Methuen, 1982.
3. Chalmers AF. *What is this Thing called Science?* Buckingham: Open University, 1999.
4. Grossman LI. Endodontics 1776–1996: a bicentennial history against the background of general dentistry. *J. Am. Dent. Assoc.* 1976; 93: 78–87.
5. Hughes GJ. *Aristotle on Ethics*. London: Routledge, 2001.

6. Kant I. *Foundations of the Metaphysics of Morals* (1785). Indianapolis: Bobbs-Merrill, 1959.
7. 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.
8. Nussbaum M. *Poetic Justice. The Literary Imagination and Public Life*. Boston: Beacon Press, 1995.
9. Polanyi M. *Personal Knowledge: Towards a Postcritical Philosophy*. London: Routledge, 1958.
10. Ryle G. *The Concept of Mind*. London: Penguin, 1949.
11. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. *J. Endod.* 2004; 30: 846–50.

