Pitt Ford's Problem-Based Learning in Endodontology

Second Edition

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WILEY Blackwell

This edition first published 2025

Registered Office(s)
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

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Library of Congress Cataloging-in-Publication Data

Names: Perry, Elizabeth Shin, editor. | Patel, Shanon, editor. | Kanagasingam, Shalini, editor. | Hamer, Samantha, editor.
Title: Pitt Ford's problem-based learning in endodontology / edited by Elizabeth Shin Perry, Shanon Patel, Shalini Kanagasingam, Samantha Hamer.
Other titles: Problem-based learning in endodontology
Description: Second edition. | Hoboken, NJ : Wiley, 2025. | Includes bibliographical references and index.
Identifiers: LCCN 2023017104 (print) | LCCN 2023017105 (ebook) | ISBN 9781119565970 (paperback) | ISBN 9781119566014 (adobe pdf) | ISBN 9781119565963 (epub)
Subjects: MESH: Dental Pulp Diseases–diagnosis | Dental Pulp Diseases–therapy | Endodontics | Problems and Exercises | Case Reports
Classification: LCC RK351 (print) | LCC RK351 (ebook) | NLM WU 18.2 | DDC 617.6/342–dc23/eng/20230901
LC record available at https://lccn.loc.gov/2023017104
LC ebook record available at https://lccn.loc.gov/2023017105

Cover Design: Wiley
Cover Image: Courtesy of Elizabeth Perry

Set in 11/13pt STIXTwoText by Straive, Pondicherry, India

The publishers thank the contributors and acknowledge that the images used in this textbook are owned by the individual contributors except where indicated.

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First Foreword

Over the last 50 years of endodontics, we have witnessed immense technical and biological advances that have helped to underpin our understanding of pulpal and apical disease and the appropriate therapies to manage these conditions. Notably, many of these advancements have not been fully translated into practice with shortcomings in educational dissemination and limitations to conventional teaching methodology highlighted. *Pitt Ford's Problem Solving in Endodontology*, now in its second edition, uniquely addresses this in that it challenges the reader to be the problem solver, asking pertinent questions based around every day clinical vignettes. This form of case-based learning increases the relevance for the reader and also challenges them to consider how best to manage these scenarios with a research-led mindset. A particularly welcome facet of the book is that it does not aim to provide all the answers, but rather stimulates the reader to further develop their knowledge.

The book covers a wide range of topics from the biological rationale for endodontic treatment, diagnosis, and treatment planning, through vital pulp treatment, root canal treatment, regenerative endodontics, and endodontic microsurgery, while also covering critical areas that are often ignored such as pain of non-odontogenic origin, dental trauma, and medico-legal aspects. The topics have been brought together in such a way that the overall scope of this text is much greater than the simple summation of the individual components. It will appeal to postgraduates, residents in training, researchers, and practicing clinicians, and I am sure it will help to inspire many people in the clinical endodontic area. It is led by a talented and experienced editorial group that has recruited an exceptional range of talented and prominent endodontists working and researching globally. I am grateful to the editors and authors for providing us with this valuable insight and know that the text will become essential reading for those working in the area.

Of particular pride to me to see that the book carries the name and legacy of Tom Pitt Ford, a personal mentor and pioneer in the field and development of the science endodontology. I know he would have been immensely proud of the new edition of this important text.

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President of the European Society of Endodontology

Second Foreword

In clinical dentistry, problem solving and critical thinking are crucial in the accurate diagnosis and delivery of clinical care for patients. In this second edition of *Pitt Ford's Problem Solving in Endodontology*, the editors have produced an outstanding pragmatic guide to endodontic therapy. Since the first edition, the field of endodontics has undergone impressive developments in the evolution of more conservative minimally invasive therapies that incorporate innovations in biomedical imaging, microscopy, and risk factor discovery to benefit patients. This edition beautifully holds up the legacy of Professor Tom Pitt Ford. The book brings together real-life clinical scenarios to enhance the education of dental and postgraduate students alike on key principles involved in patient management, especially in situations of traumatic injury to the dentition and/or alveolus for the promotion of tooth support, function, aesthetics, and long-term survival.

The book is subdivided into nine valuable sections that comprehensively address areas such as aetiology, diagnosis, and treatment planning. Pertinent new chapters have been added on vital pulp therapy and regenerative endodontics and reflect the rapidly evolving area of tissue engineering and regenerative medicine, leading much of dentistry to improve clinical outcomes for enhanced delivery of the minimally invasive treatments that patients have come to expect. Chapters on management of both failure and/or complications during endodontic therapy are also very relevant, as we know that it is desirable to retain teeth for as long as practically possible. Advancements in endodontic microsurgery and the many challenges in managing exquisite restorative work to preserve teeth that require either initial endodontic treatment or retreatment have also been updated.

Additional considerations for patient management such as the (potential) association between apical periodontitis and systemic disease, medicolegal issues, and determining prognosis of teeth that may eventually support clinical decision making in patient risk stratification have been added in this second addition.

In summary, I am excited for readers to delve into this second edition of *Pitt Ford's Problem Solving in Endodontology* to partake in this assembly of pertinent clinical scenarios. This text will advance students' understanding in order to better deliver clinical care to preserve the dentition by enhancing long-term endodontic outcomes. Please enjoy!

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Preface

The success and positive feedback of the first edition of Pitt Ford's Problem-Based Learning in Endodontics led to the commissioning of this second edition. As with the first edition, the aim of this novel textbook is to enable readers to become adept problem solvers in real-life clinical scenarios, mirroring their experiences in patient care. This case-based approach fosters problem-solving skills and cultivates critical thinking.

This book does not replace traditional Endodontology textbooks but is intended as a supplementary resource to help readers consolidate their knowledge. Each chapter maintains an accessible question-and-answer format, covering the core topics of endodontics. This approach encourages inquisitive readers to delve deeper into specific subjects and cultivates a self-learning approach throughout their careers.

This textbook is designed to benefit undergraduate dental students in their final years looking to enhance their clinical skills, as well as postgraduates preparing for Royal College Diplomas or advanced graduate programs in North America. It is also a valuable resource for specialists in training in non-endodontic disciplines who seek to understand the relevance of endodontics. Additionally, it serves as a contemporary reference for experienced endodontic specialists looking to update their core clinical knowledge. In recognition of its global scope, this book has been crafted to serve the needs of endodontists worldwide, embracing the universal tooth numbering system to ensure a consistent and comprehensive approach.

From the outset, we were committed to upholding the first edition's focus on the biological rationale behind Endodontology, rather than merely providing a step-by-step guide. Each chapter and clinical case is intentionally structured to encourage readers to systematically and logically assess patients' presenting complaints and clinical information. This edition has been thoroughly revised and incorporates the latest advances in our specialty where appropriate.

As with the first edition, the contributors and editors represent a spectrum of expertise, encompassing a range of backgrounds in academia, clinical practice, and professional development. The result is a publication that is richly diverse in its content and perspectives.

The original concept for this book originated from the late Professor Tom Pitt Ford, a true pioneer and well-respected clinical academic. We hope you enjoy reading this new edition of Pitt Ford's Problem-Based Learning in Endodontology and that it contributes to the elevation of excellence in our specialty worldwide.

Elizabeth Shin Perry
Shanon Patel
Shalini Kanagasingam
Samantha Hamer
2025

Acknowledgements

We extend our heartfelt gratitude to our families, whose unwavering support and understanding have been instrumental in our journey to bring the second edition of "Pitt Ford's Problem-Based Learning in Endodontology" to fruition. Your patience and encouragement have been our pillars of strength.

We would also like to extend our thanks the dental teams we collaborate with daily in our specialist practices and within the universities where we are affiliated, as their dedication has been invaluable in shaping this work.

Furthermore, we wish to express our deep appreciation to the contributors who generously shared their knowledge, insights, and expertise to make this publication a comprehensive and valuable resource for the field of Endodontology.

This publication stands as a testament to the collective effort of many, and we are truly grateful for the support and collaboration of all those who have played a role in its creation.

Elizabeth Shin Perry

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Samantha Hamer

Figure 1.1.1 Periapical radiograph of tooth UL2, showing an apical radiolucency. The root canal is necrotic and infected, and an inflammatory response associated with bone resorption has developed at the periradicular tissues (apical periodontitis) in an attempt to prevent spread of the infection to the bone and other body sites.

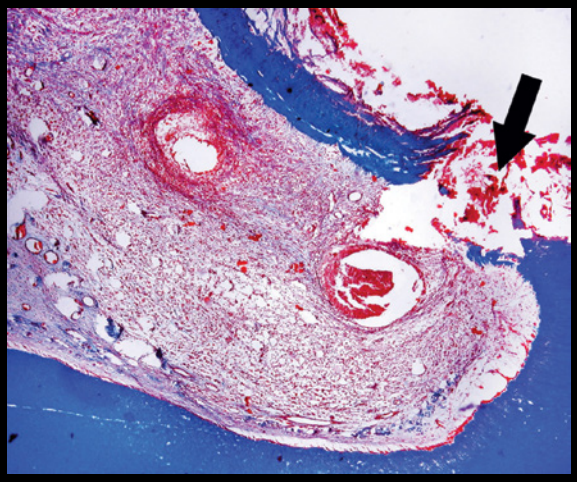

Figure 1.1.2 Histological section of a tooth with caries exposure (arrow). The pulp was vital, but severely inflamed at the area of exposure.

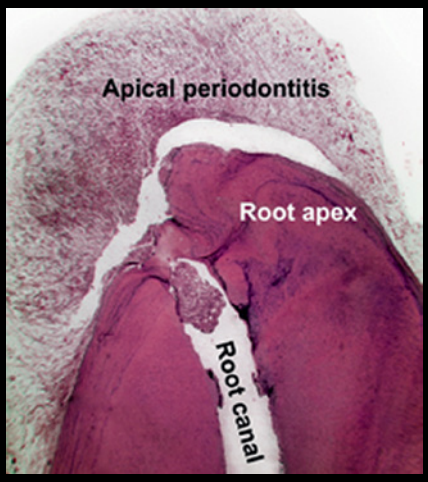

Figure 1.1.3 Histological section of a tooth with necrotic pulp and apical periodontitis.

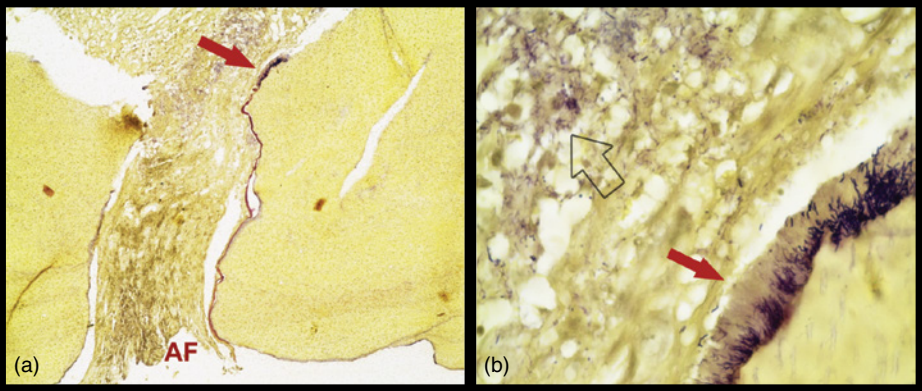

Figure 1.1.4 (a) Histological section of the very apical part of the root canal of a tooth evincing apical periodontitis. A bacterial biofilm (red arrow) is seen adhered to the canal wall very close to the apical foramen (AF). (b) Higher magnification of the biofilm shown in (a). Planktonic bacterial cells are also seen in the main canal (empty arrow).

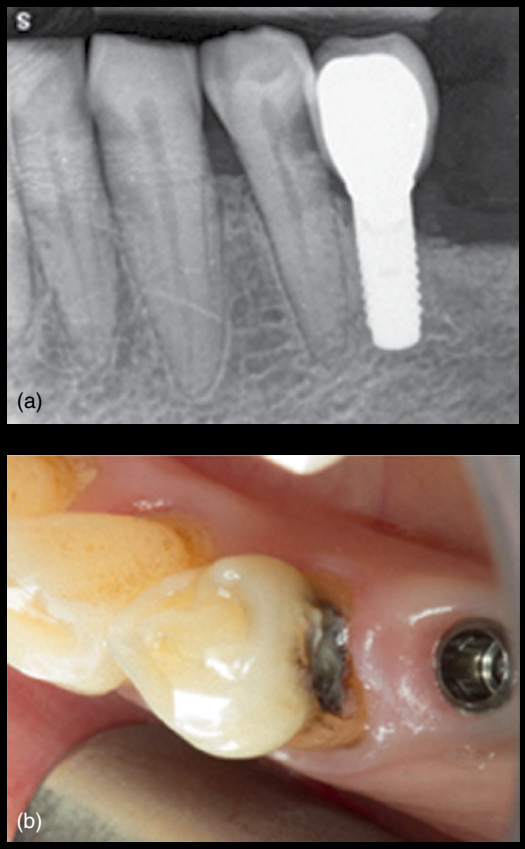

Figure 1.2.1 (a) Periapical radiograph of the LL4 demonstrating the extension and proximity to the pulp of the distal interproximal carious lesion. There appeared to be reactionary dentine in close relation to the carious lesion. No noticeable changes in the periapical tissues could be appreciated. (b) After removal of the implant-supported crown, the size of the carious lesion was assessed. The deep cavity was darkened and covered with soft plaque. It was also possible to visualise the undermined enamel in relation to the lesion.

Figure 1.2.2 (a) Dental dam isolation and excavation of the peripheral area; (b) retraction of the dental dam/soft tissues with PTFE; (c) detail of the cavity after caries excavation, etching, rinsing and drying. Note the affected dentine and the peripheral area of sound dentine.

Figure 1.2.3 (a) After bonding application; (b) after restoration with composite resin; (c) view after completion and with implant crown in situ, showing an adequate contact point.

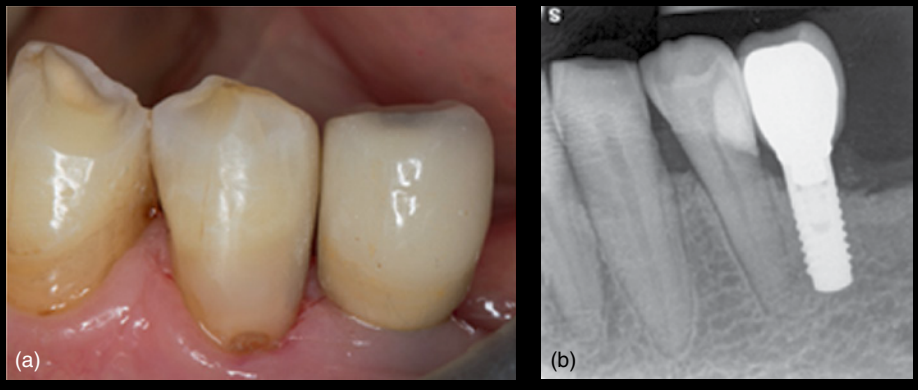

Figure 1.2.4 (a) Buccal view of the restored tooth. The interproximal contour and contact point were optimised to prevent food trapping and allow the facilitated interproximal cleaning. (b) Final periapical radiograph.

Table 1.4.1 The Dental Practicality Index.

Weighting	Tooth integrity	Endodontic	Periodontal	Extra considerations
0 No treatment required	Unrestored Existing restoration OK	Vital pulp Existing root canal treatment OK	Probing <3.5 mm Periodontal disease treated	Local: Adjacent teeth are healthy General: History of intravenous bisphosphonates, head and neck radiotherapy
1 Simple treatment required	Simple direct or indirect restoration Suitable for general dental practitioner	Simple root canal treatment Canal(s) visible, straight	Probing 3.5–5.5 mm Root surface debridement suitable for hygienist or general dental practitioner	Local: Whether this tooth will be a bridge abutment General: Planned radiotherapy of head and neck region Immunocompromised patient
2 Complex treatment required	Minimal sound tooth Subgingival margins Post-core	Complex root canal system Sclerosed canal(s) Acute curvatures Fractured instrument Perforation	Probing >5.5 mm Short root Crown lengthening Grade 2 mobility Grade 2–3 furcation involvement	Local: Prosthodontic treatment planned of multiple teeth General:High caries rate Poor oral hygiene, active perio Parafunctional habits/ tooth surface loss Limited mouth opening/severe gags Anxious, requiring sedation
6 Impractical to treat	Inadequate structure for ferrule	Untreatable root canal system	Untreatable periodontal disease	Local: Keeping the tooth would complicate a simple plan, e.g. one remaining over-erupted tooth affecting denture construction General: Potentially life-threatening medical conditions where the objective of dental treatment is pain relief only

Figure 1.4.1 Periapical radiograph of the LR7, showing negative crown margin, sparsely condensed root canal filling with apical radiolucency.

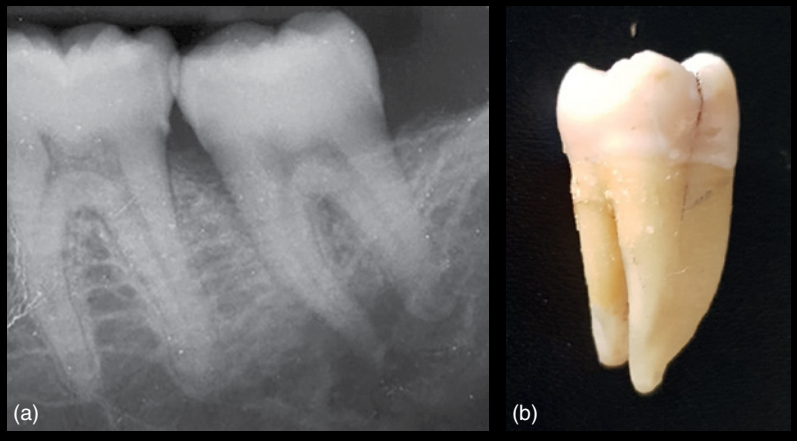

Figure 1.4.2a and b Periapical radiograph and photograph of the LL7 with intact clinical crown. Note the mesial vertical bone loss with apical radiolucency and the corresponding crack with radicular extension on the mesial root.

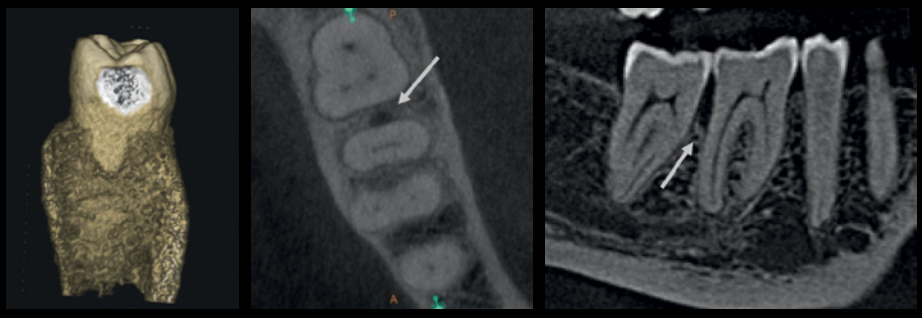

Figure 1.6.4 Cone beam computed tomography three-dimensional, axial and sagittal views of a cracked lower right first molar demonstrating the narrow area of low density in the periodontium (arrows), highly suggestive for a cracked tooth with radicular extension.

Figure 1.6.5 Lower left second molar (LL7). (a) Pre-operative radiograph showing periapical periodontitis. (b) Immediate post-operative radiograph. (c, d) Two- and eight-year follow-up radiographs, respectively, showing resolution of the apical lesion. (e, f) Eight-year sagittal and axial sections of cone beam computed tomography scan showing isolated distal periodontal defect.

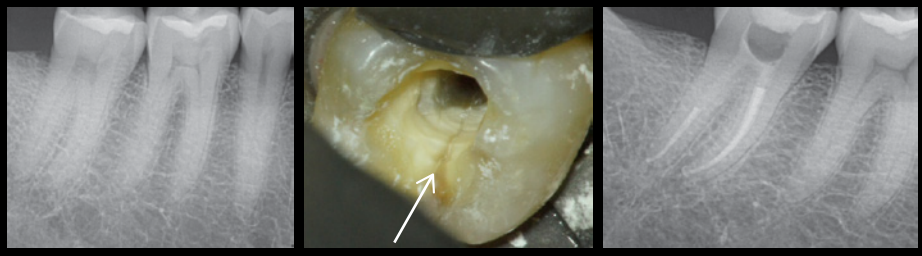

Figure 1.6.6 Angular bone loss on the radiograph suggesting a crack on the distal. Visualisation of the crack under the microscope with placement of a resin-modified glass ionomer intracanal barrier.

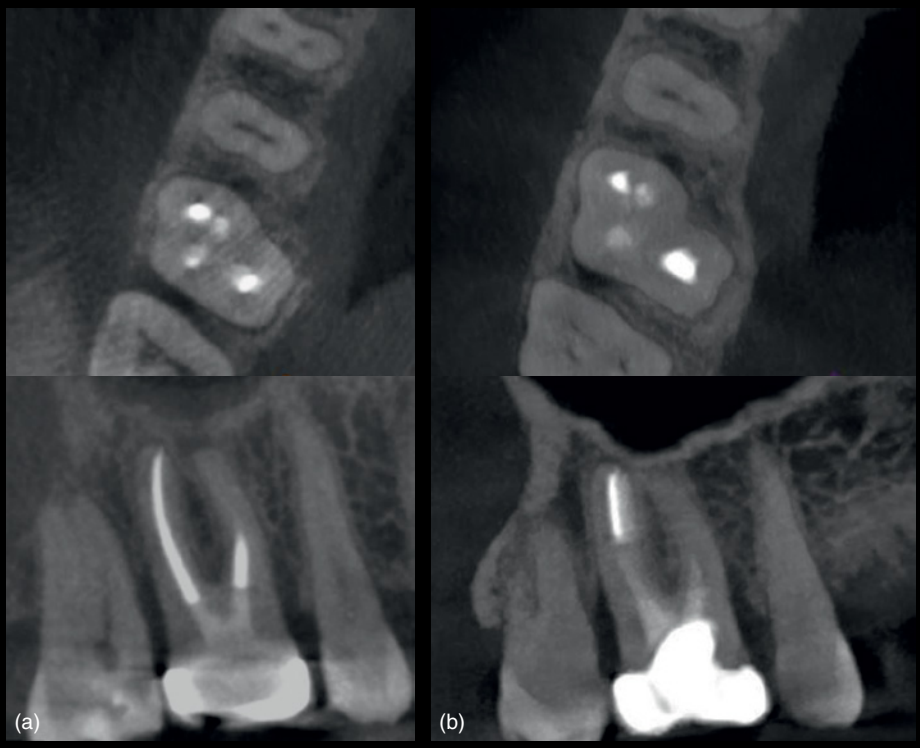

Figure 1.6.7 Cone beam computed tomography axial and sagittal views of an upper right first molar (UR6) exhibiting cracks with radicular extension at both the mesial and distal surfaces. (a) Three-year follow-up images and (b) seven-year follow-up images showing minimal to no change in the appearance of the isolated, narrow periodontal defects over four years.

Figure 1.9.1 Periapical radiograph showing bilateral radiopacity overlying the teeth (bilateral mandibular tori); the LL1 and LR1 with intact coronal tooth structure; root canals visible in the coronal to mid-third of the root, with no canals visible in the apical third of the root (fast break), which can often indicate bifurcation of the root canal; periapical radiolucency.

Figure 1.9.2 Clinical photographs: (a) anterior view and (b) occlusal view of the mandibular dentition.

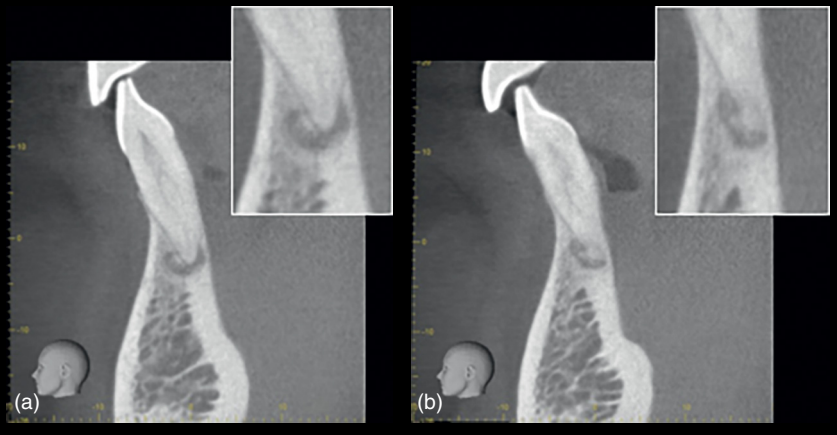

Figure 1.9.3 Cone beam computed tomography scan of the mandibular anterior teeth. (a) Sagittal view of the LL1; (b) sagittal view of the LR1, showing mixed radiolucent and radiopaque lesions at the apices of the LL1 and LR1. LL1 and LR1 both have two canals, as suspected from the fast break seen on the periapical radiograph.

Figure 2.1.1 Left sectional orthopantomogram (OPG).

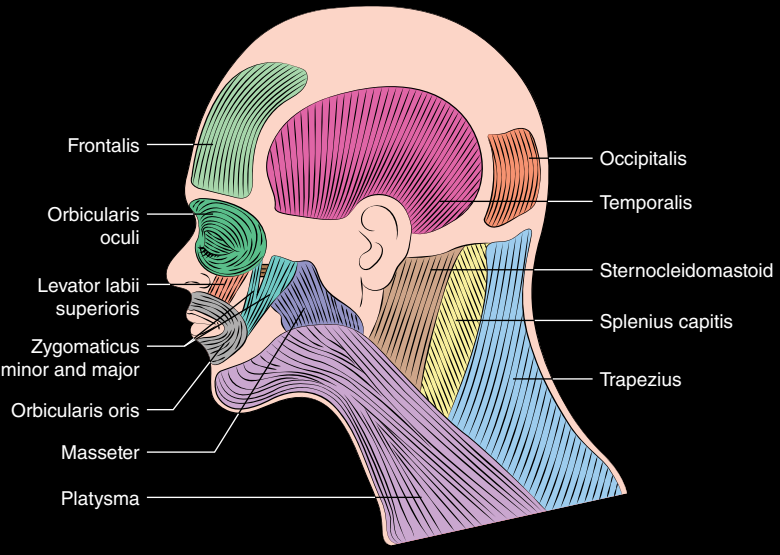

Figure 2.1.2 Major muscles of the head neck and face.

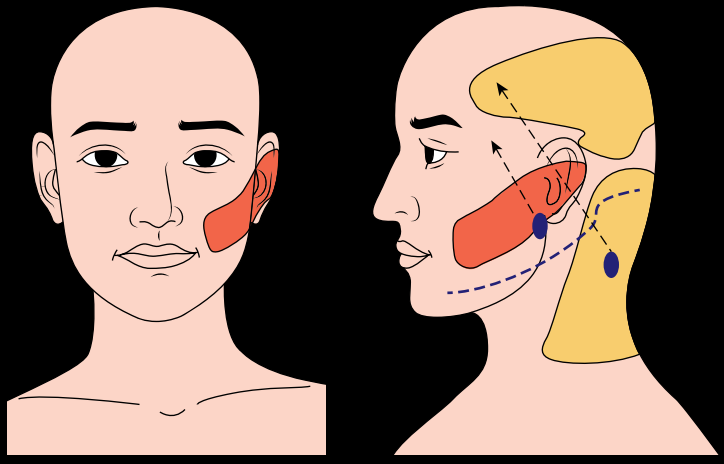

Figure 2.1.3 Trigger points in the left masseter and superior head of the left trapezius muscle, with pain referral beyond the boundary of the muscle palpated.

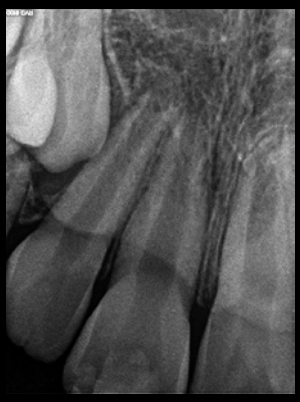

Figure 3.1.1 Pre-operative radiograph of the upper right central incisor with immature root formation, large root canal and open apex.

Figure 3.1.2 Initial access revealed inflamed and hyperaemic pulp tissue in the pulp chamber.

Figure 3.1.3 Partial pulpotomy was performed with a sterile high-speed diamond bur to remove the inflamed pulp tissue. Dilute sodium hypochlorite (2.5%) on a cotton pellet was applied with gentle pressure to control haemorrhage of the pulp.

Figure 3.1.4 Bioceramic material was placed directly over the vital pulp tissue. MTA was used in this case; however, Biodentine or bioceramic putty is preferred due to the tendency for MTA to cause discolouration of dentine.

Figure 3.1.5 Immediate post-operative radiograph showing 3 mm MTA placed over the remaining vital pulp followed by composite.

Figure 3.1.6 Five-month follow-up radiograph showing dentine bridge formation over the vital pulp.

Figure 3.1.7 Two-year follow-up radiograph showing increased thickness in the dentine bridge over the vital pulp, apical closure and increased length and width of the root canal walls.

Figure 3.1.8 Follow-up radiograph after 4.5 years showing continued root development.

Figure 3.1.9 Eight-year follow-up. The patient is completing orthodontic treatment and there is obvious grey discolouration of the upper right central incisor.

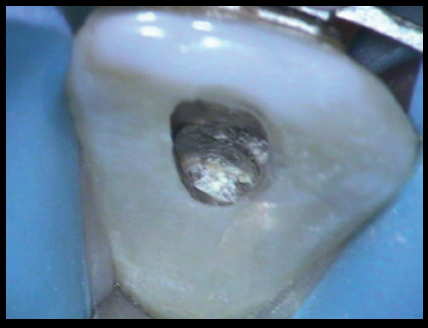

Figure 3.1.10 Removal of the restorative material and MTA revealed a significant dentine layer over the pulp.

Figure 3.1.11 Eight-year follow-up after orthodontic treatment was completed and internal bleaching was performed.

Figure 3.1.12 Eight-year follow-up radiograph shows continued root development and no endodontic pathology. Sensibility tests indicate that the pulp is vital.

Figure 4.1.1 Pre-operative radiograph of UL7.

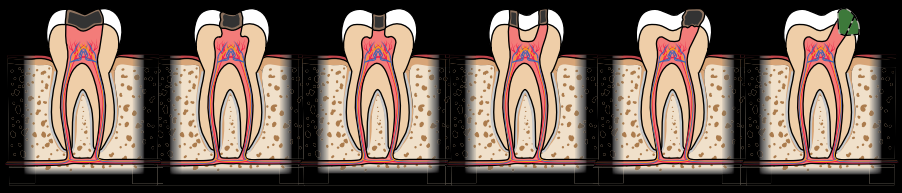

Figure 4.1.2 Access cavity designs (left to right): Traditional, Conservative, Ultra-conservative (Ninja), Truss, Caries, Restorative driven.

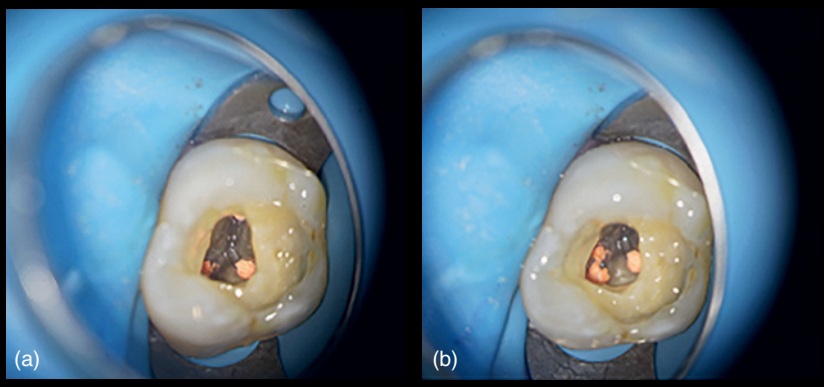

Figure 4.1.3 (a, b) Magnified intra-operative photographs of obturated canals.

Figure 4.1.4 Post-operative radiograph of obturation and restoration of UL7.

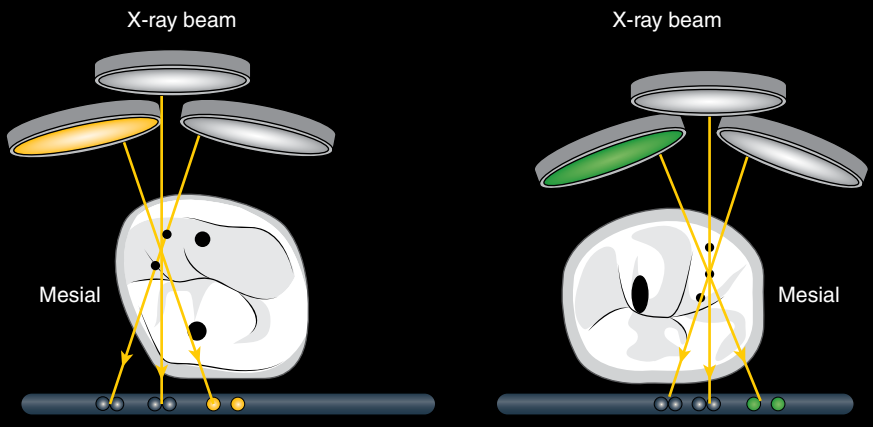

Figure 4.3.2 Parallax technique. Note how horizontal shift of the radiograph can aid in separation of the root canals.

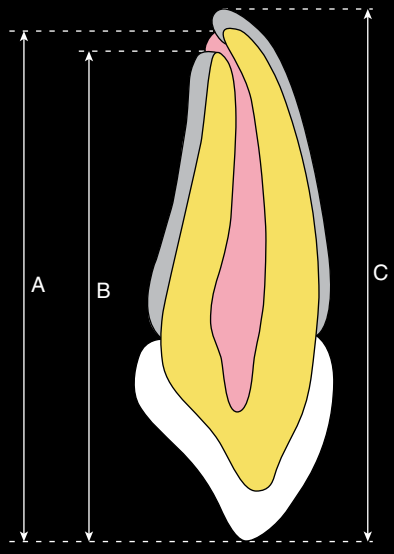

Figure 4.3.3 Working length estimation. A = distance from incisal tip to apical foramen, B = distance from incisal tip to apical constriction, C = distance from incisal tip to radiographic apex. The diagnostic radiograph only reveals the position of the radiographic apex. The radiographic apex does not accurately represent the position of the apical constriction or foramen. Therefore it is desirable to use an electronic apex locator.

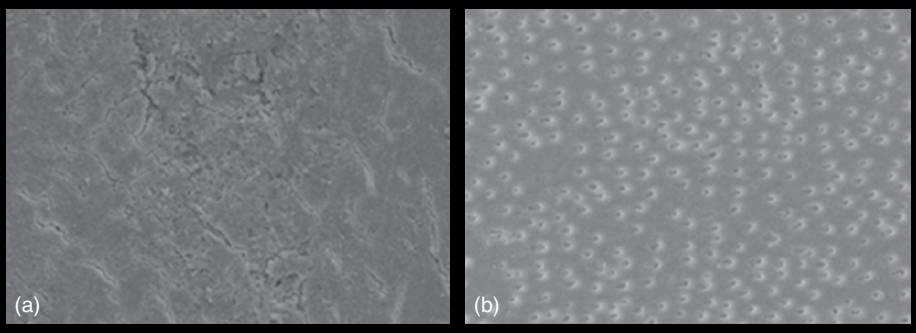

Figure 4.4.3 (a) Scanning electron microscopic (SEM) image of smear layer on a root canal surface. (b) SEM after removal of the smear layer. Note the patent dentinal tubules and clean root canal surface.

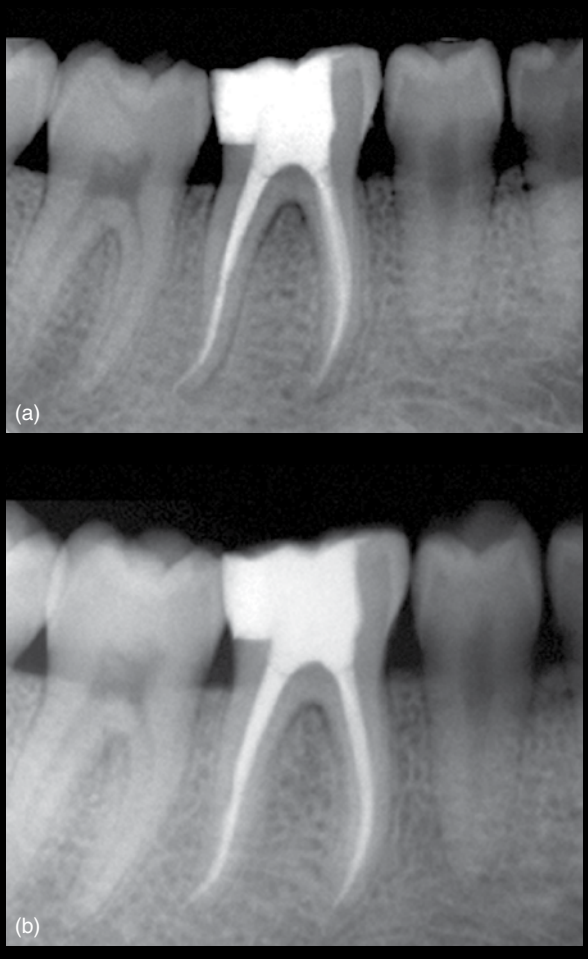

Figure 4.4.4 (a) Post-treatment radiograph. (b) One-year review radiograph. Note the complete resolution of the pre-treatment periapical radiolucency.

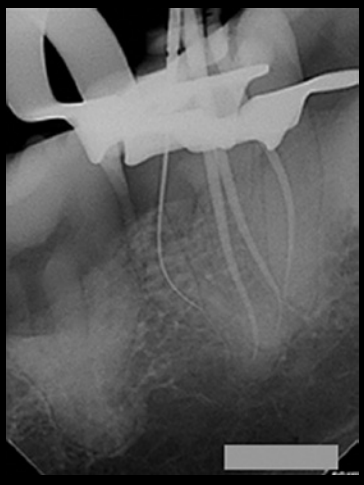

Figure 4.5.3 Working length/cone fit radiograph.

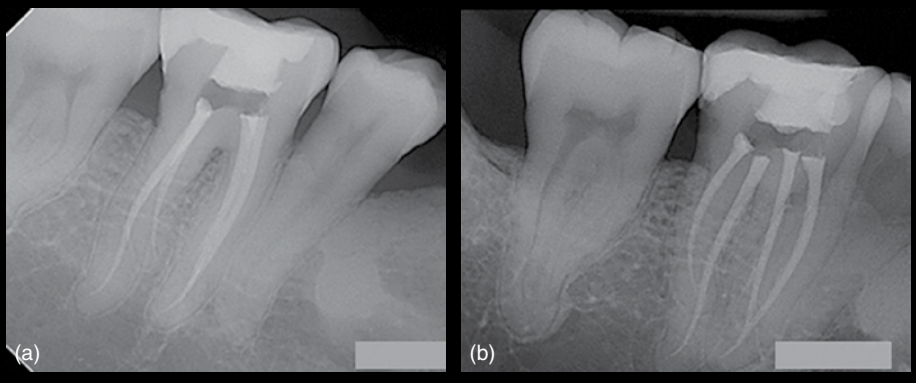

Figure 4.5.4 (a) Post-operative periapical radiographs and (b) parallax view.

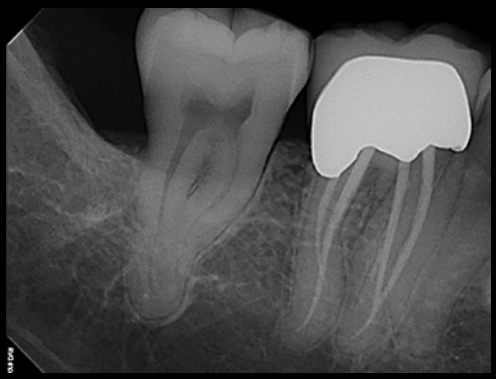

Figure 4.5.5 12 month follow-up radiograph.

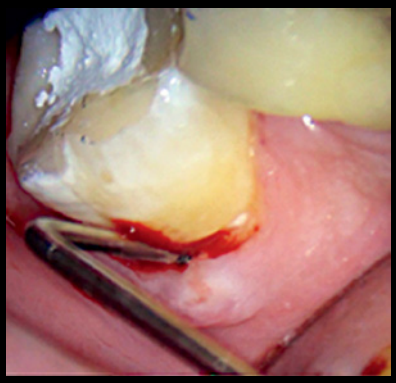

Figure 4.6.1 Buccal swelling, sinus tract and periodontal probing defect.

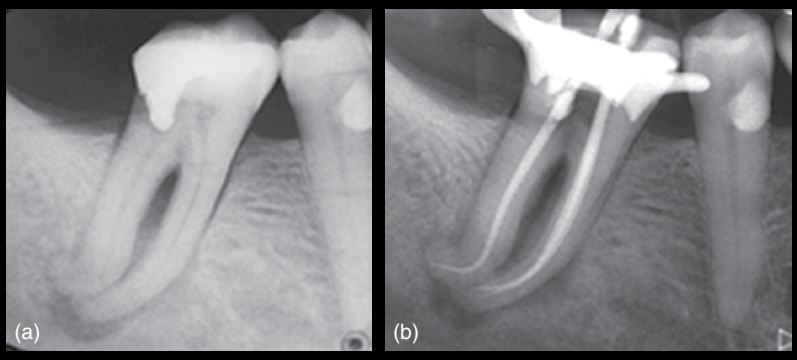

Figure 4.6.2 (a) Pre-operative radiograph. (b) Cone fit radiograph.

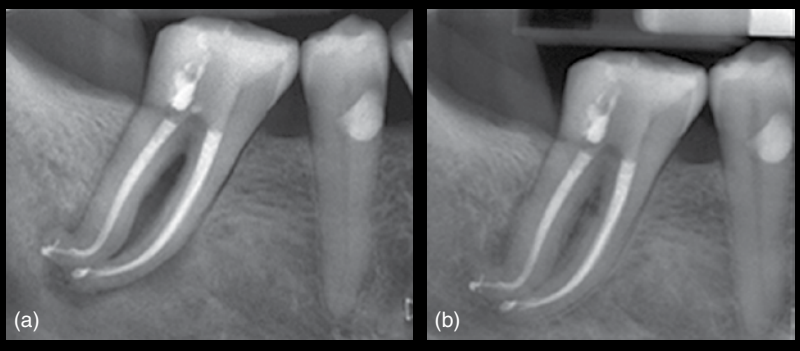

Figure 4.6.3 (a) Final radiograph. (b) 12-month recall.

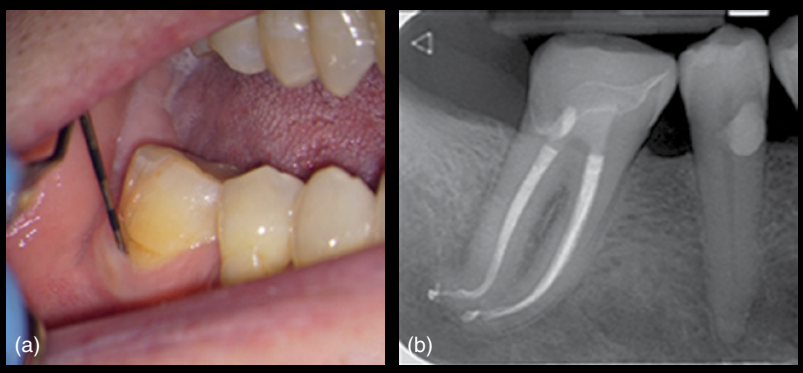

Figure 4.6.4 Four-year review. Note (a) the absence of periodontal probing and (b) resolution of the apical radiolucency.

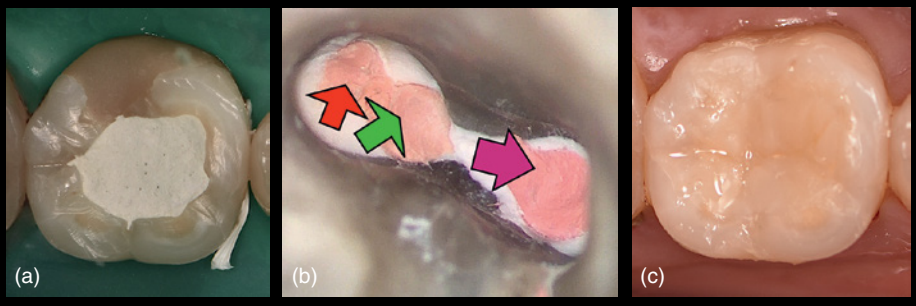

Figure 4.9.7 Restorative treatment. (a) Pre-operative clinical view. (b) Clinical view centred on the distal root. Notice the calcium silicate–based sealer volume (white material) and the gutta percha cones (radix: red arrow, disto-lingual: green arrow and disto-buccal: purple arrow). (c) Post-operative occlusal view after direct composite restoration.

Figure 4.9.8 Eight-month periapical radiographs and cone beam computed tomography (CBCT) review showing the bone healing.

Figure 5.2.1 An intraoral photograph showing the crown on tooth UR2.

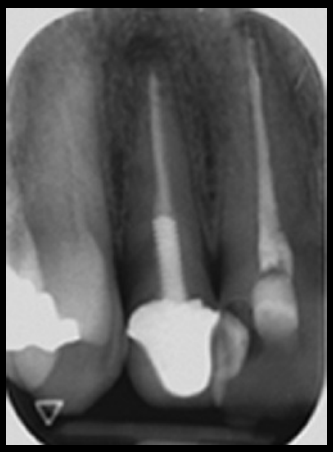

Figure 5.2.2 The paralleling pre-operative radiograph shows a technically good root filling and post crown restoration. The post is metal and has a serrated or crew thread.

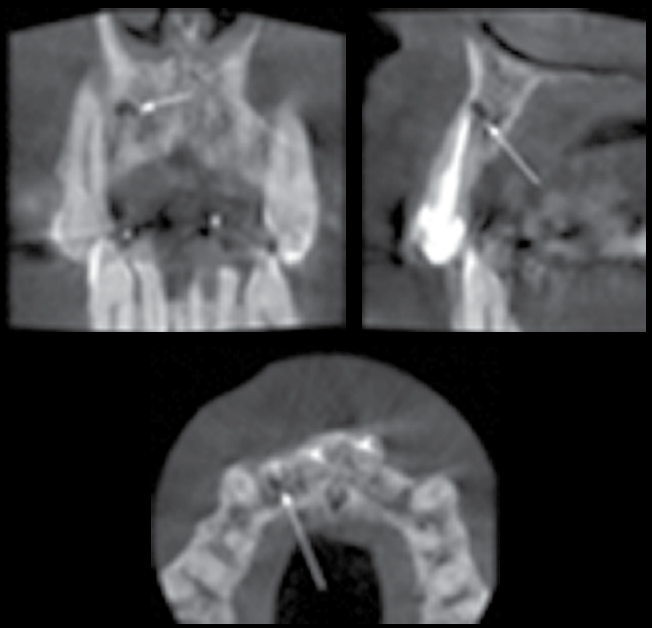

Figure 5.2.3 A small-volume cone beam computed tomography scan confirming a periapical lesion on the UR2. There was no radiolucency around the apex of the UR1.

Figure 5.2.4 Isolated with dental dam. Core material can be removed using ultrasonics.

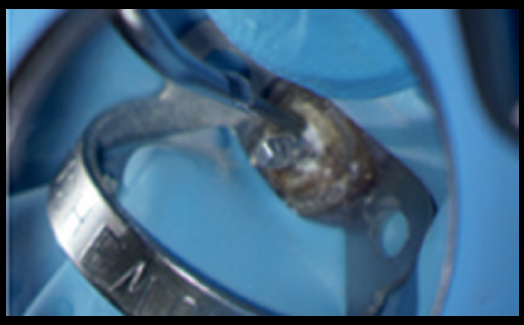

Figure 5.2.5 A Start-X no. 3 ultrasonic tip being used to remove cement.

Figure 5.2.6 The Masserann trephine can be used to remove material conservatively from around the post. It will also help with retrieval.

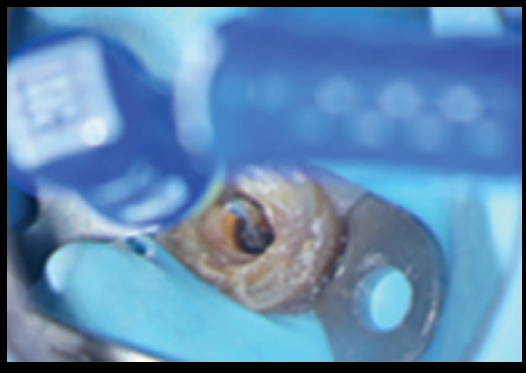

Figure 5.2.7 A FlexoFile was used for working length estimation and removal of gutta percha tags.

Figure 5.2.8 A diagnostic working length radiograph showed that the file was at good length and the gutta percha had been completely removed.

Figure 5.2.9 The dual-cure composite core has been prepared prior to fabrication of a temporary acrylic crown.

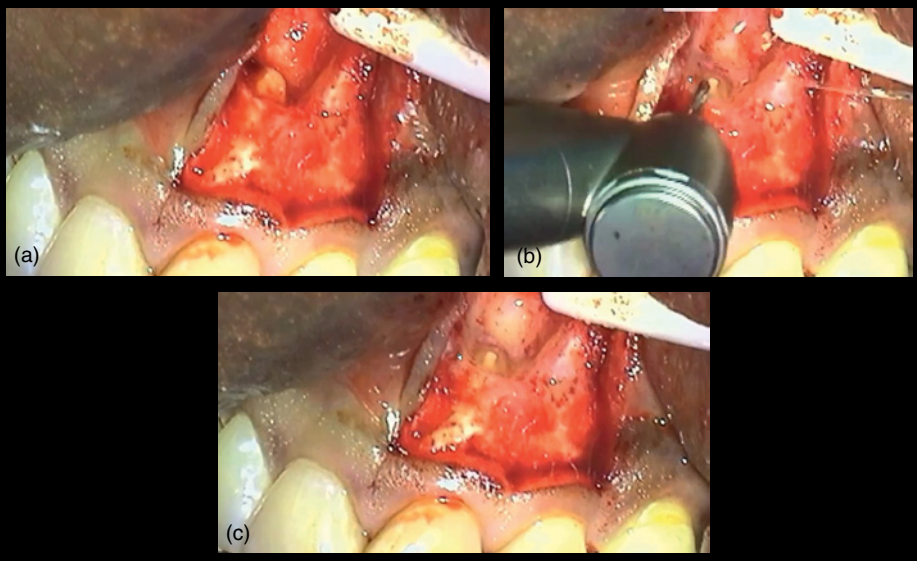

Figure 5.3.3 (a) Root end exposure after apical curettage. (b) Apical resection. (c) Resected root end.

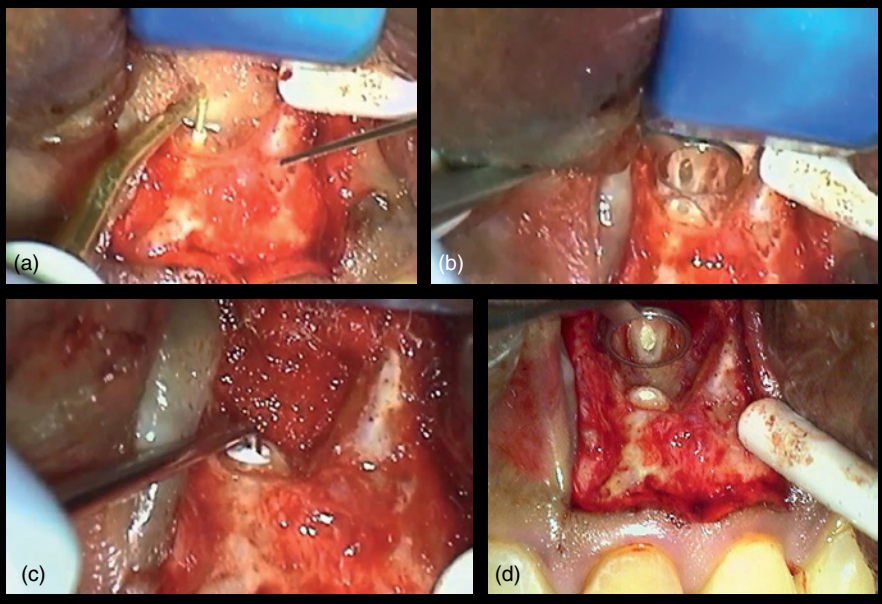

Figure 5.3.4 (a) Root end preparation using microsurgical ultrasonic instrumentation. (b) Inspection of root end preparation with microsurgical mirror. (c) Placement of bioceramic root end filling with microsurgical plugger. (d) Inspection of final root end filling with microsurgical mirror.

Figure 5.3.5 (a) Post-surgery radiograph. (b) Four-week follow-up; note the minimal scarring of the soft tissue.

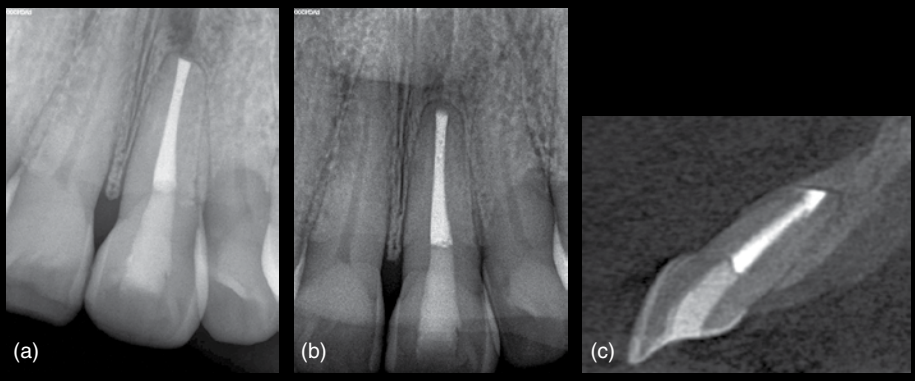

Figure 5.3.6 (a) Nine-month follow-up radiograph, showing significant resolution of the apical lesion. (b) One year follow-up radiograph shows complete resolution of the apical lesion. (c) Two-year follow-up cone beam computed tomography shows complete resolution of the apical lesion and the reestablishment of the buccal cortical plate over the apex of the tooth.

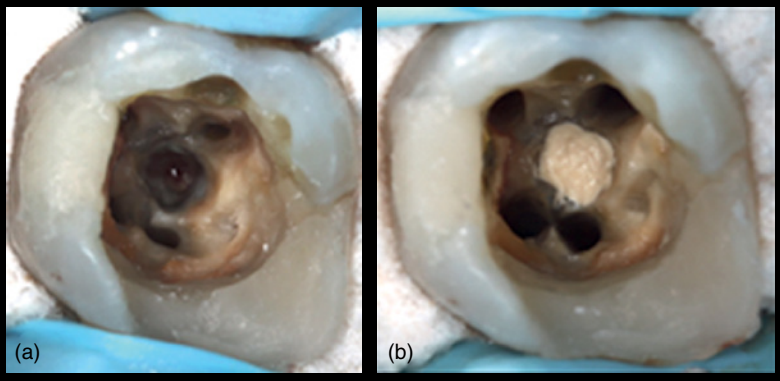

Figure 5.4.4 (a) Furcation perforation site exposed following identification and mild flaring of canals, as well as the pre-endodontic composite build-up. (b) Perforation repair with calcium silicate cement (Biodentine) and glass ionomer cement covering the site is shown. Subsequently the canals were fully prepared.

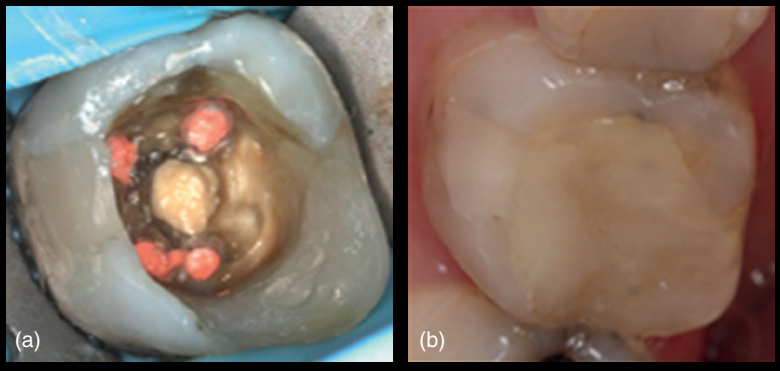

Figure 5.4.5 (a) Obturation of canals. (b) Postoperative composite core.

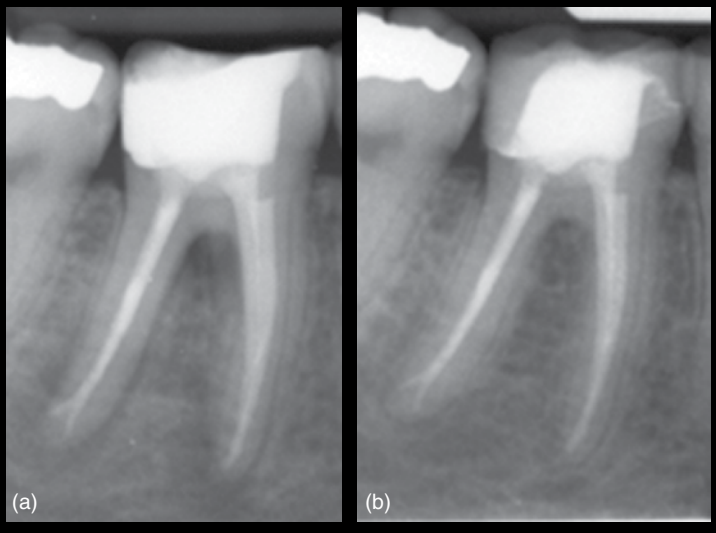

Figure 5.4.6 Periapical radiographs: (a) post treatment; (b) 12 months following treatment.

Figure 6.1.7 Following completion of the core, the preparation for a full-coverage ceramic onlay is completed.

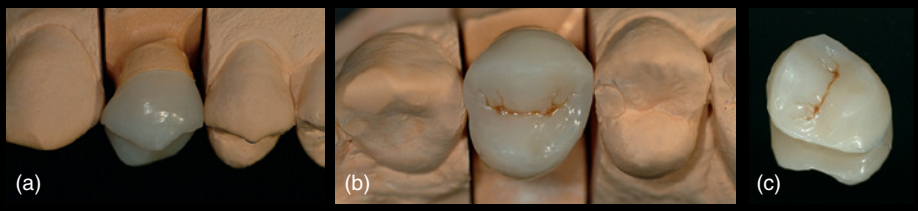

Figure 6.1.8 (a–c) A lithium disilicate ceramic onlay is manufactured; note the supragingival margins that facilitate preservation of residual sound tooth structure, particularly in the pericervical region of the tooth. This will distribute non-axial forces more favourably, reducing the risk of root fracture.

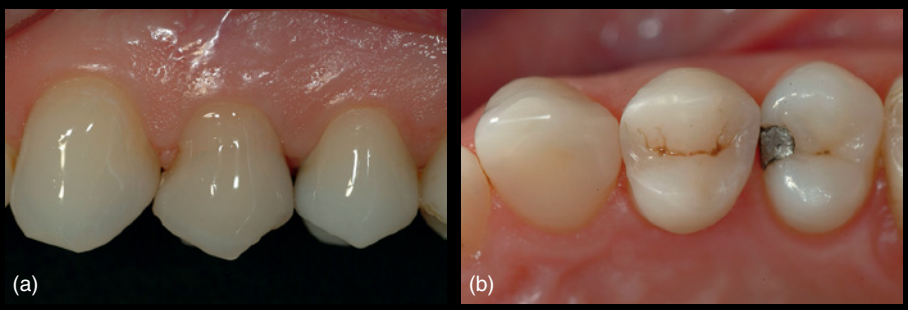

Figure 6.1.9 (a, b) The final restoration has been adhesively cemented under dental dam isolation.

Figure 6.1.10 A follow-up radiograph taken one year after the treatment demonstrates healthy periapical tissues. The marginal fit of the restoration appears satisfactory.

Figure 7.1.1 Clinical photograph showing fractured incisal edge.

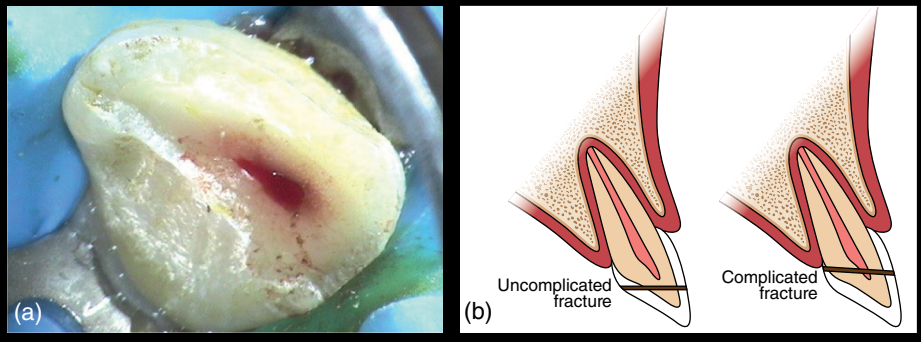

Figure 7.1.2 (a) Clinical photograph showing exposed pulp. (b) Diagram of uncomplicated and complicated crown fractures.

Figure 7.1.3 Pre-operative radiograph showing an immature root with an open apex.

Figure 7.1.4 Pulpotomy was performed and inflamed pulp tissue was removed until healthy non-bleeding tissue was observed.

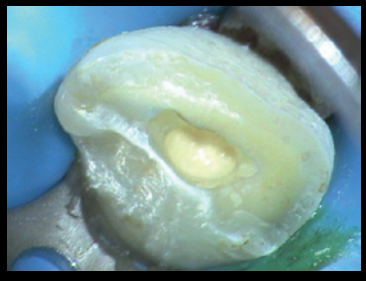

Figure 7.1.5 Biodentine was placed directly over the pulp.