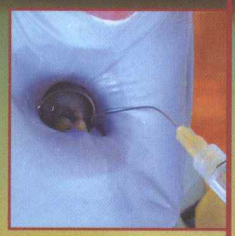
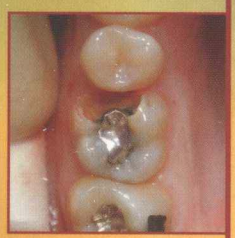
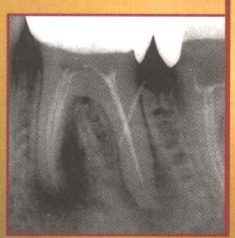
HARTY'S Endodontics in Clinical Practice







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SIXTH EDITION

HURCHILL
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Harty's endodontics in clinical practice

Sixth edition

Edited by

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Specialist in Endodontics
London, UK

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Preface

The new edition of this long-established book has come full circle, back to where it began. Fred Harty, after whom this book is named, was responsible for the first three editions and I have been a specialist in endodontics for over 20 years in the practice founded by Fred.

Tom Pitt Ford was responsible for the fourth and fifth editions of this book. We had other plans for further collaboration but, unfortunately, Tom passed away in the early stages of this project and so this edition is dedicated to him as a fitting tribute.

Tom was the Professor of Endodontology, Vice-Dean of King's College London Dental Institute at Guy's, King's College and St Thomas' Hospitals, and previously Director of Education. He was also Director of Institutional and Academic Audit at King's College, London. A man of extraordinary talent, Tom's death is an irreplaceable loss to dentistry and in particular the specialty of endodontics. Clinician, teacher, researcher, author and administrator, Tom's roles were numerous and his contributions to advancing endodontics immeasurable. Those privileged to have trained or worked with him, including many of the contributors to this edition, will forever remember and admire his example of diligence, perseverance and attention to detail.

The aim of this book is for it to be an authoritative guide to proven, current clinical endodontic practice. It is primarily intended as an essential undergraduate text for dental students in the United Kingdom. Since it is imperative that practitioners keep up to date, continuing education is now a mandatory requirement, so the book is also intended for dental practitioners seeking to update their knowledge, to help and support especially those who have chosen to embark on continuing education courses.

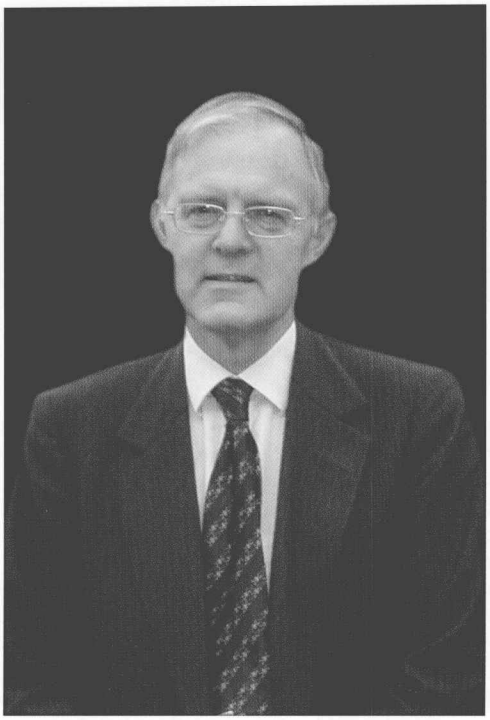
Despite the recognition and the establishment of a specialist list in endodontics in the United Kingdom, endodontic treatment will continue to be carried out mostly in general dental practice. Students and new graduates should not only be competent in treating the majority of endodontic cases but also be able to recognize, where appropriate, the need for referral to a specialist. A growing number of patients can now benefit from management of challenging or complex endodontic treatment by specially trained practitioners and can expect to receive a predictable outcome.

Diagnosis is the first step in the care and management of any patient so a new chapter on this topic is included in this edition. The style of referencing has also been replaced with the Vancouver system so that it is unobtrusive and easy to read. Illustrations, including line artwork, are now in full colour.

It is inevitable that there will be some duplication of material in this book and this should be viewed as reinforcement of relevant information. Different contributors will also have different writing styles and preferred terminology but, hopefully, not at the expense of clarity and cohesion.

I am grateful to all the contributors for providing their perspective on the topics covered in this new edition. I would also like to thank the publishers. I acknowledge the patience and understanding of my family, Grace, James and Louisa.

B.S. Chong
2009



Dedicated to
Professor Thomas Russell Pitt Ford
BDS (Lond), LDS RCS (Eng), PhD (Lond),
FDS RCPS (Glas), FDS RCS (Eng), FDS RCS (Edin)
1949–2008

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Introduction and overview

B.S. Chong

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SUMMARY

The science and art of endodontics has come a long way since the early days. A brief review of the history of endodontics is helpful in understanding its influence on current practice. The scope of modern endodontics is now wider and encompasses a variety of procedures. Patients are no longer willing to accept tooth loss and have higher treatment and care expectations. Microorganisms have an essential role in the pathogenesis of pulpal and periapical diseases. The host defence response against root canal infection includes numerous inflammatory mediators and a range of cells. Continuing research is increasing our knowledge of the root canal microbiota, which will hopefully result in dedicated strategies to manage the different types of root canal infection. Advances in endodontics are continuing and many recent developments have been successfully translated into everyday clinical practice.

INTRODUCTION

Endodontology is the branch of dental sciences concerned with the form, function, health of, injuries to and the diseases of the dental pulp and periradicular region, and their relationship with systemic well-being and health. Endodontic treatment can be defined as the prevention or treatment of apical periodontitis, the principal disease. The concept of treating the pulp of the tooth to preserve the tooth itself is a relatively modern development in the history of dentistry and it may be useful to review, very briefly, the history of pulp treatment in order to appreciate better modern views on endodontic treatment. Toothache has been a scourge of mankind from the earliest times. Both the Chinese and the Egyptians left records describing caries and alveolar abscesses. The Chinese believed that these abscesses were caused by a white worm with a black head which lived within the tooth. The 'worm theory' was current until the middle of the eighteenth century when doubts were raised,[1] but they could not be expressed forcibly because those in authority still believed in the worm theory.[2] The Chinese treatment for an abscessed tooth was aimed at killing the worm with a preparation that contained arsenic. The use of this drug was taught in most dental schools as recently as the 1950s in spite of the realization that it was self-limiting and that extensive tissue destruction occurred if even minute amounts of the drug leaked into the soft tissues. Pulp treatment during Greek and Roman times was aimed at destroying the pulp by cauterization with a hot needle or boiling oil, or with a preparation containing opium and hyoscyamus. About the end of the first century AD, it was realized that pain could be relieved by drilling into the pulp chamber to obtain drainage. In spite of modern antibiotics, there is

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still no better method of relieving the pain of an abscessed tooth than drainage.

Endodontic knowledge remained static until the sixteenth century when pulpal anatomy was described. Until the latter part of the nineteenth century, root canal therapy consisted of alleviating pulpal pain and the main function of the opened root canal was to provide retention for a dowel crown.[3,4] At the same time, bridgework became popular and many dental schools taught that no tooth should be used as an abutment unless it was first devitalized.[5] Root canal therapy became commonplace partly for these reasons and also because the discovery of cocaine led to painless pulp extirpation. The injection of 4% cocaine as a mandibular nerve block was first reported in 1884;[4] and 20 years later, the first synthetic local anaesthetic, procaine was produced. Around this time, reports of endodontic surgery appeared.[6] The first radiograph of teeth was taken in 1896,[3,7] shortly after the discovery of X-rays by Roentgen in 1895. This further popularized root canal therapy and gave it some respectability. About the same time dental manufacturers began to produce special instruments, which were used primarily to remove pulp tissue or clean debris from the canal. There was no concept of filling the root canals since the object of the procedure was to provide retention for a post crown.

By 1910 'root canal therapy' had reached its zenith and no self-respecting dentist would extract a tooth. Every root stump was retained and a crown constructed. Sinus tracts often appeared and were treated by various ineffective methods for many years. The connection between the sinus tract and the pulpless tooth was known but not acted upon. In 1911, William Hunter[8,9] attacked 'American dentistry' and blamed bridgework for several diseases of unknown aetiology. He reported recovery from these conditions in a few patients following extraction of their teeth. It is interesting to note that he did not condemn root canal therapy itself but rather the ill-fitting bridgework and the sepsis that surrounded it. About this time microbiology became established and the findings of microbiologists added fuel to the fire of Hunter's condemnations. Radiography, which at first helped the dentist, now provided irrefutable evidence of apical periodontitis surrounding the roots of pulpless teeth.

Whilst the theory of 'focal infection' was not enunciated by Billings[10] until 1918, Hunter's condemnations started a reaction to root canal therapy, and there began the wholesale removal of both non-vital and perfectly healthy teeth. The blame for obscure diseases was placed on the dentition, and as dentists could not refute this theory, countless mouths were mutilated. Naturally, not all dentists accepted this wholesale dental destruction. Some, particularly in continental Europe, continued to save teeth in spite of the focal sepsis theory. It is difficult to know why dentists in continental Europe disregarded this theory and one explanation may be that their patients equated the loss of teeth with a loss of virility, and therefore, did not allow their dentists to mutilate their dentitions. Alternatively, it could be that these practitioners were not so readily swayed by fashion as were their British colleagues.

MODERN ENDODONTICS

The re-emergence of endodontics as a respectable branch of dental science began in the 1930s.[11,12] The occurrence and degree of bacteraemia during tooth extraction was shown to depend on the severity of periodontal disease and the amount of tissue damage at operation. The incongruity between microbiological findings in the treatment of chronic oral infection and the histological picture was demonstrated. When the gingival sulcus was disinfected by cauterization before extraction, microorganisms could not be demonstrated in the bloodstream immediately postoperatively.

Gradually, the concept that a 'dead' tooth, one without a pulp, was not necessarily infected began to be accepted. Further, it was realized that the function and usefulness of the tooth depended on the integrity of the periodontal tissues and not on the vitality of the pulp.[13] Another important advance was clarification of the 'hollow tube' theory[14] by research using sterile polyethylene tube implants in rats.[15,16] The tissue surrounding the lumina of clean, disinfected tubes, which were closed at one end, was relatively free of inflammation and displayed a normal capacity for repair. When such tubes were filled with muscle, the inflammatory reaction was only severe around the openings of the tubes containing tissue contaminated with Gram-negative cocci. These findings place stress on the microbial contents of the tube; if the tube contains microorganisms then the potential for repair is far less favourable than when the lumen of the tube is clean and sterile.[17] This infected situation is likely to be found in most root canals requiring treatment. The concept that 'apical seal' was important led to the search for filling and sealing materials that were stable, non-irritant and provided a perfect seal at the apical foramen. With the more recent realization of the importance of coronal leakage[18,19] and the biodegradation of root canal fillings, total filling of the root canal space, including lateral and accessory canals, has assumed much greater importance.

Until relatively recently, practitioners were preoccupied with a mechanistic approach to root canal treatment and to the perceived effects of various potent drugs on the microorganisms within the root canal rather than a total antimicrobial approach of effective cleaning, adequate shaping and complete filling of the root canal space.[20] This preoccupation diverted attention from the effects of such drugs on the periapical tissues. Medicaments that kill microbes may also be toxic to living tissue.[21] The

consequences of such materials passing out of the tooth into the surrounding vital tissues can be localized tissue necrosis. These avoidable problems cause distress to patients and can lead to litigation. Effective elimination of microorganisms from root canal system is best achieved by instrumentation combined with irrigation.

SCOPE OF ENDODONTICS

The extent of the subject has altered considerably in the last 50 years. Formerly, endodontic treatment confined itself to root canal filling techniques by conventional methods; even endodontic surgery, which is an extension of these methods, was considered to be in the field of oral surgery. Modern endodontics has a much wider field[22,23] and includes the following:

- the differential diagnosis and treatment of orofacial pain of pulpal and periradicular origin
- prevention of pulpal disease and vital pulp therapy
- root canal treatment
- management of post-treatment endodontic disease
- surgical endodontics
- bleaching of endodontically treated teeth
- treatment procedures related to coronal restorations using a core and/or a post involving the root canal space
- endodontically related measures in connection with crown-lengthening and forced eruption procedures
- treatment of traumatized teeth.

ROLE OF MICROORGANISMS

The Chinese belief that dental abscesses were caused by small organisms, worms, persisted until the eighteenth century. At the end of the nineteenth century Miller[24] demonstrated the role of bacteria in root canal infection, and noted that different microorganisms were found in the root canal compared with the open pulp chamber. Shortly afterwards, systematic culturing of root canals was undertaken.[25] Unfortunately, these methods, which were potentially so valuable for improving the outcome of root canal treatment, were used to condemn much of the dentistry carried out at the time.[9] During the 1930s, microbiological techniques were used to re-establish the scientific basis of root canal treatment. However, techniques at that time only readily identified aerobic bacteria, and led to confusing results in later clinical studies.[26,27] This resulted in clinicians being complacent about the role of microorganisms, and performing treatment simply as a technical exercise.

The development of anaerobic culturing allowed the identification of many previously unknown microorganisms present in root canals.[28] This led rapidly to the demonstration that the majority of these microorganisms were anaerobes,[29,30] and the realization that canals previously considered sterile contained anaerobes alone. Furthermore, when traumatized teeth were examined, there was a close correlation between the presence of anaerobic bacteria in the root canal and a periapical radiolucency;[30] in the absence of infection, the necrotic pulp and stagnant tissue fluids cannot induce or perpetuate a periapical lesion. This was later demonstrated experimentally in teeth where the pulp tissue had been removed; only in those where the pulp was infected did periapical inflammation occur.[31] Although anaerobic culturing of root canals is not a technique applicable to everyday clinical practice, the results of research have provided rational explanations for pulp and periapical diseases and its treatment.[32] Microorganisms, which previously could not be cultured, and so were mistakenly considered absent, can now be identified. Over 50% of the oral microbiota is still uncultivable.[33,34] However, the use of molecular biology techniques has enabled the identification of microbes that would be undetectable by conventional culturing techniques.[33,35,36] As knowledge in this area expands, our understanding of the root canal microbiota is changing. The presence of specific or combination of microorganisms and their implications are yet to be fully appreciated.[37]

Most root canal infections contain a mixture of microorganisms with bacteria being the main candidate pathogen.[30,38,39] It has also been shown that the relative proportions of different microorganism are determined by the local environmental conditions.[39] Endodontic pathogens do not occur at random but are found in specific combinations.[40] If a selection of microorganisms is inoculated into root canals in fixed proportions, their relative numbers will change over time, with a decline in aerobes and an increase in anaerobes.[39] It has also been established that combinations of microorganisms are more likely to survive than inocula of single species.[38] It is clear that one species can produce substances that others can metabolize in order to survive, forming complex ecological and nutritional relationships.[32]

Microorganisms are normally confined to the root canal system in pulpless teeth and exist in two forms:

- planktonic – loose collections or suspensions within the root canal lumen
- biofilm – dense aggregate, forming plaques on and within the root canal wall.

The intraradicular infection may be divided into three categories:

- Primary – caused by microorganisms that initially invaded and colonized the necrotic pulp.
- Secondary – caused by microorganisms that were not present in the primary infection but were introduced into the root canal system following dental intervention.

- Persistent infection – caused by microorganisms associated with the primary or secondary infection that managed to survive treatment procedures and nutritional deprivation.

It is unusual for microorganisms to be present in periapical lesions; the host defences prevent them from invading the periapical tissues.[41] However, in certain circumstances and with some species, microorganisms may establish an extraradicular infection, which can be dependent or independent of the intraradicular infection; thankfully, the incidence of independent extraradicular infection in untreated teeth is low.[42]

TISSUE RESPONSE TO ROOT CANAL INFECTION

The role of infection in the demise of damaged pulps was demonstrated in a classic study by Kakehashi and coworkers in the 1960s,[43] and eventually led to a biological approach to operative dentistry.[44] The presence of microorganisms, their byproducts or damaged tissue in the root canal can cause apical periodontitis, typically at the apical foramen but also around the foramina of any lateral or accessory canals or at a fracture. The periapical inflammation prevents the spread of infection from the tooth into the alveolar bone, otherwise osteomyelitis would occur. The inflammatory lesion contains inflammatory mediators and numerous inflammatory cells, e.g. polymorphonuclear leucocytes, macrophages, B- and T-lymphocytes and plasma cells.[45] The interaction between these cells and the antigenic substances from the root canal results in the release of a large number of inflammatory mediators. The inflammatory mediators include neuropeptides, the complement system, lysozymes and metabolites of arachidonic acid.[46] Prostaglandins, leucotrienes and cytokines play an important role in the development of periapical lesions.[45,46]

As long as antigens emerge from the canal foramina, there will be a continuing inflammatory response, mediated in a number of different ways. This is a very dynamic response to rapidly multiplying microorganisms in the root canal, and may not be readily apparent to the clinician observing a radiograph or a histologist examining a slide of fixed cells. Endodontic treatment is primarily directed at effective elimination of the microorganisms, allowing inflammation to subside and healing to occur.

QUALITY ASSURANCE

The general public across the world now expect professional people to deliver a high standard of service; dentistry, and endodontic treatment in particular, is no exception. In the UK, guidance has been published by the regulatory body on the standards expected of,[47] and the scope of practice for,[48] the whole dental team. The European Society of Endodontology has issued quality guidelines for endodontic treatment.[49] It is essential that dental practices have a quality control system to ensure that each step in history, diagnosis and treatment is carried out in a logical and consistent manner. This is to ensure a high standard of care and treatment, known as clinical governance. Patients are increasingly well informed and will not tolerate poor standards, e.g. in sterilization procedures or out-of-date views. In the UK and in line with many other countries, one of the largest source of dental negligence claims relate to endodontics.[50] The dramatic rise in litigation is a reflection that patients are increasingly prepared to seek redress for any failures regarding their care or treatment.

In a recent survey in England of newly qualified dentists in vocational training to join the National Health Service, most expressed a lack of preparedness with regards to complex/molar endodontics, with 66% rating their preparedness as 'poor' and 3% 'very poor'.[51] Those dentists who have undertaken further training to become specialists are expected to achieve consistently high standards in diagnosis and treatment. However, general practitioners cannot continue to practise in the way that they were taught at dental school many years ago; they must keep up to date and offer referral to an appropriate specialist when the treatment required is beyond their skill. This change has already occurred in the USA and is spreading to other countries. In the UK, continuing professional development is now mandatory for recertification with the regulatory body and practitioners are also required to refer patients for further advice or treatment when it is necessary, or if requested by the patient.[47]

Almost all endodontic procedures can be carried out with a predictable outcome. Root canal treatment has a reported success rate of over 90%,[52,53] even though closer analysis reveals that retreatment of teeth with apical periodontitis is less successful than initial treatment in teeth without apical periodontitis.[52,54] It is essential that individual practitioners monitor their outcomes against accepted criteria,[55] and that their treatment protocols conform to published guidelines.[49] Success of treatment can be measured in different ways[56] and should encompass not only clinical but also radiological evidence.

RECENT DEVELOPMENTS

The dental pulp may be damaged as a result of caries or infection consequent to trauma or operative dentistry. With a reduced incidence of dental caries, a greater emphasis on preventing sports injuries, and the preparation of smaller cavities combined with better restorative materials

in operative dentistry, the expectation is a decline in the number of teeth with damaged pulps. However, the trend and popularity of 'cosmetic' dentistry potentially risks irreversibly compromising the pulp. The degree to which adhesive restorative materials will be successful in preventing pulp damage in clinical practice is another unquantifiable variable.

Recent progress in the understanding of the cellular and molecular processes involved in the dentine/pulp complex has heralded a new era of regenerative dentistry.[57] The media trumpeted research in this field with the assertion that one day everyone will be able to grow a completely new set of teeth. The identification of stem cells in the dental pulp, the bioactive molecules within the dentine matrix and specific processes promoting tissue regeneration will, hopefully, translate into biologically-based therapies in everyday clinical practice. The ability to control tissue injury, microbial infection, and inflammation will tip the balance so that instead of necrosis there will be regeneration and maintenance of pulpal vitality. Case reports have appeared on the revascularization of necrotic pulps in immature permanent teeth.[58,59] In the new and allied field of regenerative endodontics, the ultimate goal is to replace diseased, damaged or missing pulp tissues with healthy tissues to revitalize teeth.[60,61]

The management of persistent infection in previously endodontically treated teeth is challenging.[62,63,64] Endodontic pathogens have the capability to adapt, including the formation of biofilms, in response to changes in the root canal environment.[65,66] As the breadth of microbial diversity in the oral cavity has been revealed by molecular techniques,[33] several newly identified species/phylotypes have emerged as potential pathogens.[67] Findings have revealed new candidate endodontic pathogens, including as-yet-uncultivated bacteria and taxa, which may participate in the mixed infections associated with apical periodontitis in previously treated teeth.[61,68] Improved knowledge of the microbiota should, eventually, lead to dedicated strategies for managing different types of root canal infection, including those that are recalcitrant.

Images captured on X-ray films or via digital sensors are two-dimensional 'shadowgraphs' with inherent problems of geometric distortions and anatomical noise.[69] Cone Beam Computed Tomography (CBCT) is a relatively new imaging technique.[70] It is designed to overcome some of the deficiencies of conventional radiography.[71] CBCT produces undistorted and accurate images of the area under investigation enhancing diagnosis and in the process aiding, for example, the planning of endodontic surgery and the management of resorption lesions. Since CBCT is able to detect lesions that are not discernible on conventional radiographs, it should also enable more objective assessment of healing after endodontic treatment.

Since its introduction, the use of the operating microscope in endodontics has increased[72] and it has become an invaluable tool.[73] From diagnosis to canal location, through to canal preparation and filling, the improved vision and illumination afforded by the operating microscope is immensely beneficial.

Techniques, and in particular instruments, for preparation of root canals has altered substantially in recent years.[74,75] A crown-down concept is now the major approach to shaping and cleaning the root canals.[76] Manufacturers are always introducing, onto the market, newer instruments for preparation of root canals. The development of nickel-titanium rotary systems continues unabated, coupled with the promise of speed, ease and efficiency. However, not all claims can be substantiated and any instrument or technique is only as good as the operator. Endodontic treatment should always be guided by biological and evidence-based principles. Speed, expediency and technical wizardry does not guarantee a favourable treatment outcome.

There has been a quiet revolution in endodontic surgery. This treatment modality is no longer a substitute for failure to manage properly the root canal system non-surgically. The indications for endodontic surgery are reduced and non-surgical retreatment should first be considered. Newer root-end filling materials, among other advances, including developments in surgical armamentarium, the implementation of microsurgical techniques, enhanced illumination and magnification have helped improve the predictability and outcome of endodontic surgery.[77] The use of amalgam as a root-end filling material is confined to history with zinc oxide-eugenol materials and Mineral Trioxide Aggregate (MTA) now being widely used.[77] In the first prospective clinical study on the use of MTA as a root-end filling material, a high rate of success (92%) was achieved.[78] Further development of this novel material, with the unique ability to encourage hard tissue deposition, has helped promote the use of MTA not only as a root-end filling, but also a perforation sealant and pulp capping agent. Other similar tissue regenerative materials are being investigated.

The advent of implants has led to clinicians being confronted with the decision to either extract a tooth and place an implant or preserve the natural tooth by root canal treatment. There are debates about the advantages of implants versus endodontics[79,80,81] fuelled by the myopic perception within both camps that one discipline is a threat to the other. This has led to the movement to incorporate implant placement into endodontic surgery. In reality, both disciplines are complementary to each other.[82] Endodontic treatment of a tooth represents a feasible, practical and economical way to preserve function in a vast array of cases and in selected situations in which prognosis is poor, a dental implant is a suitable alternative.[83]

The importance of good coronal restoration of root-filled teeth has been highlighted.[18,19] This is facilitated by the use of adhesive materials where appropriate, and the placement of suitable bases, and well-fitting restorations.

Despite conflicting arguments about the relative importance between the quality of the root filling and the coronal restoration on treatment outcome, there can be no disagreement that both should be performed well[84,85,86] and are mutually beneficial to the long-term prognosis of the root treated tooth.[52,87]

A majority of endodontic treatment is within the capability of general practitioners but there will, inevitably, be cases that are best managed by specialists. Endodontic referral practice is undertaking more root canal retreatment because of technical deficiencies in the original treatment. In many cases, this is difficult and challenging but success can be very rewarding, particularly when in the past, the alternative would have been extraction. It is encouraging that many more patients are refusing to allow a tooth with an exposed or infected pulp to be extracted, but instead ask for it to be saved by root canal treatment. High quality endodontic treatment will make a significant contribution to good oral health.

LEARNING OUTCOMES

At the end of this chapter, readers will be able to understand and discuss the:

- history of endodontics and its influence on current practice;
- scope of modern endodontics;
- essential role of microorganisms in the pathogenesis of pulpal and periapical diseases;
- tissue response to root canal infection;
- high standard of endodontic care and treatment expected by patients;
- recent developments in endodontics.

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