Bobby Patel
Editor

Endodontic Treatment, Retreatment, and Surgery

Mastering Clinical Practice

Springer

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This book is dedicated to my endodontic mentor:

Ms Serpil Djemal

Preface

The discipline of endodontics and its principles have undergone a vast array of changes over the last 100 years shaped by evolving advances in both our understanding of the biological aetiology of periapical disease and rationale for treatment as well as improved technology, instruments, materials and techniques to achieve this purpose.

From a clinical standpoint we are often faced with a decision to decide whether to adopt these newer and "proven" techniques requiring some period of disruption to our daily routines or remain sceptic with the knowledge that our traditional views will continue to impart the best level of care to our patients.

To master any given subject one must be able to reflect on current views and opinions that are based on the best evidence provided. In order to determine whether these views are accurate, reliable and relevant, one must therefore be able to critically evaluate and understand at a deeper level trying to get to the heart of the matter.

It is with this concept of critical thinking in mind that I offer this compact yet comprehensive text with emphasis placed on both traditional and newer materials and techniques that can offer the potential for endodontic success.

Similar to my first book *Endodontic Diagnosis, Pathology and Treatment Planning*, each chapter describes many of the techniques and methods available for practitioners who wish to undertake the planning and treatment of complex endodontic cases. Numerous illustrations with high-quality photographs and radiographs highlight clinical cases, which serve to demonstrate practical non-surgical and surgical techniques. The text is referenced to provide a comprehensive source of scientific evidence and principles that underline these techniques.

It is hoped that readers will be provided with a concise literature-based approach to clinical problem-solving rather than a quick fix "recipe book" for everyday problems. Certainly it is not a replacement for existing contemporary textbooks but further serves as an accompaniment with emphasis placed on clinical hints and tips that may not be covered in standard endodontic textbooks.

The reader is reminded that this text is also aimed at allowing deep learning for students, dental practitioners and specialists alike. The understanding of key concepts will allow the reader to appertain to and consolidate knowledge from other parts of their study, from which they can hopefully derive solutions to novel problems. Deep learning involves the critical analysis of new ideas, linking them to already known concepts and principles, and leads to understanding and long-term retention of concepts so that they can be used for problem-solving in unfamiliar contexts.

I hope this text stretches you towards excellence recognizing the importance of attention to multiple dimensions and enabling you to progress towards establishing clinical and academic understanding of the subject *par excellence*!

Canberra, ACT, Australia Bobby Patel

Acknowledgements

Firstly I would like to thank my associate editor Antonia von Saint Paul and project co-ordinator Wilma McHugh at Springer DE for bringing this project to fruition and above all their patience whilst I completed this second endeavour. I would also like to express my deepest appreciation to the Production Editor, Abha Krishnan and Project Manager, Suganya Selvaraj, who were responsible for perfecting the language, design and layout of the book and final copy-editing of the completed text. I also acknowledge Gursharan Minhas, Robert Fell, John Cho, Roberto Sacco, Sarita Atreya, Anthony Greenstein and Mark Stenhouse for allocating time out of their busy schedules in order to contribute to their respective chapters and numerous proofreads along the way.

I would like to express my gratitude to the staff (Kathleen, Julie, Jess R, Jess Ellis and Deb) for their endless help throughout including photography skills using various Android and Apple phones and patients at *Canberra Endodontics* who agreed to be photographed for illustrative material; I would also like to thank both Dr Luke Maloney and Ms Serpil Djemal for providing me with their trauma presentations and access to images. Special mention also goes to Dr Kim Mai Dang, Dr Daniel Felman and Dr Aovana Timmerman for providing many of the excellent trauma images throughout the "Traumatic Injuries" *chapter*; I must also mention special thanks to Kim for providing me with full access to all journals and articles throughout the preparation of this manuscript and providing numerous passwords at short notice! I must also give recognition to Phil Gaff who provided me with many images courtesy of Dentsply. I would like to thank Steven W Dahlstrom my first mentor in specialist clinical practice who gave me full clinical freedom as well as support in those early years.

I thank my parents for their faith in me and allowing me to fulfil my dreams. It was only through their hard work, sacrifice and determination that I was able to achieve what I have from the very beginning. I must also thank Sarita's parents who have provided us with unending encouragement, support and love. To my wife Sarita whose unwavering love has been the bedrock upon which the last 23 years of our lives have been built. She has been my true inspiration and motivation and brings out the very best in me even in the worst of times. Without her none of this would have ever been conceivable. Finally to my three all-inspiring children Raya, Sofia and Iyla, for always making me laugh, the realization of the true purpose of life and the reason to escape from my daily workload. I hope that these books are a testimony to you that one day you too can follow your dreams with some hard work and conviction to make them a reality.

The great pleasure in life is doing what people say you cannot do. *Walter Bagehot*

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About the Editor

Bobby Patel, BDS, MFDS RCS (ED) MClinDent (ENDO) (Dist) MRD RCS (ENG) MRACDS (ENDO), graduated from Bart's and the London Medical and Dental School in 1999. He subsequently gained experience as a dentist in general practice and the community dental services. He gained further experience within the hospital settings working as a restorative senior house officer at Bart's and the London Medical and Dental School. He then completed a 12-month surgical posting at Basildon hospital working as a clinical fellow in oral maxillofacial surgery. He was accepted onto the UK mono-speciality endodontic training pathway at the Eastman Dental Institute where he completed his MClinDent in 2006. He was awarded a distinction for his academic achievement during this time. In 2006, the British Endodontic Society awarded him a poster prize for his innovative research entitled "Development of an in vitro model for the study of microbial infection in human teeth". In 2007, he was awarded membership in restorative dentistry, the highest formal qualification in the UK and registered on the specialist list for endodontics thereafter. He then moved to Australia to work in specialist referral practice from 2007 to present. In 2012, he was awarded membership of the Royal Australian college of Dental Surgeons (Endodontics). He is very active in continuing education programs, with a particular interest in hands-on courses dealing with diagnosis, treatment planning, root canal therapy, and surgical endodontics. He is a Dentsply Maillefer key opinion leader and certified trainer, regularly giving lectures to general dentists regarding the latest endodontic Ni-Ti rotary file techniques. His particular interests are with surgical endodontics, intentional re-implantation procedures, and endodontic re-treatment.

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1 Access Preparation

Bobby Patel

Summary

The main objective of access preparation is to identify all canal anatomy prior to preparation and obturation of the root canal system. Correct access preparation is a key to successful treatment outcome and avoidance of mishaps. Inappropriate access preparation can lead to inadequate cleaning and shaping and subsequent obturation mishaps. Iatrogenic errors such as instrument separation, canal transportations, zipping and possible perforation may also result as a consequence of inadequate access design.

Clinical Relevance

An appropriately designed pulp chamber opening represents the most important step in order to locate and negotiate root canals optimally. A correct opening should provide complete removal of the pulp chamber roof and all internal interferences such as calcifications and restorations. Straight-line access is key to avoiding instrumentation mishaps particularly in curved root canals where the propensity for canal transportation or instrumentation failure is high. An important prerequisite for achieving success is the fundamental understanding of root canal anatomy gained through knowledge of normal anatomy and the deviation from the norm that exists within specific teeth types. Visualisation of the three-dimensional anatomy using more than one film when using plain radiography or cone beam CT scanning will provide valuable information before access preparation is initiated.

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1.1 Overview of Endodontic Access Design Preparation

Cavity design preparation can trace its roots back to the principles heralded by GV Black including outline form, convenience, retention and resistance forms [1]. Traditional endodontic ideal access preparations, often described in textbooks, have been focused primarily on the operator needs rather than the restorative needs showing easily identifiable canal entrances at the base of a large pulp floor. Recently proponents for minimally invasive endodontics (MIE) aimed at directed

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dentine conservation have tried to shift the focus towards the tooth, whereby maximal tooth conservation has been heralded as the primary aim in an effort to maintain optimal strength and fracture resistance of the tooth [2–4]. Care must be taken when adopting the concepts of MIE in that there are proponents that would have you believe that MIE exists solely with the framework of preserving a few millimetres or less of cervical tooth structure whilst their empirical claims lack documented and meaningful longer term studies [5].

The endodontic access preparation influences all ensuing steps and provides the opening for ideal shaping of canals, cleaning root canal systems, and three-dimensional obturation [6].

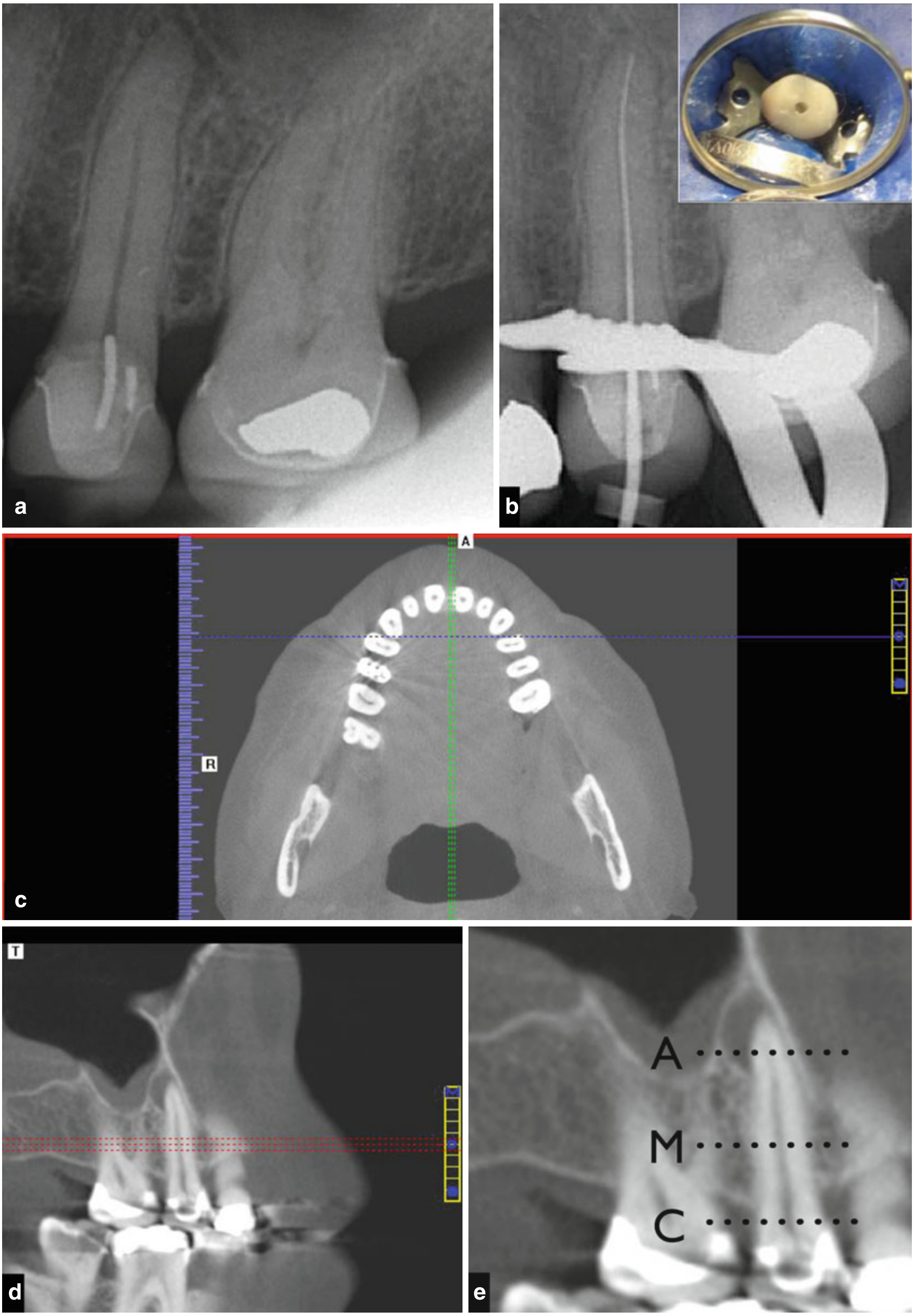
Good knowledge of canal morphology in mandibular and maxillary teeth will guide clinicians in creating correct pulp chamber openings necessary for location of all canals [7, 8]. Radiographic assessment should always be integrated with this knowledge to recreate a mental image of the proposed access cavity before any drilling is begun. A minimum of two diagnostic periapical radiographs should be taken, giving a two-dimensional image of a three-dimensional root canal system. The radiographs should be taken parallel and with either a mesial or distal horizontal tube shift to visualise superimposed roots. A parallel radiograph will allow minimal distortion and enable the clinician to correctly identify the coronal pulp chamber location with respect to the furcal floor and the cement-enamel junction. Both of these landmarks are helpful when trying to locate the level of the pulpal floor and location of canal entrances. The author routinely uses a beam-aiming device to ensure that minimal image distortion occurs and reproducible radiographs can be taken throughout the procedure. Cone beam CT (CBCT) scans may be available that can demonstrate anatomical features three-dimensionally. CBCT projection data can be reconstructed to provide images in three orthogonal planes (axial, sagittal and coronal) demonstrating true spatial relationships. Tooth morphology assessment can easily be visualised in 3D including the number of root canals and their interrelationship (see Figs. 1.1 and 1.2). In young patients, large pulp chambers will be noted with obvious canal spaces. Older patients whose teeth have undergone repeated insults will often have secondary or tertiary dentine deposited reducing pulp chamber volume and root canal lumens and increased calcifications encountered making access preparation even more challenging. Any sudden changes in the radiographic density of the pulp space will usually indicate an additional canal. Furthermore a sudden narrowing or disappearance of the root canal space may indicate a bi- or trifurcation [9–11].

The anatomical laws formulated by Krasner and Rankow should be taken into consideration when opening pulp chambers because they give clinicians general anatomical landmarks that are very useful when localising all canal anatomy [12].

Several studies have concluded that the dental operating microscope provides and enhances lighting and magnification, which are essential for the clinicians' ability to correctly localise and negotiate canals [13–15].

The use of an ultrasonic unit (magnetostrictive or piezoelectric) with an appropriate tip confers unique advantages for refinement of access cavities, location of canal orifices and removal of obstructions such as calcifications. Magnetostriction ultrasonic unit devices operate between 18 and 4 kHz, converting electromagnetic energy into mechanical oscillation when an alternating magnetic field is applied to metal strips in a stack. Piezoelectric units operate between 28 and 36 kHz, converting electrical energy into mechanical energy through a crystalline piezoelectric

Fig. 1.1 Note (**a**) and (**b**) clinical periapical radiographs demonstrating nonsurgical root canal treatment of tooth 25. Note they reveal limited two-dimensional view of the true three-dimensional image. Insert shows (**c**) access preparation, (**d**) limited volume cone-beam computed tomography reconstruction of the projection data providing axial and sagittal views of tooth 25 demonstrating extent of periradicular pathology and internal root canal anatomy, and (**e**) sagittal view and various slices (apical (*A*), middle (*M*), and coronal (*C*) dotted lines) highlight anatomy of the root canal space further seen in Fig. 1.2 axial views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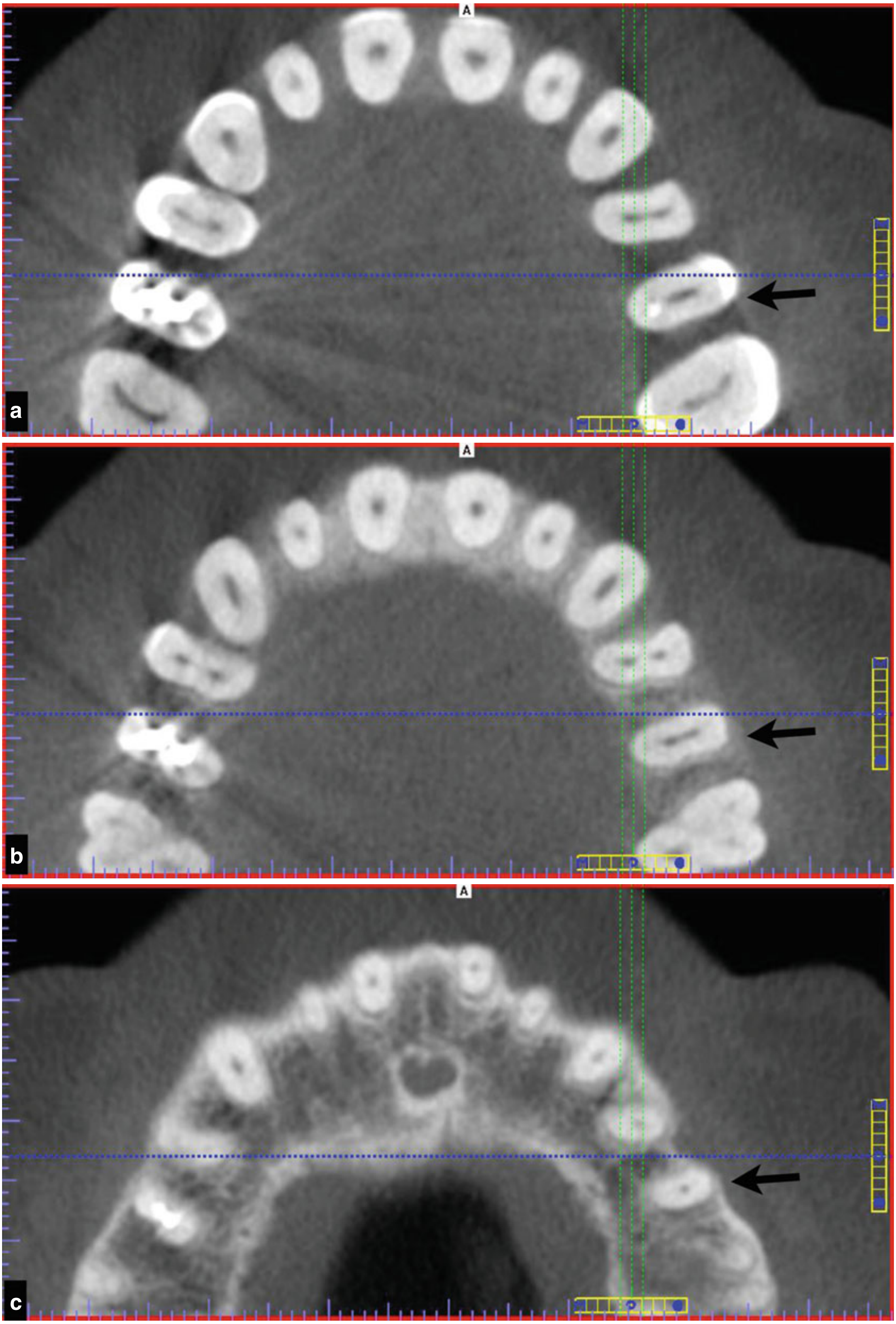
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material. This mechanical energy is transferred to the cutting tips resulting in micro-vibratory movements in the ultrasonic frequency range. The tips should be used with a light brush and touch action, selecting a medium power setting under direct control using the operating microscope [16–18].

Ultrasonic tips are available in different lengths, diameters, angles and designs used with or without water. Length of tip is critical when determining whether the tip is to be used solely in the coronal aspect of the pulp chamber or within the root canal itself. Longer thinner tips are ideal in the case of the latter. Tip design is further classified according to whether it is constructed from stainless steel or titanium alloy. Stainless steel tips may be coated with zirconium nitride (ProUltra ultrasonic instruments; Dentsply, Tulsa, Oklahoma) or diamond grit (Spartan CPR instruments, Fenton, Missouri), which increases efficiency and durability. Most current available systems are designed to function either wet or dry. The former come with water ports to increase washing and cooling effects [19, 20].

Patients with cardiovascular implantable electronic devices, such as pacemakers, and the use of ultrasonics has been a concern. Dental equipment, which can pass a current to a patient, can potentially interfere with the pacemaker. Current guidelines recommend the avoidance of magnetostrictive devices, whereas the use of piezoelectric devices does not seem to have an affect on pacemakers [21, 22]. In the best interests of the patient, it would be prudent to discuss the case with the patients' cardiologist to ensure that there are no undue concerns with this regard.

1.2 Opening the Pulp Chamber

A front surface mirror, a Hu-Friedy DG16 endodontic probe, illumination and magnification are essential for preparation of the tooth for endodontic treatment. Caries and failing restorations must be completely removed prior to endodontic access cavity preparation. Where there is any doubt in relation to the restorability of the tooth in question, then dismantling of the existing restoration and preliminary assessment of the remaining tooth structure is an essential first step.

Removal of existing restorations also allows the examination of axial walls and the presence of any hairline cracks which could also influence the endodontic outcome. A restorability assessment is made in order to ensure that the planned future permanent coronal cast restoration is feasible.

Unsupported cusps are removed, and where any axial wall crack-lines are evident or a diagnosis of cracked tooth syndrome is suspected, then the tooth should be protected by placement of an orthodontic band during and following completion of treatment.

The roof of the pulp chamber should be penetrated through the central portion of the crown at a point where the roof and floor are at the widest (e.g. the palatal canal of a maxillary molar). An EndoZ bur, which has a non-end cutting tip, is ideal once the roof is penetrated, preventing potential damage to the floor of the pulp. All dentine ledges and lips should be removed.

Once the roof, in its entirety, has been removed, then the floor of the pulp chamber can be inspected. In cases, which are not calcified, dark developmental lines may be identifiable linking canal entrances. Following this 'road map' may reveal additional undetected canal entrances, and further probing with the DG16 may confirm a 'sticky' feeling.

Typical textbook description of pulp chamber anatomy is based on teeth with complete crowns and pulp chambers that are ideal in terms of position and width. Most clinical situations are far from ideal where teeth have been previously treated resulting in large restorations, cast restorations or dystrophic calcifications, which significantly alter the normal anatomy. Ideal access

Fig. 1.2 Cone-beam CT axial projection demonstrating (**a**) coronal, (**b**) middle, and (**c**) apical root anatomy. Access preparation could be carried out with confidence confirming a Vertucci 1-2-1 root canal anatomy. Note *black arrow* showing tooth 25 preparation may lead to iatrogenic errors due to inadequate or over-aggressive preparations. Access cavities should be prepared according to the internal anatomy of the tooth and refined according to the individual tooth and its unique anatomy accordingly (Fig. 1.3).

Krasner and Rankow evaluated the pulp chamber anatomy of 500 extracted teeth, and based on their findings, the following laws pertaining to general anatomical guidelines were made:

1. The floor of the pulp chamber is always a darker colour compared to the surrounding dentinal walls. This colour difference creates a distinct junction where the axial walls and floor of the pulp chamber meet (law of colour change).
2. The orifices of the root canals are always located at the junction of the axial walls and floor (law of orifice location 1).
3. The orifices of the root canals are located at the angle in the floor-wall junction (law of orifice location 2).
4. The orifices of the root canals lie at the terminus of developmental fusion lines, if present (law of orifice location 2).
5. The developmental root fusion lines are darker than the colour of the floor.
6. Except for maxillary molars, the orifices of canals are equidistant from a line drawn in a mesial-distal direction through the pulp chamber floor (law of symmetry 1).
7. Except for the maxillary molars, the orifices of canals lie on a line perpendicular to a line drawn in a mesial-distal direction across the centre of the floor of the pulp chamber (law of symmetry 2).

These generalised laws should be taken into consideration when preparing access cavities since they give clues to generalised landmarks independent of the crown anatomy (Fig. 1.4).

1.3 Access Through a Crown

It is not uncommon to carry out endodontic treatments in teeth already restored with crowns. Access preparations through existing crowns whose margins are deemed good require careful consideration and diligence. It is necessary to mentally visualise the pulp chamber position from preoperative parallel radiographs. The distance of the pulp chamber floor from the most coronal aspect of the crown can be premeasured and noted. The angulation and any rotation of the tooth should be assessed and initial access preparation without the use of rubber dam may be advisable to ensure that penetration is carried out correctly without risk due to mis-angulation resulting in perforation. The position of the cement-enamel junction and furcation should also be noted as these landmarks help the clinician locate the level of the pulpal floor and likely position of canal entrances.

Tungsten carbide burs are ideal for cutting through metal such as full gold crowns. When mapping out the access through initial porcelain, a diamond bur should be used to reduce the likelihood of porcelain fracture. If the canals cannot be identified, then removal of the crown may be indicated to prevent iatrogenic perforation and unnecessary removal of sound dentine (see Figs. 1.5, 1.6 and 1.7).

1.4 Straight-Line Access

Once the canal entrances have been identified, it may be necessary to refine the outline shape of the access cavity to allow endodontic instruments unimpeded straight-line access in the coronal 1/3rd of the canal. Straight-line access will prevent or reduce the likelihood of unfavourable iatrogenic mishaps such as canal transportation including ledging, zipping and perforation. Straight-line access will also reduce file distortion, particularly important when using rotary nickel-titanium instruments, which may undergo unnecessary torsional loading and cyclic fatigue leading to instrument fracture (see Chap. 11). Access openings must be designed to preserve sound tooth structure and is fundamentally important to prevent unintentional gouging laterally, cervically or into/beyond the floor of the pulp chamber (see Fig. 1.11). Conversely, access that is too restricted may impact on correct identification of all internal

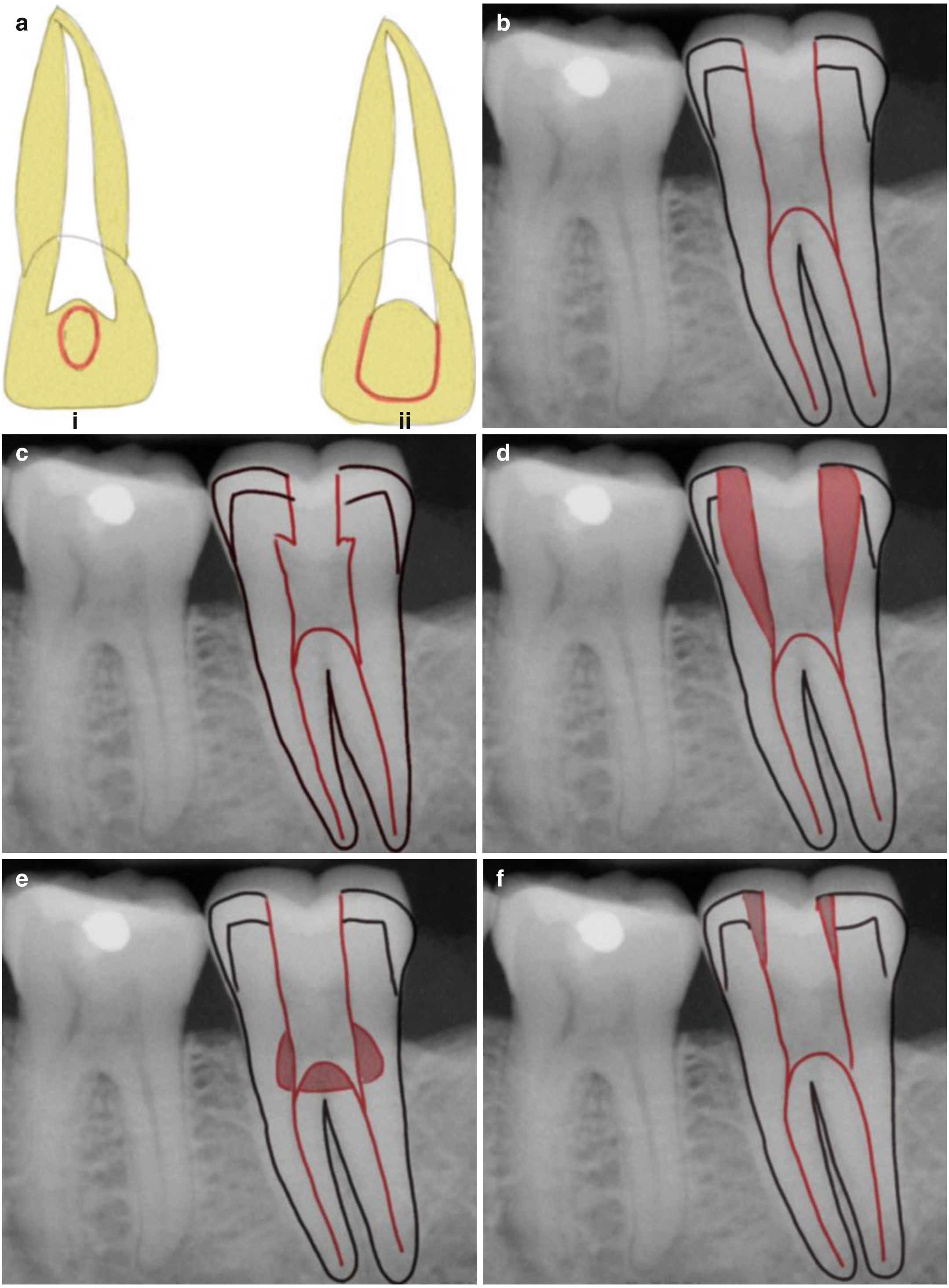


Fig. 1.3 Diagrams representing (**a**) incorrect (*i*) and correct (*ii*) removal of the pulp chamber in an incisor tooth. (**b**) Correct and (**c**) incorrect straight-line access in a posterior molar tooth. (**d**) Excessive removal of tooth structure leading to weakening and potential fracture of the tooth. (**e**) Damage to the floor of the pulp chamber will not only risk possible perforation but also hinder location of canal entrances. (**f**) The walls of the coronal access should not deflect an instrument placed in the canal

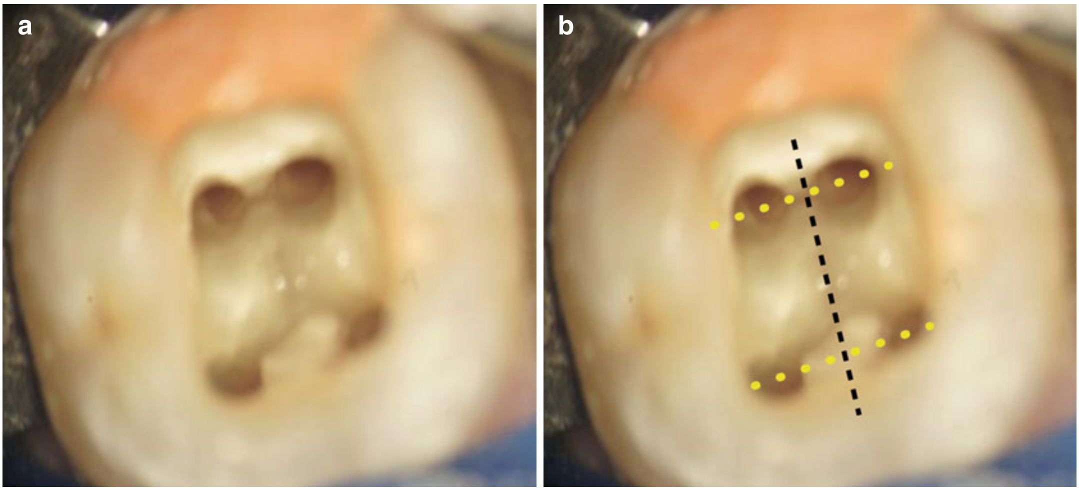


Fig. 1.4 Clinical photographs showing (**a**) internal anatomy of a tooth. Note dark developmental grooves on the floor of the pulp and darker color associated with root canal orifices. (**b**) As described by Krasnoe and Rankow Law of symmetry 1 and 2

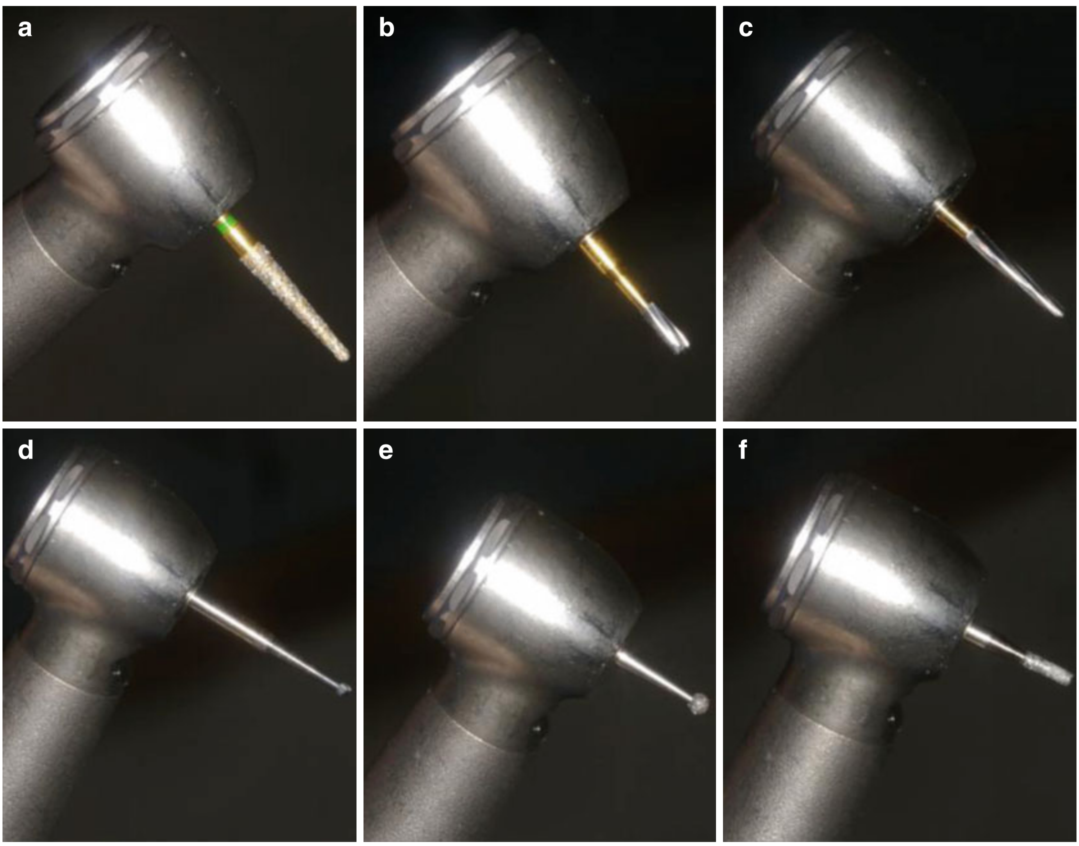


Fig. 1.5 Clinical photographs showing typical armamentarium of burs used for access preparations: (**a**) diamond grit tapered bur, (**b**) tungsten carbide bur, (**c**) non-end cutting Endo-Z bur, (**d**) long shank diamond, (**e**) diamond grit round diamond, and (**f**) parallel tapered short diamond bur

Fig. 1.6 Clinical photographs showing access preparation through a porcelain-metal crown. (**a**) Tungsten carbide bur is selected and (**b**) carefully aligned to long access of the tooth to (**c**, **d**) gain initial access through the metal infrastructure. Preoperative radiographs and clinical assessment of the tooth-root relationship is important to prevent misalignment. Occasionally, access can be carried out prior to placement of rubber dam if the long axis tooth is difficult to ascertain or the crown-root relationship is of concern

anatomy leading to iatrogenic errors during subsequent preparation as discussed earlier (Fig. 1.8).

Whilst unmistakable orifice location and careful canal penetration are warranted, efforts should be made to minimise excessive removal of cervical tooth structure in the canal orifice. Commonly used instruments such as Gates Glidden drills should be avoided since these instruments tend to

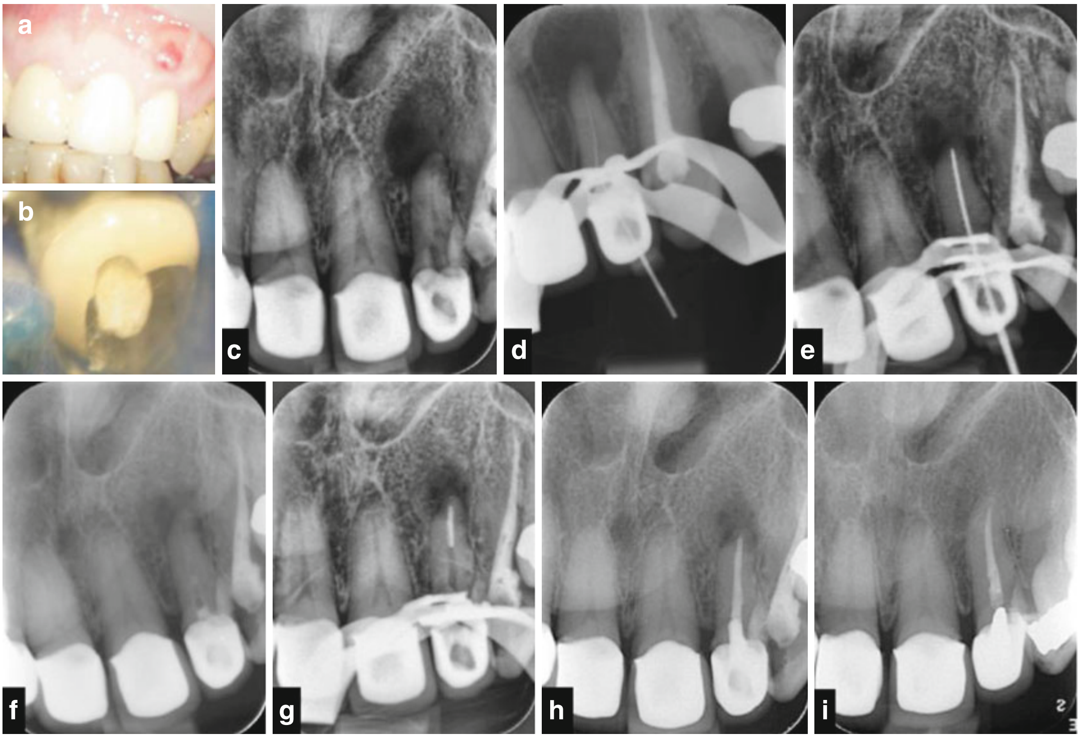


Fig. 1.7 Clinical photographs and radiographs demonstrating nonsurgical endodontic treatment through a ceramic-metal crown. Note (**a**) draining sinus in relation to tooth 22 and (**b**) prior endodontic access carried out by the general dental practitioner. (**c**) Preoperative radiograph confirming endodontic access. The dentist was unable to locate the canal orifice. Note access preparation extends below the cervical margin of the tooth and an obvious root canal can be seen. An extensive periradicular radiolucency is evident. (**d**) IAF demonstrating successful canal negotiation after careful access refinement. Initial access was misaligned due to orientation difficulties arising from the cast restoration in place. Access had been directed towards the facial aspect but no perforation was noted. Access refinement was carried out using ultrasonic troughing under constant guidance using magnification. (**e**) MAF radiograph following working length determination. (**f**) 3-month follow-up radiograph showing intra-canal medicament dissolution and significant reduction in the pre-operative radiolucency. (**g**, **h**) Obturation was completed using a warm vertical compaction technique using AH plus cement. (**i**) The patient was reviewed a further 9 months later. The radiograph demonstrates an intact periodontal ligament space associated with the peri-apex of tooth 22 correlated with complete healing

straighten the canal and weaken the root canal walls, and overzealous use in some cases may lead to irreparable defects such as stripping or perforation.

Straight-line access is achieved by firstly correct access preparation with correct axial wall refinement. Once the floor of the pulp chamber has been identified, the use of a non-end cutting bur (Endo Z) is excellent for gross refinement and removal of dentinal overhangs that prevent unimpeded orifice location. Finer refinement can be carried out using ultrasonic tips under magnification allowing precision removal with minimal damage when carried out correctly. Creating straight-line access within the coronal 1/3rd of the canal can be achieved by introduction of initial rotary instruments that can be safely used in a brushing action, away from the danger areas, removing cervical dentine efficiently. Initial preflaring with the S1 ProTaper file can effectively remove this triangle if dentine is commonly encountered coronally. The angle of the inserted instrument within the canal is a good indicator as to whether straight-line access has been achieved

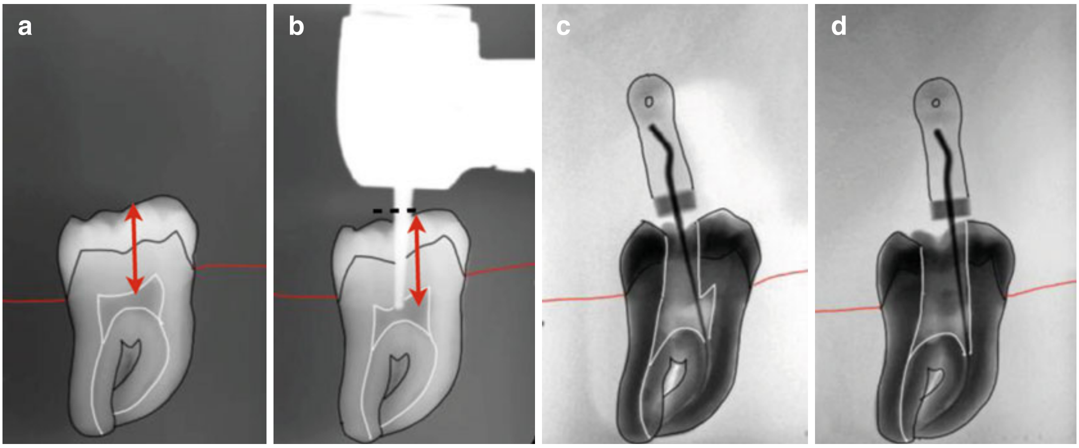


Fig. 1.8 Diagrammatic representation of straight-line access preparation in a mandibular molar tooth. A parallel preoperative radiograph is obtained, and (**a**) an initial measurement is calculated as to the depth of the pulp chamber in relation to the occlusal surface (*red arrow*). (**b**) This length is used as a guide for initial penetration into the pulp chamber. (**c**) Initial access preparation is incomplete with inadequate extension distally. Note file deflection as a result causing increased stress and potential for iatrogenic errors. (**d**) Correct access extension using appropriate non-end cutting to refine distally. Note file is now no longer deflected and therefore less likely to result in iatrogenic errors such as apical canal transportation or file separation

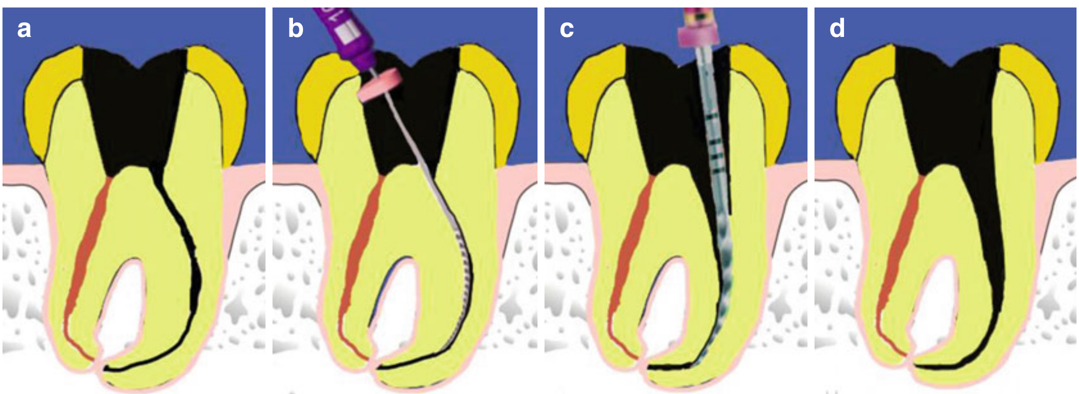


Fig. 1.9 (**a–d**) Clinical diagrams representing use of ProTaper shaping file S1 in a brushing action to aid removal of coronal interferences that prevent straight-line access. A lateral cutting action on withdrawal is recommended away from the danger area such as the furcation

(i.e. the instrument should stand upright). Radiographic imaging of initial apical file placement will also indicate whether any further coronal dentine removal is indicated. Once straight-line access is achieved, the clinician can be assured that iatrogenic errors such as transportations, which are common in any curved canal space, can be minimised with subsequent apical preparation and introduction of files of greater taper (Fig. 1.9).

1.5 Use of Ultrasonics

Ultrasonic tips are an excellent tool for refining access cavities, removing calcifications and finding canal orifices often hidden by deposition of secondary or tertiary dentine. The tips should be used with a light brush stroke and medium power setting and under constant vision using a dental operating microscope. Tips can be selected according to intended use, which can be broadly classified as bulk removal, access refinement or troughing (see Fig. 1.14).

Bulk removal

Bulk removal of dentine and core material such as amalgam or composite that can often obstruct the initial access preparation can be carried out using specifically designed tips. Axial wall refinement can be carried out using Start-X tip 1, CPR2D or BUC 1 tips. The Start-X tip number 1 has a non-end cutting tip diameter of 0.8 mm, a maximum diameter of the active portion of 1.6 mm and a blade length of 12 mm. The main indication for using this tip is for refinement of the axial walls. The tip can be used to remove restorations, filling material, caries and dentine interferences that may be present on the axial walls without altering the morphology of the pulpal floor due to its non-end cutting tip (Fig. 1.10).

Access refinement

Use of ultrasonic tips to enhance access can be carried out with precision with no hand-piece head to obscure indirect vision, allowing progressive cutting of dentine with minimal risk of danger. Dentine can be brushed away in smaller increments with greater control compared to traditional use of burs. Traditional techniques employed to unroof a pulp chamber advocated using large stainless steel round burs which would simply drop into the pulp chamber remove the roof by a back and forth action without damaging the floor. Unfortunately most endodontic cases are not carried out in young adults with pulp chambers that are so large that they can easily accommodate such burs. Typically teeth requiring endodontic treatment have often undergone multiple insults resulting in calcifications and a diminished pulp volume. Overzealous use of burs in these cases will typically result in gouging laterally, cervically and towards the furcation and beyond (see Figs. 1.11 and 1.12).

Ultrasonic tips can be used to uncover the floor of the pulp chamber with less risk of unfavourable damage to the tooth. A number of tips are available to refine the access cavity. The uncovering of the floor of the pulp chamber can be accomplished using the help of the Start-X tip 2 or 3, CPR2D or BUC 1 tips (see Fig. 1.10).

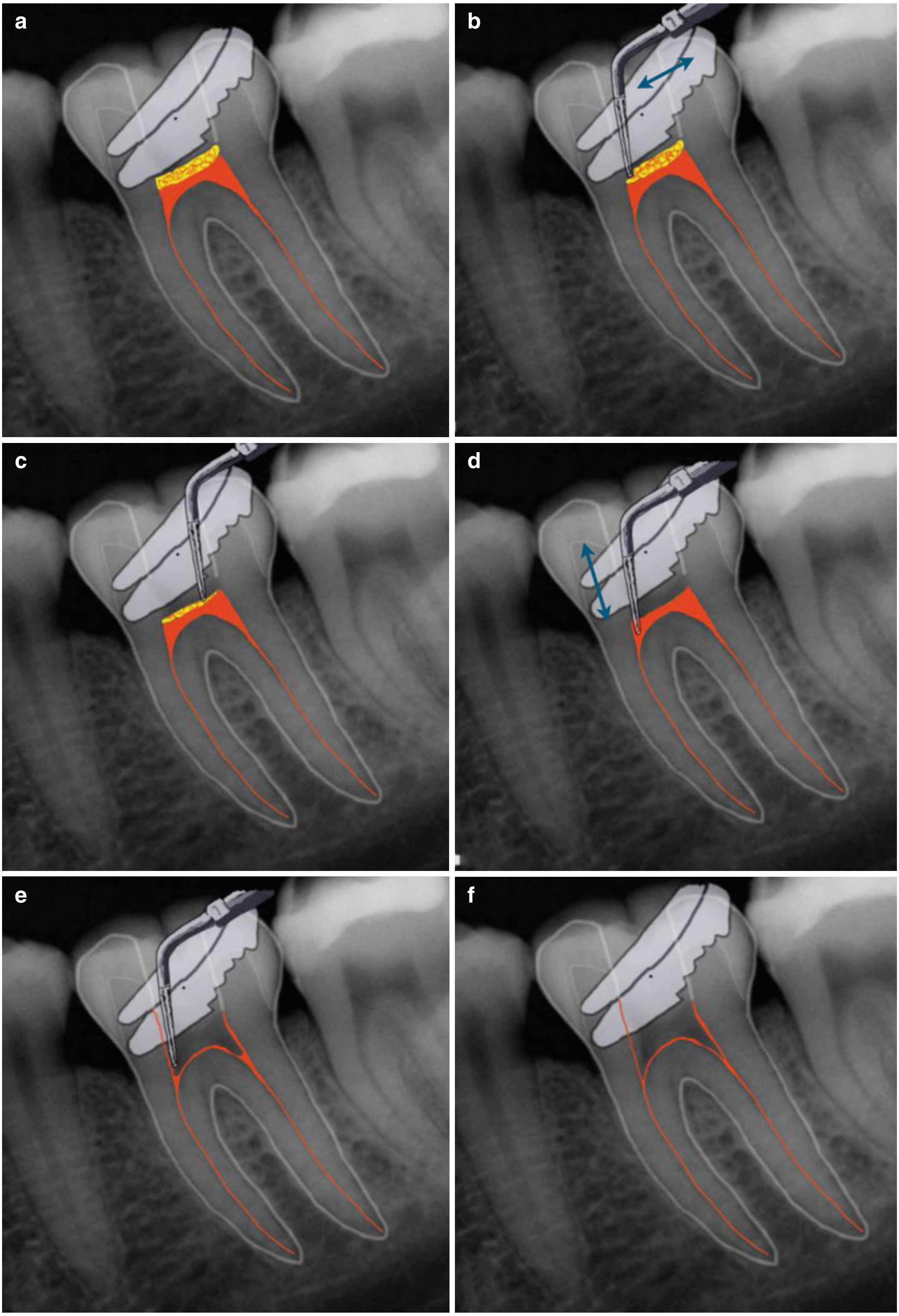
If the dark floor of the pulp chamber is not visible, it may often be obscured with pulp stones or tertiary dentine deposits. Removal of these interferences is not only important to enable location of canals but also prevent stones from blocking apical anatomy during preparation stages later.

The calcified deposits can be carefully vibrated or planned away until the dark coloured dentinal floor is visible (see Fig. 1.10). A sharp, tapered point at its end characterises the Start-X number 3 tip. The diameter of the tip at the base of the end is 0.64 mm; the maximum diameter of the active portion is 0.9 mm and has a blade length of 8 mm. It is very useful when removing calcifications from the floor of the pulp chamber or from the coronal 1/3rd of the root canal. Additionally this tip is useful for the removal of fibre posts encountered in retreatment cases. Note the tip is aggressive and should only be used in a very light touch to avoid iatrogenic damage.

Troughing

During fine refinement of the floor of the pulp chamber, dentinal overhangs may be removed in order to reveal additional or hidden anatomy. Maxillary molars commonly have second mesiobuccal canal orifices located in a bucco-palatal groove overlying the mesiobuccal root. Mandibular molars may have an additional middle-mesial canal located between the mesiobuccal and mesiolingual groove. Careful troughing of these areas is required to remove overlying dentine to safely expose the hidden orifice, which may often be present. The Start-X tip number 2 has an end-cutting tip diameter of

Fig. 1.10 Showing step-by-step access refinement using ultrasonics. Note (**a**) preoperative view showing calcifications present in the coronal pulp chamber typically overlying the canal orifices (*yellow*). (**b–e**) Ultrasonic files can be used in an axial and bucco-lingual direction to carefully remove calcific material and refine the access cavity preparation. Overzealous tooth removal is avoided ensuring (**f**) correct canal orifice identification without damaging the floor of the pulp and iatrogenic perforation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1.0 mm, a maximum diameter of the active portion of 1.54 mm and blade length of 8 mm. This tip is particularly useful for removal of dentine or calcifications overlying the floor of the pulp chamber and creating grooves allowing the removal of all dentinal interferences such as MB2 orifice location (see Fig. 1.13).

Troughing must be carried out diligently since removal of dentine in areas such as the floor of the pulp chamber can lead to irreversible damage. The clinician must be aware of the spatial relationship in terms of the danger area and where dentine is actively being removed. This is based on anatomical knowledge, radiographic pre- and

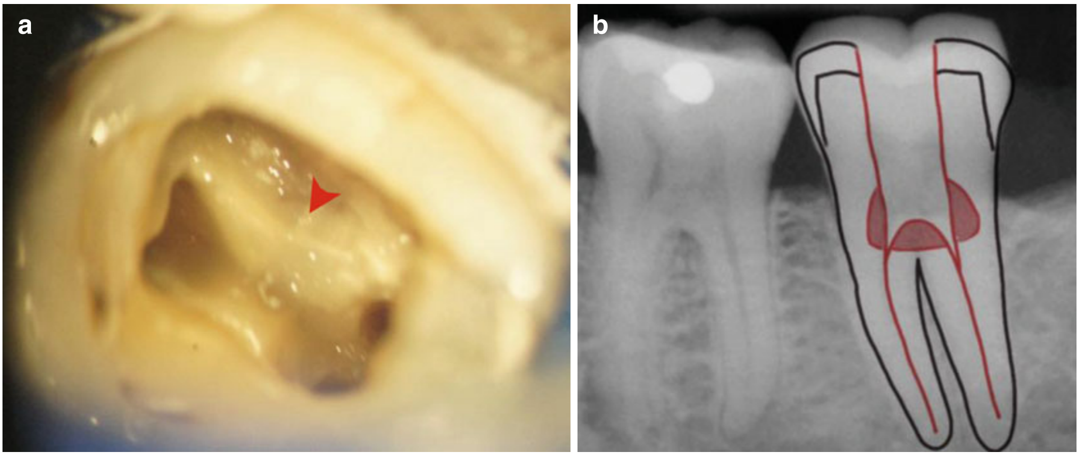


Fig. 1.11 Clinical photograph showing (**a**) excessive lateral dentine removal with gouging of the flow (*red arrow*) and (**b**) diagrammatic representation showing areas at risk which can be avoided (*red shaded*) by the use of ultrasonic instrumentation and microscopic visualization

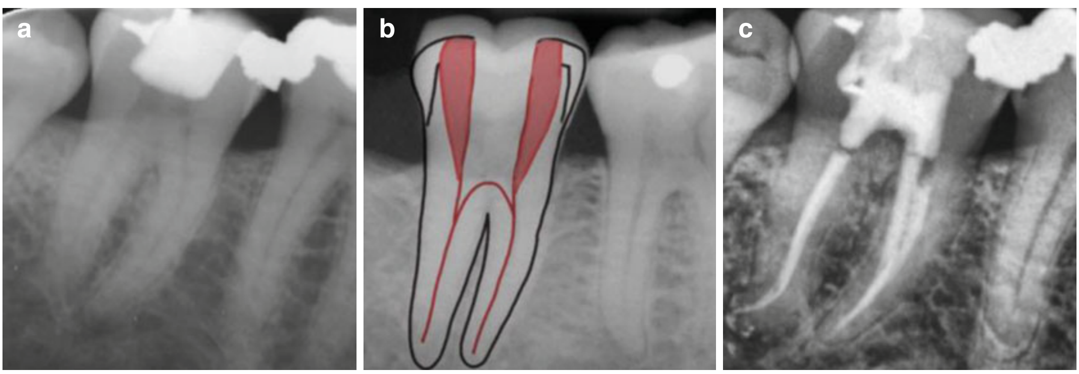
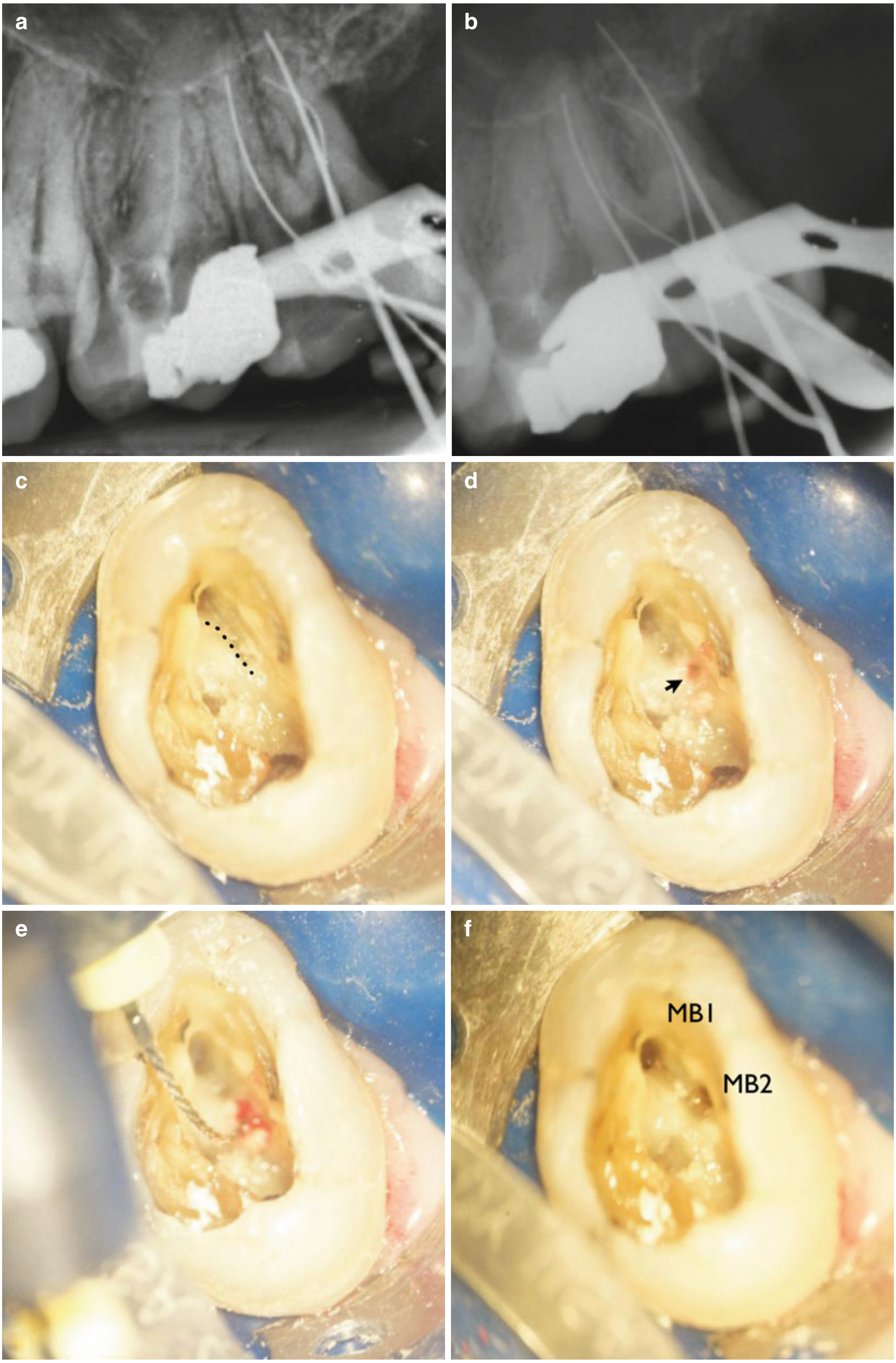


Fig. 1.12 Clinical radiographs and diagrammatic representations showing (**a**–**c**) pre- and postoperative view of a case with prior access where overzealous access preparation has resulted in excessive dentine removal. Axial wall refinement with selection of appropriate ultrasonic tips with non-end cutting properties would have been more suited to prevent this occurrence

Fig. 1.13 Clinical radiographs and photographs demonstrating (**a**) MB1, DB, and P canal working lengths, (**b**) additional MB2 located, (**c**–**f**) MB2 canal orifice (*arrow*) located using ultrasonic troughing in a buccopalatal direction (*dashed line*) followed by careful preparation. Care must be exercised when carrying out troughing in this area due to risk of perforation of the mesial root floor of the pulp chamber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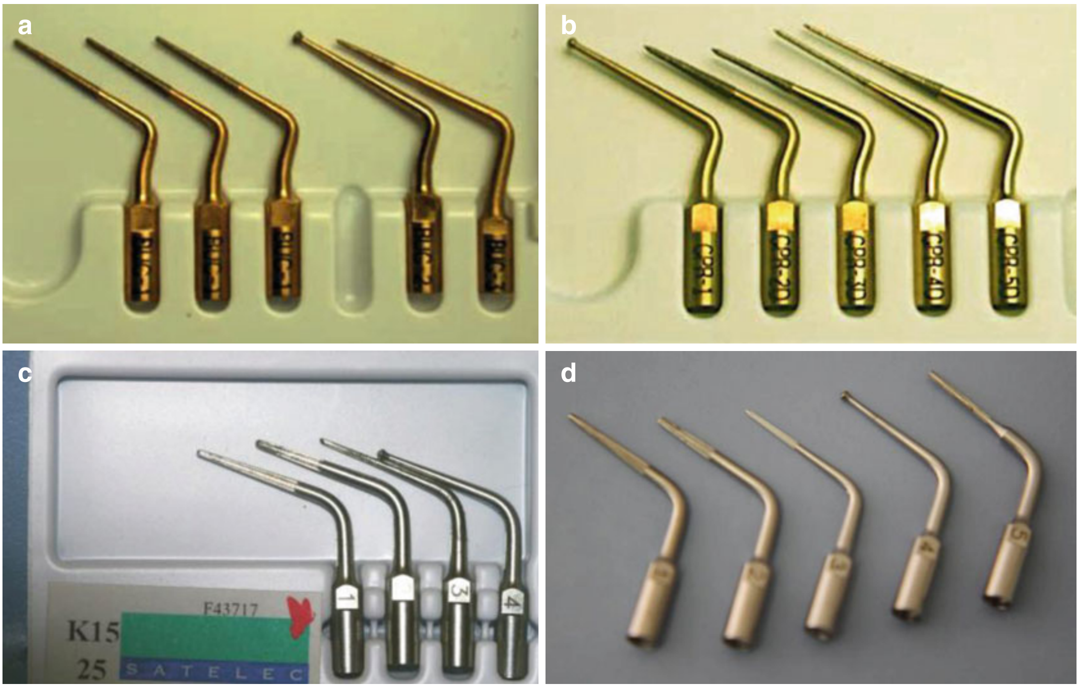


Fig. 1.14 Clinical photographs showing ultrasonic tips typically used in endodontics. (**a**) BUC tips, (**b**) CPR tips, and (**c**, **d**) Start-X tips

peri-assessment and clinical spatial assessment of the site of troughing, and its relationship to internal (dentine colouration and pre-existing roadmap) and external landmarks (axial walls and long axis of the tooth). When in doubt, it may be best to stop and take a further radiograph to help determine positioning within the tooth (Fig. 1.14).

1.6 Calcified Canals

Calcified canal systems are a consequence of ageing and the cumulative effects of restorative procedures and previous insults. The pulp chamber will often be reduced in volume due to the deposition of secondary dentine (yellow/grey colour) resulting in greater risk of pulpal floor iatrogenic errors during access preparation procedures. Tertiary dentine deposition (whiter and more opaque in appearance) in response to caries or micro-leakage may also be encountered, further reducing the overall pulp volume. The natural dome-shaped floor of the pulp chamber may appear flatter resulting in narrower canal entrances, which are more difficult to locate. Pulp stones and calcifications are best removed using ultrasonic tips (see Figs. 1.15 and 1.16).

1.7 Clinical Cases

Case 1 Endodontic treatment of tooth 16 heavily calcified and restored with a ceramic metal crown

A fit and healthy 73-year-old patient was referred for endodontic treatment of tooth 16. The general dental practitioner had carried out an indirect pulp capping procedure on the mesiobuccal canal 2 years ago. A crown had been placed thereafter. Recently the tooth had become sore to touch and exacerbated with chewing/biting. Clinical examination confirmed tooth 16 was tender to percussion. Radiographic examination revealed a peri-radicular radiolucency associated with the palatal root. The root canals appeared calcified. A decision was made to carry out conventional non-surgical root canal therapy through the existing cast restoration, which had good marginal integrity. Access cavity preparation was carried out

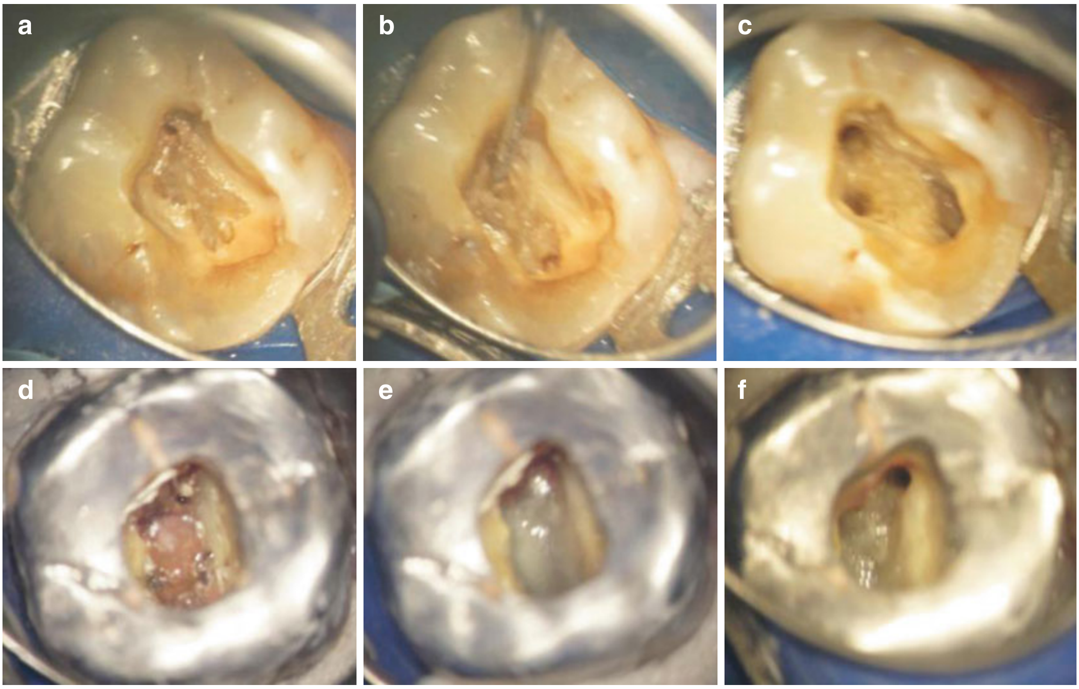


Fig. 1.15 Showing (**a**–**f**) clinical photographs of access refinements in cases with calcifications overlying the canal orifices. Careful removal using ultrasonic files eventually reveals canal orifices. Following canal preparation, canal orifices can be visualized line access

Fig. 1.16 Showing clinical photographs of access refinement using ultrasonics in tooth 36. Note (**a**) highly calcified root canal system with (**b**) multiple pulp stones which following removal reveals the (**c**) darker road map in the floor of the pulp chamber that leads to canal orifices

initially using a tungsten carbide bur confirming a completely calcified pulp chamber. Ultrasonic preparation was carried out and the palatal canal was located first (Fig. 1.17). Previous pulp capping material was identified and removed. Following extensive troughing mesially, the MB1 and DB canals were identified. Patency was achieved in all the canals and manual glide path preparation completed using stainless steel endodontic files. Chemomechanical preparation was completed using 1 % sodium hypochlorite solution. Rotary files were used to prepare the canals (ProTaper Universal) with recapitulation and patency filing throughout. All three canals had acute apical curvatures, which were maintained. An intra-canal dressing of calcium hydroxide was placed for a period of 4 weeks. Obturation was completed using a warm vertical compaction technique using AH Plus cement. The access cavity was temporarily sealed and the patient was discharged back to the referring dentist for permanent coronal restoration (Fig. 1.18).

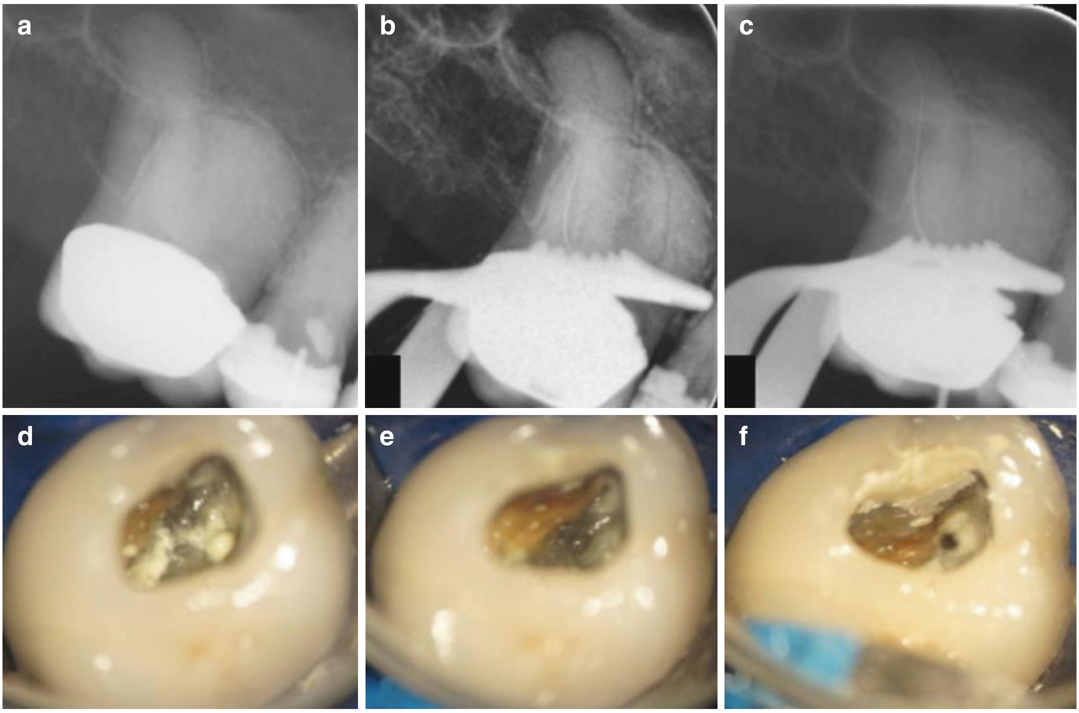


Fig. 1.17 Clinical radiographs and photographs demonstrating (**a**) preoperative x-ray showing crowned tooth 16 with completely calcified roof canal system. The patient had undergone a direct pulp capping of the MB root 12 months previously and then a crown preparation. (**b**) Initial access preparation revealed a palatal canal which could initially be partially negotiated. (**c**) Palatal canal negotiated to length (note DB and MB canals remain unlocated). Following further ultrasonic debridement and (**d**) removal of pulpal floor calcifications (*white areas*), the darker pulpal floor anatomy starts to become visible (**e**). (**f**) Successful MB1 canal orifice located and negotiated

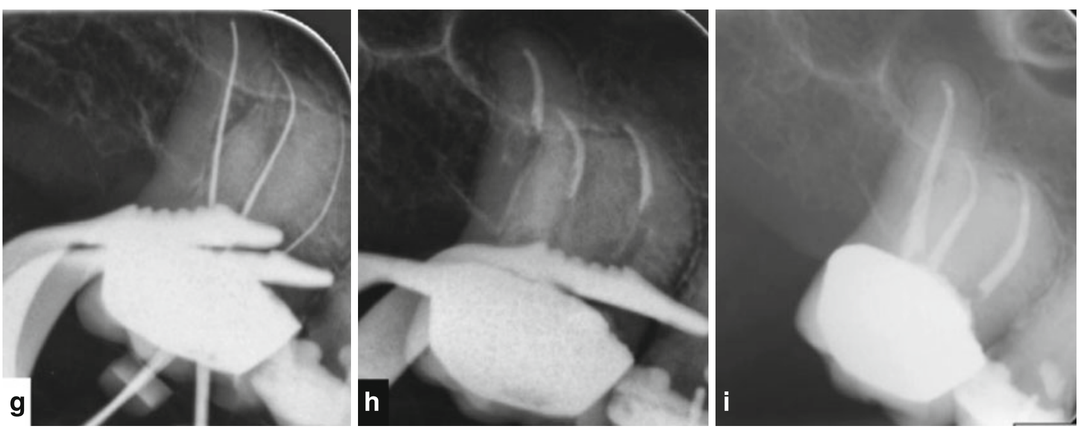


Fig. 1.18 Clinical radiographs demonstrating (**g**) MAF radiographs following successful negotiation of the MB1, DB, and P canals, (**h**) mid-fill x-ray demonstrating apical 1/3 obturation, and (**i**) final postoperative radiograph showing completed case. This case had all the ingredients of difficult access preparation through a metal-ceramic crown, calcified pulp canal system, and acute apical curvatures. Correct access design and preparation from the outset case to be completed without any iatrogenic errors along the way

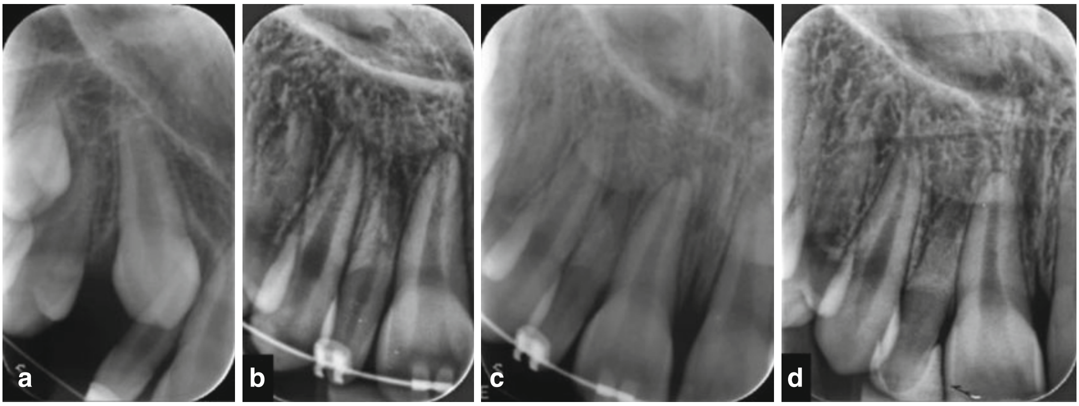


Fig. 1.19 Clinical radiographs demonstrating preoperative views of tooth 12. Note (**a**) radiograph taken in 2012 showing the impacted canine (tooth 13) and peg-shaped lateral incisor (tooth 12). Tooth 13 was brought into the line of the arch using surgical exposure and bracket and chain attachment. (**b**) Radiograph taken in 2013 showing tooth 13 in the line of the arch. Note orthodontic fixed appliance therapy was started. Note tooth 12 has a normal root canal space and volume at this time. (**c**) Further radiographic examination taken in 2014 showing pulp canal obliteration in tooth 12. The tooth was asymptomatic at this stage. (**d**) Radiographic examination taken in 2015. Orthodontic fixed appliance therapy was completed, brackets have been removed and tooth 12 has been masked with a composite restoration for aesthetic purposes. The root canal appears heavily calcified with a widened periodontal ligament space noted at the peri-apex. The patient was experiencing symptoms of irreversible pulpitis and an endodontic referral was made for further management

Case 2 Endodontic treatment of tooth 12 peg-shaped lateral masked with composite restoration and severely calcified

A fit and healthy 14-year-old patient presented with severe localised pain and discomfort associated with tooth 12. The patient had initially presented to her general dental practitioner in 2012 with an unerupted impacted canine tooth. The patient was seen for orthodontic treatment including canine exposure and alignment using a bracket and chain. Further fixed orthodontic appliance therapy was carried out over a period of 2 years. The tooth had been reshaped with a final composite restoration to improve the final aesthetics (Fig. 1.19).

Radiographic examination revealed a widened periodontal ligament space associated with the peg-shaped lateral incisor (tooth 12) and severe calcification of the pulp chamber. The tooth had undergone progressive pulp canal obliteration following orthodontic fixed appliance therapy (Fig. 1.19). A decision was made to attempt orthograde root canal treatment. The patient was forewarned of the inherent risks when attempting to locate canals and that the case was further complicated by the composite coronal restoration that masked the true orientation of the crown and root. Careful alignment was made parallel to the long axis of the tooth and initial coronal access preparation was completed using a small tapered diamond bur. The access cavity was deepened with an ultrasonic tip under the use of the dental operating microscope. To gain access through the calcified dentine, a #08K-file was modified with the final 1 mm removed using a sterile pair of surgical scissors. This modification allowed an improved cutting efficiency of the file with more resistance to both deformation and fracture. The file was carefully advanced 1–2 mm increments apically and an apex locator was used to confirm no perforation was evident. Irrigation was carried and performed using copious amounts of 1 % sodium hypochlorite solution throughout. Once the file was engaged within the canal, its presence was further verified by the observation of 'bubble' formations indicating contact with organic pulp tissue remnants under the dental operating microscope. Patency was eventually achieved and chemomechanical preparation completed using rotary files. An intra-canal medicament of calcium hydroxide was placed for 4 weeks and

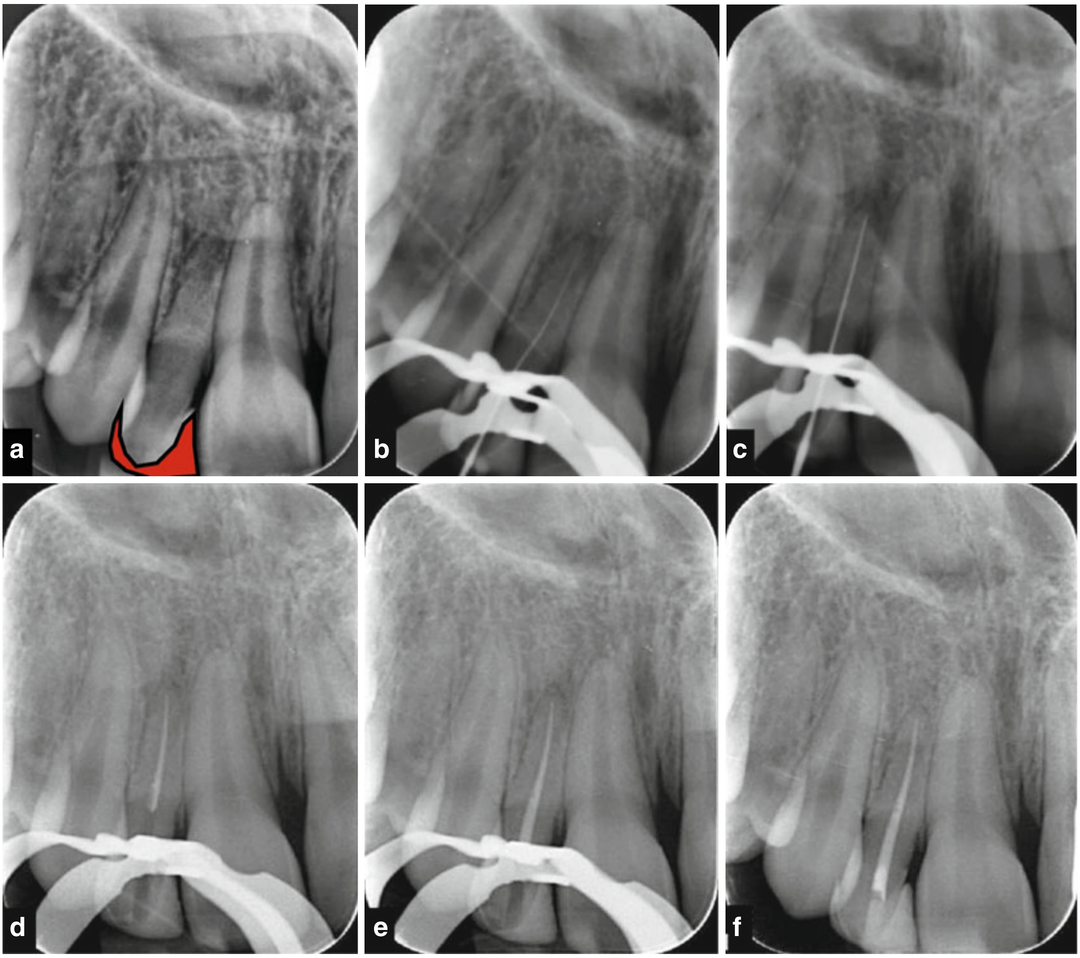


Fig. 1.20 Clinical radiographs demonstrating root canal treatment of tooth 12. Note (**a**) preoperative view with obvious pulp canal obliteration. A composite resin restoration (*red*) has been placed to mask the peg-shaped lateral to mimic a normal lateral incisor tooth. Access in this tooth is fraught with danger. (**b**) Initial apical file size radiograph following correct access preparation and use of ultrasonic troughing. Patency is eventually achieved using small K files (08 and 010). (**c**) Master apical file radiograph. Chemo-mechanical preparation has been completed. Care was taken to ensure that canal enlargement was carried out bearing in mind the overall size of the tooth in question. (**d–f**) Obturation is completed using a warm vertical compaction technique using AH Plus cement. The access cavity is restored with IRM and glass ionomer cement. The patient is discharged back to her general dental practitioner for placement of a permanent coronal restoration and further follow-up is arranged in 6 months

the patient was seen again for review. At the review appointment, the patient was asymptomatic and a decision was made to proceed to obturation. Root canal obturation was completed using AH Plus cement and a warm vertical compaction technique. A temporary double-seal restoration of IRM and glass ionomer cement was placed and the patient advised to see her general dental practitioner for placement of a permanent coronal restoration (see Fig. 1.20).

Case 3 Non-surgical root canal treatment of tooth 36 with minimal occlusal access

A fit and healthy 60-year-old patient was referred for non-surgical endodontic therapy of tooth 36. At the consultation appointment, the patient was complaining of pain and tenderness in relation to tooth 36. Radiographic examination revealed a supracrestal coronal restoration with degenerative pulpal changes.

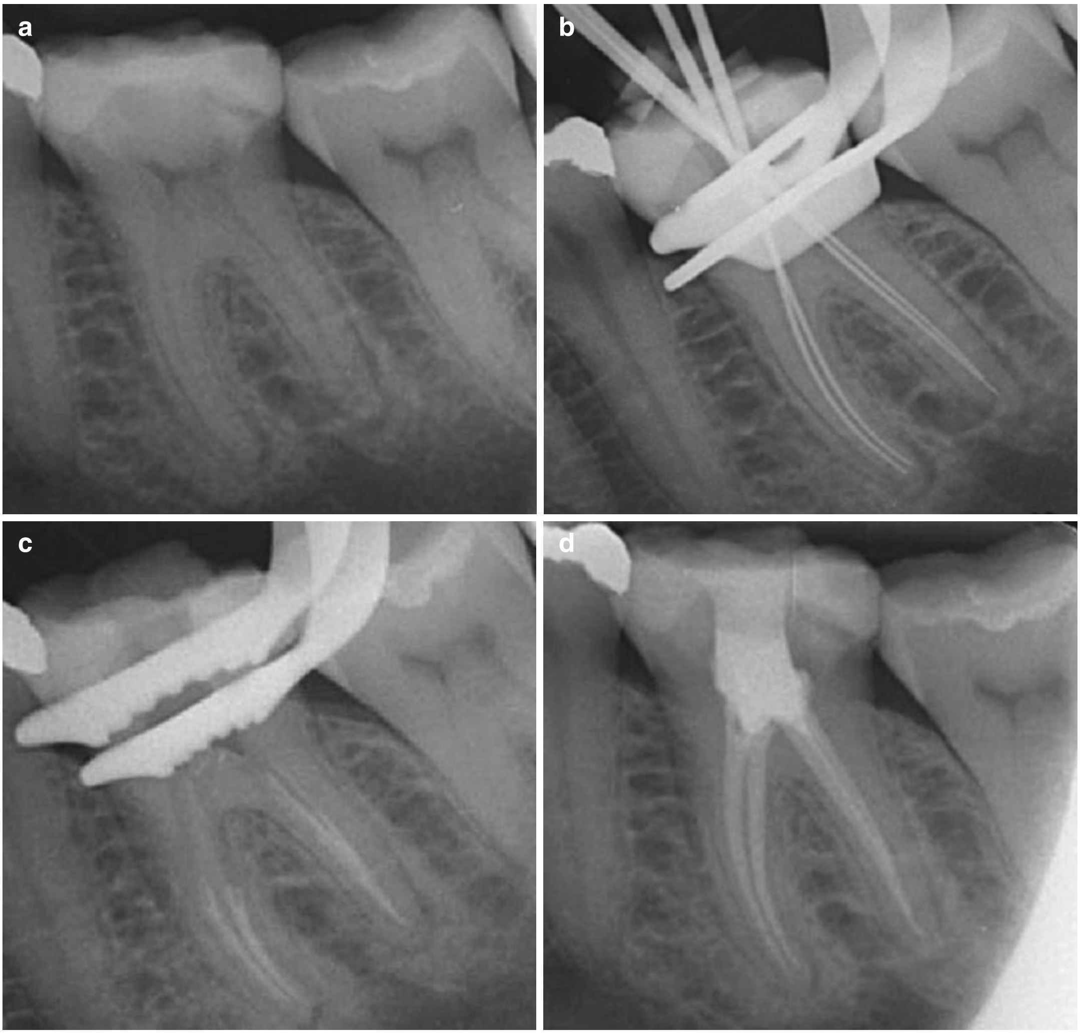


Fig. 1.21 Clinical radiographs demonstrating nonsurgical root treatment of tooth 36 with minimal occlusal access cavity preparation. Note (**a**) preoperative view showing calcified coronal pulp chamber and sclerosed canals with periradicular radiolucent lesions. (**b**) MAF preparation (DB and DL canal confluent in the apical 1/3. (**c**) Mid-fill radiograph following warm vertical compacting using AH Plus cement and gutta-percha. (**d**) Postoperative view showing completed obturation and coronal temporary restoration. Minimal access preparations aimed at dentine conservation serve to maximize tooth longevity. The clinician must balance this aim with the additional risks of iatrogenic problems such as file deformation and fracture and obturation difficulties that can arise as a result

The coronal pulp chamber appeared diminished in volume with sclerosed root canals. Peri-radicular radiolucencies were noted with both mesial and distal apices. Access preparation was completed through the coronal restoration directed at preserving as much dentine as possible. Use of the dental operating microscope was essential in being able to visualise internal anatomy and location of four canals. Ultrasonic preparation was used to refine both the axial walls and removal of pulp calcifications obscuring canal orifices. Chemomechanical preparation was completed using 1 % NaOCl solution. A manual glide path was created to size .20 before introducing rotary instrumentation. Following completion of preparation, an interim dressing of calcium hydroxide was placed for 4 weeks (Fig. 1.21).

Obturation was completed using a warm vertical compaction technique using AH Plus cement and gutta percha. A temporary coronal double seal was placed using IRM and glass ionomer cement. The patient was referred to his general dental practitioner for placement of a cast cuspal coverage restoration.

Case 4 Non-surgical endodontic treatment of tooth 42 requiring improvised access cavity preparation

A well-controlled hypertensive 46-year-old female patient was referred for endodontic management of tooth 42. The patient had previously seen his general dental practitioner for extensive caries treatment in the lingual aspect of the tooth. The patient had been warned of the deep restoration and possible pulpal sequelae. Following this treatment procedure, the patient recalled progressive pain and discomfort with the tooth exacerbated initially with chewing/biting and thermal stimulus. She recalled recent spontaneous dull pain from the tooth, which was relieved by analgesics. The patient had seen her dentist who prescribed some oral steroids (dexamethasone 4 mg) and a referral was sought. The dentist mentioned difficult access due to labial incisor imbrication in the area. Clinical examination revealed tooth 42 was restored with a lingual restoration. Tooth 43 was impacted against the lingual surface making conventional access impossible (see Fig. 1.23). Tooth 42 was tender to percussion. Radiographic examination revealed an extensive coronal restoration overlying the pulp chamber. Two canals were noted with no obvious signs of apical pathology (Fig. 1.22).

The patient was keen to try and retain the tooth and understand the difficulties with conventional access preparation. The patient was advised that a labial approach would be the alternative, requiring some aesthetic masking following endodontic completion. The patient was advised to stop taking the oral steroids and a further emergency treatment appointment was scheduled. After adequate anaesthesia, the tooth was isolated under rubber dam and a labial access preparation created. Access cavity was refined with an EndoZ bur to ensure that both labial and lingual canals were accessible. Working length radiograph was taken confirming the presence of two canals with separate apical foramina (Fig. 1.22). Chemomechanical preparation was completed using 1 % NaOCl solution. An intracanal dressing of calcium hydroxide was placed and the patient reviewed a week later. At the review appointment, all the patients' symptoms had resolved and tooth remained asymptomatic.

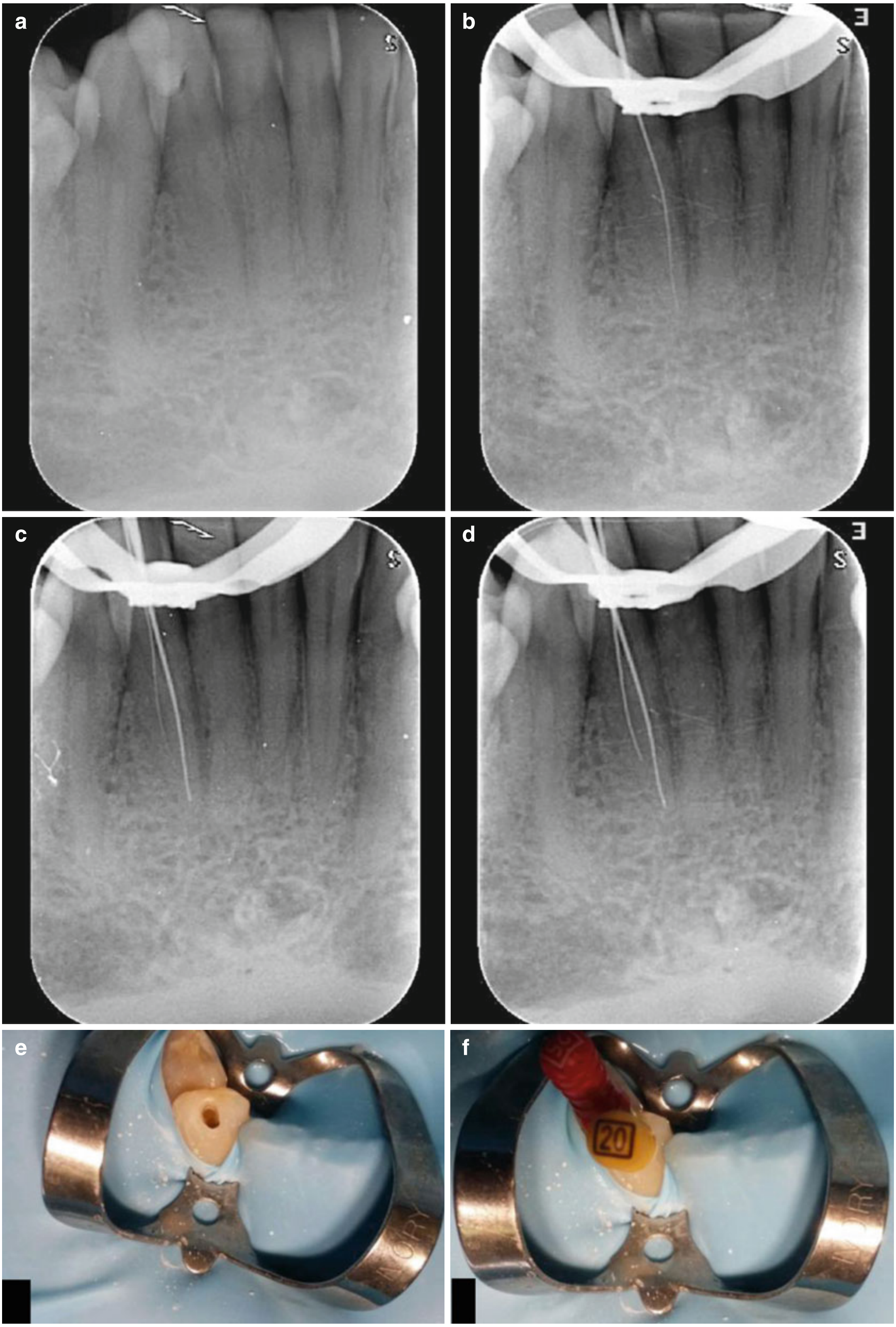
The patient was seen for a second treatment appointment 3 weeks later for completion of endodontic treatment. Obturation was completed using AH Plus cement and a warm vertical compaction technique. A coronal double-seal Biodentine/GIC temporary restoration was placed prior to discharging the patient back to her general dental practitioner (Fig. 1.23).

This final case highlights that every case should keep in mind the basic principles of cavity design procedures discussed but occasionally an alternative unconventional access design may be required to enable adequate treatment to be carried out.

Clinical Hints and Tips for Access Preparations

- **Use of magnification, illumination and ultrasonic equipment**
  Greatly improves the ability to successfully identify all the root canals in any tooth.
- **Preoperative parallel radiographs**
  Allows the clinician to mentally visualise the precise location of the canals. Assess the angulation and rotation of the tooth. Identify the position of the cement-enamel junction, which indicates the location level of the pulpal floor. Also identify where the

Fig. 1.22 Clinical radiographs and photographs demonstrating nonsurgical root canal treatment of tooth 42 with unconventional buccal access cavity. Note (**a**) preoperative view, (**b**) initial apical file (IAF) in buccal canal, (**c**) master apical file size # 25 in buccal canal and IAF # 010K file in lingual canal, (**d**) MAF buccal and lingual canals, (**e**) buccal access cavity, and (**f**) MAF files in place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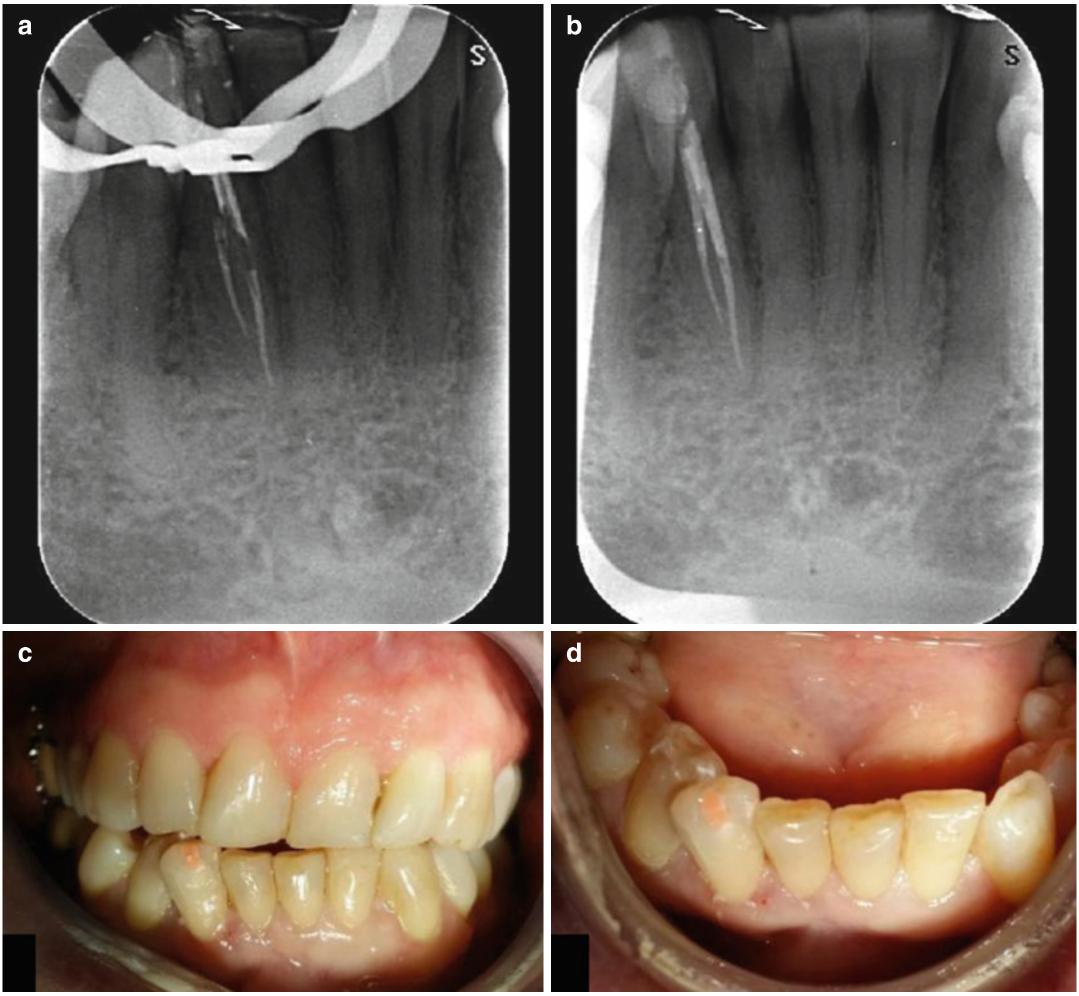

Fig. 1.23 Clinical radiographs and photographs demonstrating non-surgical root canal treatment of tooth 42 with unconventional buccal access cavity due to imbrication with tooth 43. Note (**a**) mid-fill radiograph following warm vertical compaction using AH plus cement and gutta-percha. (**b**) Completed endodontic treatment following backfill using Obtura. A final coronal restoration of Biodentine and glass ionomer cement (GIC) was placed. Pink GIC was selected so the general dental practitioner would not disturb the Biodentine seal overlying the root canal orifices. (**c**, **d**) Completed buccal access cavity. The patient was discharged back to her general dental practitioner for a permanent tooth coloured restoration

furcation is and to approximately what length preventing iatrogenic damage.

- **Anatomical knowledge**
  Pretreatment knowledge and experience of what to expect in individual teeth will give the clinician the ability to ensure that he can locate all anatomy.
- **Straight-line access**
  The importance of gaining straight-line access into the root canals prevents iatrogenic damage or problems occurring with subsequent cleaning, shaping and obturating procedures.

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