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

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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*

Contents

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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Access Preparation

1

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.

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].

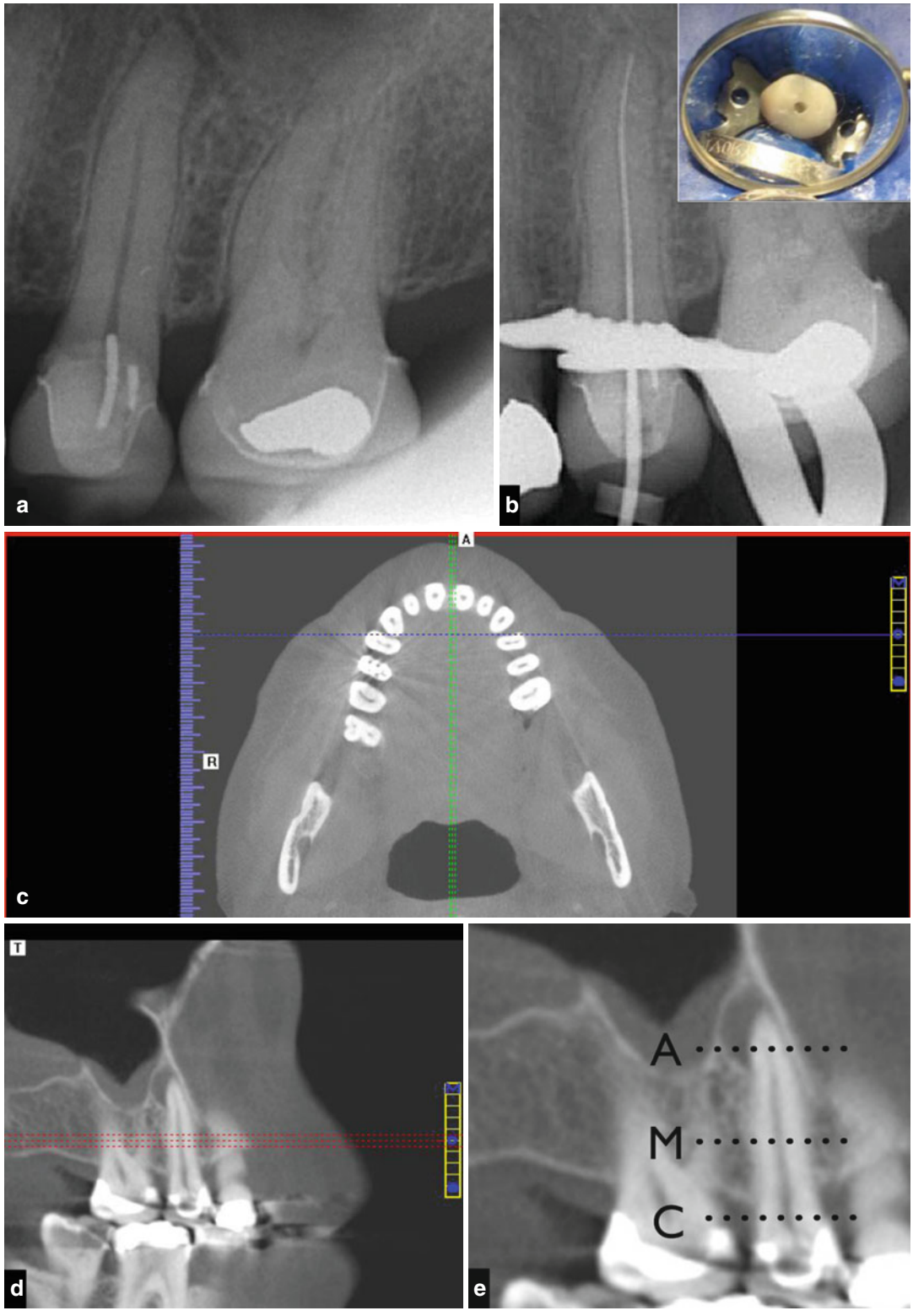
Good knowledge of canal morphology in mandibular and maxillary teeth will guide clinicians in creating correct pulp chamber openings necessary for location of all canals [7, 8]. Radiographic assessment should always be integrated with this knowledge to recreate a mental image of the proposed access cavity 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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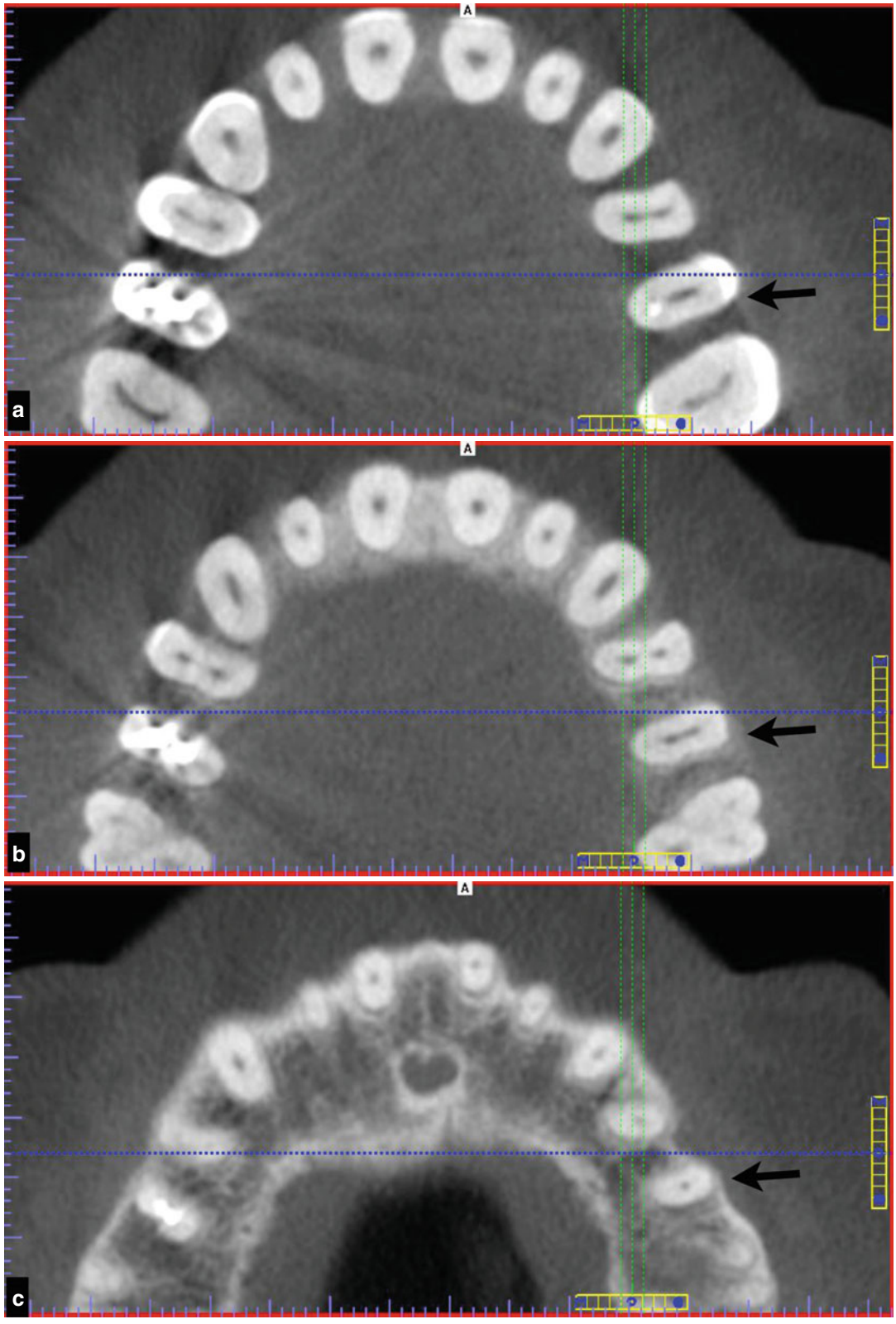
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material. This mechanical energy is transferred to the cutting tips resulting in micro-vibratory movements in the ultrasonic frequency range. The tips should be used with a light brush and touch action, selecting a medium power setting under direct 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

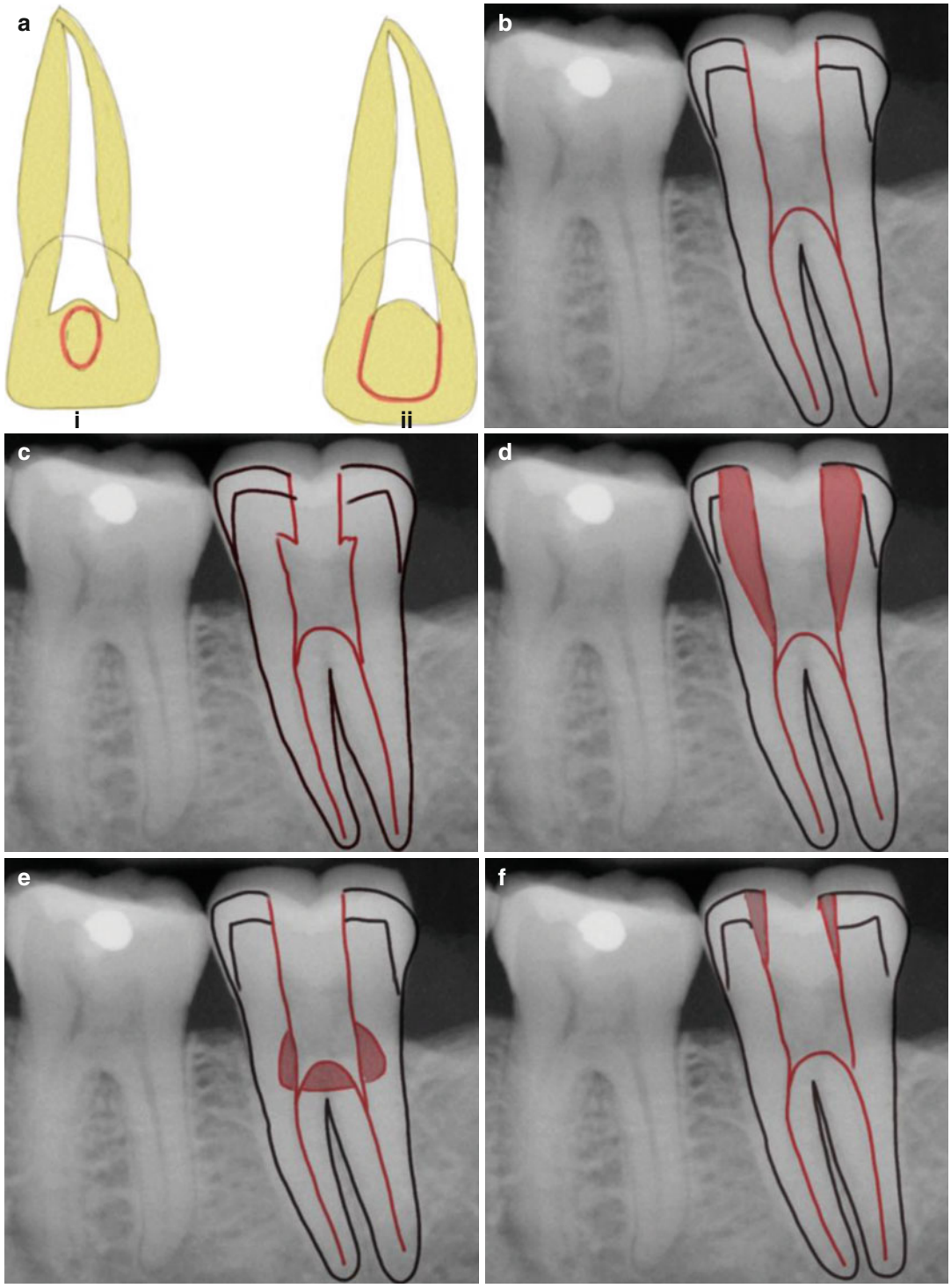

Fig. 1.3 Diagrams representing (**a**) incorrect (*i*) and correct (*ii*) removal of the pulp chamber in an incisor tooth. (**b**) Correct and (**c**) incorrect straight-line access in a posterior molar tooth. (**d**) Excessive removal of tooth structure leading to weakening and potential fracture of 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

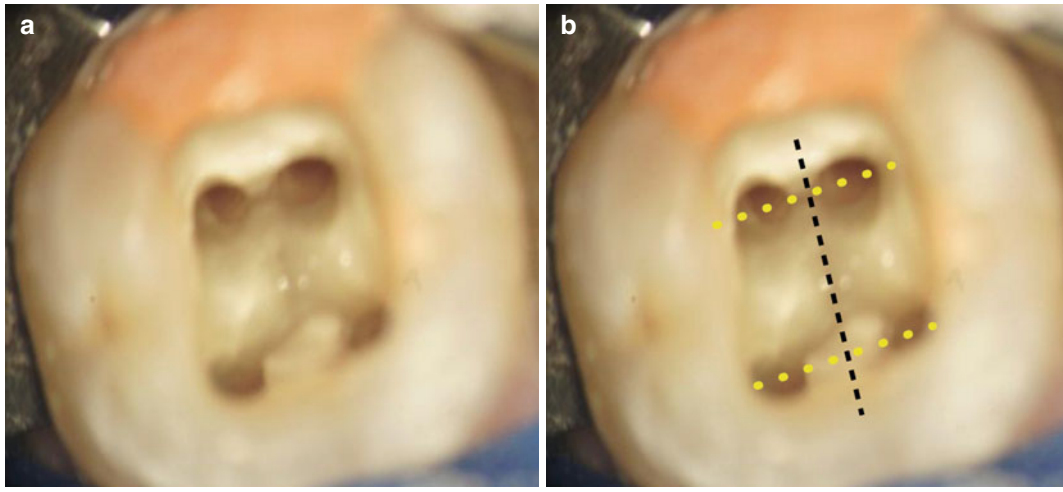

Fig. 1.4 Clinical photographs showing (**a**) internal anatomy of a tooth. Note dark developmental grooves on the floor of the pulp and darker color associated with root canal orifices. (**b**) As described by Krasnoe and Rankow Law of symmetry 1 and 2

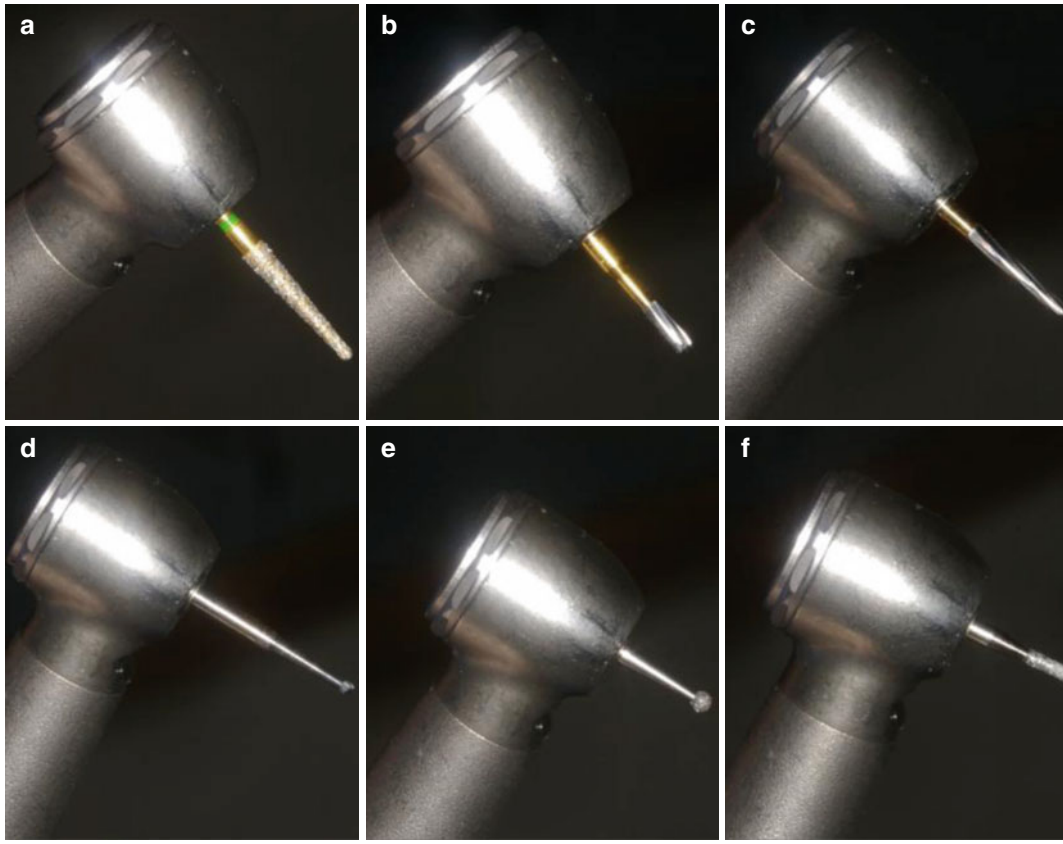

Fig. 1.5 Clinical photographs showing typical armamentarium of burs used for access preparations: (**a**) diamond grit tapered bur, (**b**) tungsten carbide bur, (**c**) non-end cutting Endo-Z bur, (**d**) long shank diamond, (**e**) diamond grit round diamond, and (**f**) parallel tapered short diamond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