Contemporary Restoration of ENDODONTICALLY TREATED TEETH

Evidence-Based Diagnosis and Treatment Planning

Edited by

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Foreword

It is an honor to have been invited to write the foreword for Dr Nadim Baba's text on the restoration of endodontically treated teeth. The last book on this topic, published by Quintessence, was authored by Shillingburg and Kessler in 1982. Three decades later, this new book is much needed and long overdue.

Dr Baba's interest in the restoration of pulpless teeth dates back to his graduate-school days. I served as his program director and his principal research advisor during his studies at Boston University in the postdoctoral prosthodontic program, where the title of his master's project and thesis was "The Effect of Eugenol and Non-eugenol Endodontic Sealers on the Retention of Three Prefabricated Posts Cemented with a Resin Composite Cement." Dr Baba certainly has come a long way since receiving his certificate of advanced graduate study and master of science in dentistry degree in 1999. He is now a Diplomate of the American Board of Prosthodontics and a full professor at Loma Linda University School of Dentistry, and he is about to publish this comprehensive book on the restoration of endodontically treated teeth.

This new text has a wealth of evidence-based information on all facets of restoration of endodontically treated teeth and will serve as an indispensable reference not only for dentists involved in the restoration of pulpless teeth, such as general practitioners and prosthodontists, but also for dentists who do not place restorations but are engaged in planning treatment for structurally compromised teeth, such as endodontists, periodontists, and oral surgeons. With the well-documented success of osseointegrated implant-supported fixed restorations, combined with a better understanding of the factors that can influence the prognosis of severely broken down teeth, the profession's approach to planning treatment for these teeth has evolved, and this text offers a well-balanced, contemporary approach to the topic of treatment planning.

Dentists encountering treatment planning dilemmas, such as determining when to extract a compromised tooth and when to retain it and restore it, can find the answers to most of their questions in this first-rate text. Traditional principles and techniques are reviewed and reinforced, along with modern materials and methods, all with a firm foundation in the best available scientific evidence and with an emphasis on clinical studies. Many of the chapters provide comprehensive, step-by-step descriptions of technical procedures with accompanying illustrations to guide the reader through all aspects of restoring pulpless teeth, including fabrication of various foundation restorations, cementation techniques, and methods of provisionalization of endodontically treated teeth. Preprosthetic adjunctive procedures, such as surgical crown lengthening, repair of perforations, and orthodontic measures, are also described and illustrated.

Dr Baba has assembled a group of renowned experts on various topics related to the restoration of pulpless teeth, and these experts have collectively produced this outstanding text, which will remain a definitive reference for years to come. The profession as a whole is very fortunate to have this text. Many thanks must go to Dr Baba for undertaking this monumental task and to all contributing authors for their time and efforts in helping Dr Baba produce this new book on such a very important subject.

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Preface

My interest in the restoration of endodontically treated teeth dates back to my graduate-school days at Boston University. When working on my master's project and thesis and later while studying for the American Board of Prosthodontics exam, I realized that very few books dealt with the restoration of pulpless teeth. The first book on that topic was published by Quintessence in 1982; two decades later, three books were published but all were somewhat limited in their scope. They dealt mainly with fiber posts, their characteristics, and their clinical applications.

This book is primarily intended to be a manuscript that reviews the basic principles of diagnosis and treatment planning and describes numerous treatment options and the techniques recommended for contemporary treatment of endodontically treated teeth. The purpose of this book is to provide general dentists, endodontists, prosthodontists, and dental students (postgraduate and predoctoral) with a comprehensive review of the literature and evidence-based information for the treatment of endodontically treated teeth, keeping in mind the integration of systematic assessments of clinically relevant scientific evidence.

Four major themes are discussed. The first part focuses on treatment planning, treatment options, and materials used for the restoration of endodontically treated teeth. The second part reviews the principles and methods of restoration along with cementation, provisional restoration, and management of discolored endodontically treated teeth. The third part describes the different aspects of the management of severely damaged pulpless teeth. In the final part, treatment of complications and failures is reported.

Acknowledgments

I wish to express my appreciation and indebtedness to all my friends and colleagues who contributed chapters, sections of chapters, or clinical cases in specific areas in which they are experts. Without them the book would not have been possible.

I would like to take the opportunity to thank Leif Bakland, Zouheir Salamoun, W. Patrick Naylor, and the dean of my school, Loma Linda University, Charles J. Goodacre, for their counsel and help during the preparation of the manuscript.

Most importantly, I extend my special thanks to Ms Lisa Bywaters and the staff of Quintessence Publishing for their professionalism and guidance in bringing my book to life.

I also would like to acknowledge my teachers and mentors who had a great impact on my visions, attitude, and career: Pierre Boudrias, Hideo Yamamoto, Steven M. Morgano, David Baraban (deceased), and Charles J. Goodacre. They remind me of the Lebanese-American poet and writer Gibran Khalil Gibran, who said: "The teacher who is indeed wise does not bid you to enter the house of his wisdom but rather leads you to the threshold of your mind."

I feel blessed, lucky, and proud to have had the chance to know and work with each one of these people in various stages of my professional career.

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Part I

Treatment Planning for Endodontically Treated Teeth

1. Impact of Outcomes Data on Diagnosis and Treatment Planning
2. Treatment Planning Considerations for Endodontically Treated Teeth
3. Treatment Options and Materials for Endodontically Treated Teeth

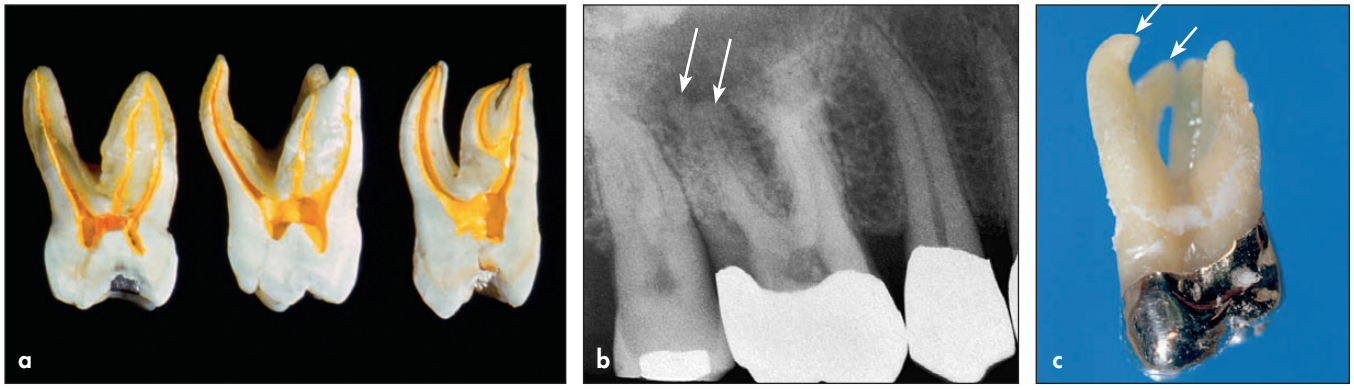

Fig 2-4 *(a)* The complexity of the root canal system is well illustrated in these sections of maxillary molars. Note the variety of canal configurations in the mesiobuccal roots and in particular the location of the second mesiobuccal canal in the molar on the right. *(b)* A radiograph of a maxillary molar seems to show two palatal roots *(arrows)*. *(c)* On the patient's request, the tooth was extracted; two palatal roots were identified *(arrows)*.

In addition, Schilder[12] named four biologic objectives for these preparations:

1. Treatment procedures are confined to the roots.
2. Necrotic debris is not forced beyond the apical foramina.
3. All pulp tissues are removed from the root canal space.
4. Sufficient space exists for intracanal medicaments and irrigants.

These objectives provide a basis for assessing the quality of the endodontic procedure prior to restoration of the tooth. Deviation from the original canal shape is referred to as *transportation of the canal*. The greater the transportation, the greater the likelihood of a poor endodontic outcome, resulting in the need for either endodontic retreatment or extraction of the tooth.

Root canal systems

The root canal system is complex (Fig 2-4), and its anatomy has been studied extensively for many years. Of special interest in the current context, Weine et al[13] called attention to the frequent presence of two canals in the mesiobuccal roots of maxillary molars. Pineda and Kuttler[14] and Vertucci[15] developed classification systems for canal configurations in individual roots. Research in root canal morphology has led to descriptions of more than 20 canal configurations.[11]

These considerations are important for the evaluation of a tooth that has undergone RCT. They also point to the challenges inherent to treating teeth with endodontic disease prior to restoration to full function. Achieving full function requires that the treatment-planning process be a teamwork process: RCT can be performed on almost any tooth, but restorability must be determined prior to the endodontic component of treatment. Communication among the various treating dentists before, during, and after RCT offers the best possibility of an optimal outcome.

Assessment of other conditions

Cracked/fractured teeth

Fracture lines involving cusps of teeth have been a problem in dentistry, probably throughout human history. The pain associated with such fracture lines was described by Gibbs,[16] who termed it *cuspal fracture odontalgia*. Every dentist has probably had a patient who complains about pain on chewing and later shows up with the broken-off cusp, usually from a premolar tooth. Whether or not the pulp is directly involved (by exposure), it is usually necessary to complete RCT before the tooth is restored. Diagnosis of a fracture line under a cusp, before it breaks off, can be a challenge and will be discussed in the next section on infractions.

Teeth may develop cracks and fracture for a number of reasons, including trauma, excessive masticatory forces, and iatrogenic incidents. Regardless of etiology, when cracks or fractures develop in dental hard tissues it is not possible to repair them, except for a short period of time with bonding agents. In contrast, bone and cartilage routinely undergo repair following fracture. Although tooth fractures and cracks cannot be healed, it is possible in many cases to maintain such teeth for various periods of time following identification and diagnosis.

For convenience in discussing cracks and fractures, three categories will be used: enamel craze lines, infractions, and vertical root fractures (VRFs).

Enamel craze lines. Craze lines are small cracks that are confined to the enamel of teeth (Fig 2-5). They are not typically visible unless light rays highlight them incidentally. They develop over time, so they probably can be found in most teeth eventually. Occasionally they will show stains from exposure to liquids such as coffee and red wine. Because these cracks are confined to enamel, they have no pulpal impact, and no treatment is necessary, except op-

Fig 2-5 Enamel craze lines *(arrow)* are common and present no particular problem other than their potential for staining.

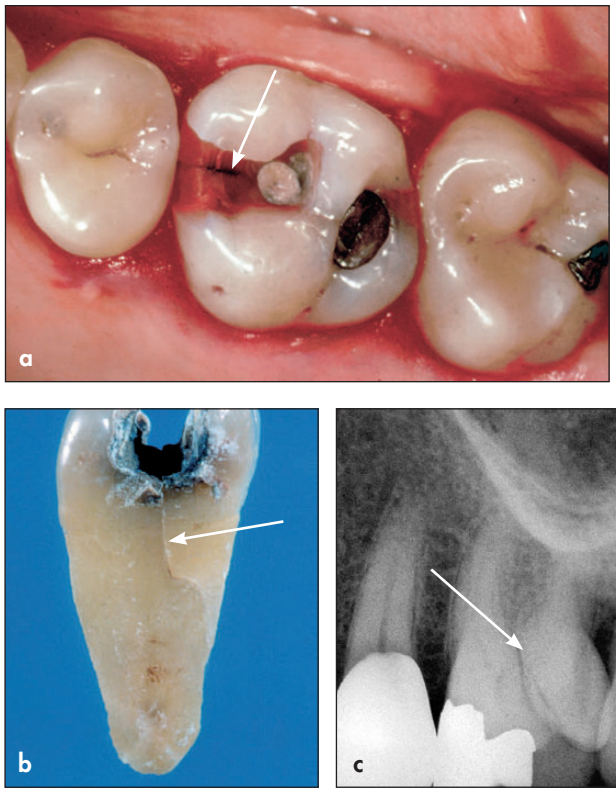

Fig 2-6 *(a)* Infractions *(arrow)* can be identified visually with the help of dyes, in this case a red dye. Infractions usually run in a mesiodistal direction; they may be asymptomatic or associated with pain on chewing and cold stimuli. *(b)* A tooth extracted because of symptoms associated with an infraction shows the presence of the infraction *(arrow)*. They typically originate in the crown of the tooth and progress in an apical direction. *(c)* On rare occasions, infractions run in a faciolingual direction *(arrow)*.

tional bleaching if they are stained. There is no evidence that craze lines progress to involve more than enamel.

Infractions (cracked teeth). The term *cracked tooth* is commonly used to describe a tooth that has developed an *infraction*, which is defined as "a fracture of hard tissue in which the parts have not separated"[17] (Fig 2-6). Cameron[18] incorrectly defined this condition as *cracked tooth syndrome*; the use of *syndrome* is not appropriate for pain associated with fractures in teeth. It is, however, a situation with a variety of symptoms, and diagnosis can be very difficult.

Mandibular molars and maxillary molars and premolars are the teeth most frequently associated with infractions. The teeth usually have vital pulps and the infractions typically run in a mesiodistal direction. They begin in the crowns of teeth and progress in an apical direction. Not all teeth with infractions are symptomatic, but when symptoms develop they can range from pain on chewing, to an exaggerated response to cold stimuli, to severe pain episodes that can mimic trigeminal neuralgia; chronic orofacial pain can also develop. The wide range of pain experiences is probably why Cameron[18] used the term *syndrome* to describe this dental situation. The etiology of infractions is probably in most cases related to occlusal forces, whether from regular daily chewing or isolated trauma such as blows to the underside of the mandible.[19–25]

It is likely that teeth with infractions become symptomatic when the infractions become invaded by bacteria[26] (Fig 2-7). Bacteria stimulate inflammation in the pulp, whether or not the infraction communicates directly with the pulp tissue. The inflamed tissue is responsible for the exaggerated cold response. It is also likely that the tooth will become sensitive to biting when the infraction progresses from the tooth crown to the root, and the bacteria that will soon occupy the infraction then stimulate an inflammatory response in the adjacent periodontal ligament (PDL).

Diagnosis of infractions is complicated by many factors. Because infractions are usually located in a mesiodistal direction in the crown, they are not visible on radiographs.

Fig 3-17 *(a and b)* A provisional fixed dental prosthesis is fabricated in resin composite material. The restoration has proper contours, thickness, proximal contacts, and adequate occlusal contacts. *(c)* Gutta-percha is removed from the orifice of the canals to aid in retention of the core. *(d)* A carbide rotary cutting instrument is used to make an occlusal access opening on the provisional prosthesis, toward the center of the foundation. *(e)* The FPD is cemented, and the amalgam is condensed in the prepared post spaces. *(f and g)* A tapered rotary cutting instrument is used carefully to make a vertical groove in the lingual surface in order to section the provisional prosthesis. *(h and i)* The amalgam foundation is refined for the definitive tooth preparation, and a final impression is taken.

3. Remove 1 to 2 mm of gutta-percha from the orifice of the canals to aid in retention of the core. This is only necessary when the pulp chamber is smaller than 3 mm in depth (Fig 3-17c).
4. Use a carbide rotary cutting instrument to make an occlusal access opening in the abutment retainer toward the center of the foundation.
5. Place the modified provisional FPD on the remaining tooth structure, and confirm adequate access to the cavity for ideal amalgam placement and condensation (Fig 3-17d).
6. Confirm proper fit and marginal adaptation of the provisional FPD.
7. Cement the modified provisional FPD with a small amount of provisional cement placed only on the margins of the provisional FPD.
8. Condense the first increments of amalgam into the prepared post spaces using a periodontal probe or an endodontic plugger. Fill the remaining pulp chamber with amalgam up to the occlusal surface of the provisional FPD to ensure an adequate seal, and make occlusal adjustments as needed (Fig 3-17e).
9. At the following appointment, carefully section the provisional FPD by using a tapered rotary cutting instrument to make a vertical groove in the buccal surface (Figs 3-17f and 3-17g).
10. Refine the amalgam foundation for the definitive tooth preparation, and take the definitive impression (Figs 3-17h and 3-17i).
11. Fabricate and cement a new provisional FPD with provisional cement.

The same procedure is used when a provisional crown is used as a matrix for an amalgam core buildup (Fig 3-18).

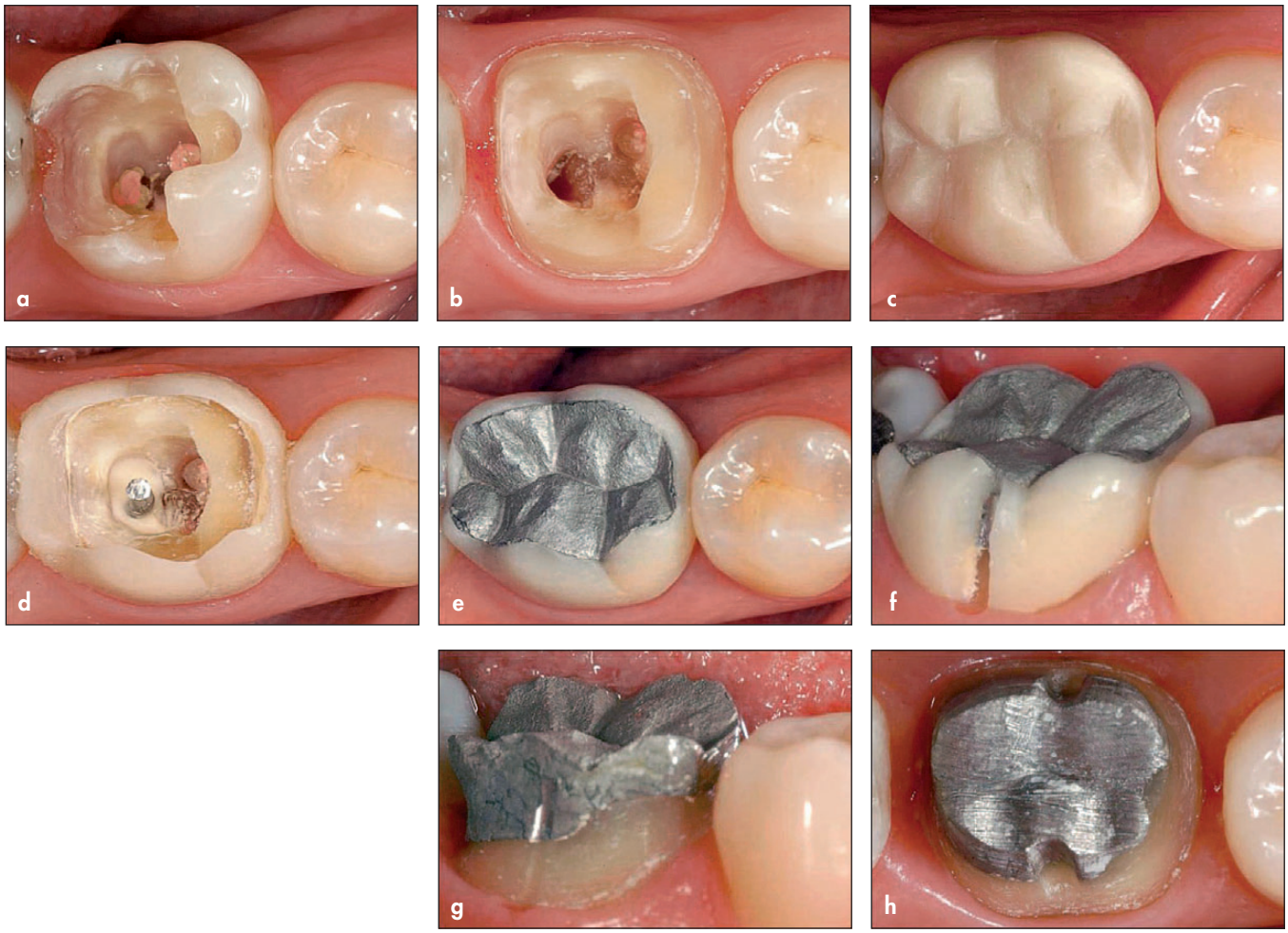

Fig 3-18 *(a)* The mandibular right first molar was endodontically treated and presented with enough remaining coronal tooth structure and adequate depth of the pulpal chamber. *(b)* Tooth preparation is finished, and the post space is prepared in the distal canal to receive a prefabricated metallic post. *(c)* The provisional crown is fabricated using resin material with proper contours, thickness, proximal contact, and adequate occlusal contacts. *(d)* An occlusal access opening in the provisional crown is made so only a peripheral shell of resin is retained using a carbide rotary cutting instrument. The provisional crown is cemented with a luting agent. The length of the prefabricated post is adjusted to the appropriate height, and the post is cemented with zinc phosphate cement. *(e)* The amalgam is condensed into the prepared post space. *(f and g)* After the amalgam has hardened or at a subsequent appointment, the provisional crown is sectioned carefully by making a vertical groove in the labial surface using a tapered rotary cutting instrument. *(h)* The amalgam foundation is refined for the definitive tooth preparation, and a final impression is taken. (Courtesy of Dr Carlos E. Sabrosa, Rio de Janeiro, Brazil.)

Composite resin

Composite resin is a popular core material because it is easy to use and satisfies esthetic demands. Certain properties of composite resins are inferior to those of amalgam but superior to glass-ionomer materials.[234,247] Kovarik et al[234] showed that composite resin is more flexible than amalgam. It adheres to tooth structure, may be prepared and finished immediately, and has good color under all-ceramic crowns. Composite resin appears to be an acceptable core material when substantial coronal tooth structure remains[235,248–253] but a poor choice when a significant amount of tooth structure is missing.[234,254]

One disadvantage of composite resin cores is the instability of the material in oral fluids (water sorption).[255,256] Oliva and Lowe[255] found that composite resin cores were not dimensionally stable when exposed to moisture. However, Vermilyea et al[257] found that the use of a well-fitting provisional restoration will provide the composite resin core with some degree of moisture protection. Hygroscopic expansion of composite resin cores and cements in layered structures with an overlying ceramic layer can generate significant stresses that have the potential to cause extensive cracking in the overlying ceramic layer. Clinically, this implies that all-ceramic crown performance may be compromised if the crowns are luted to composite cores that have undergone hygroscopic expansion.[258]

Another disadvantage is that composite resin is dimensionally unstable (setting shrinkage). Shrinkage during polymerization causes stress on the adhesive bond, resulting

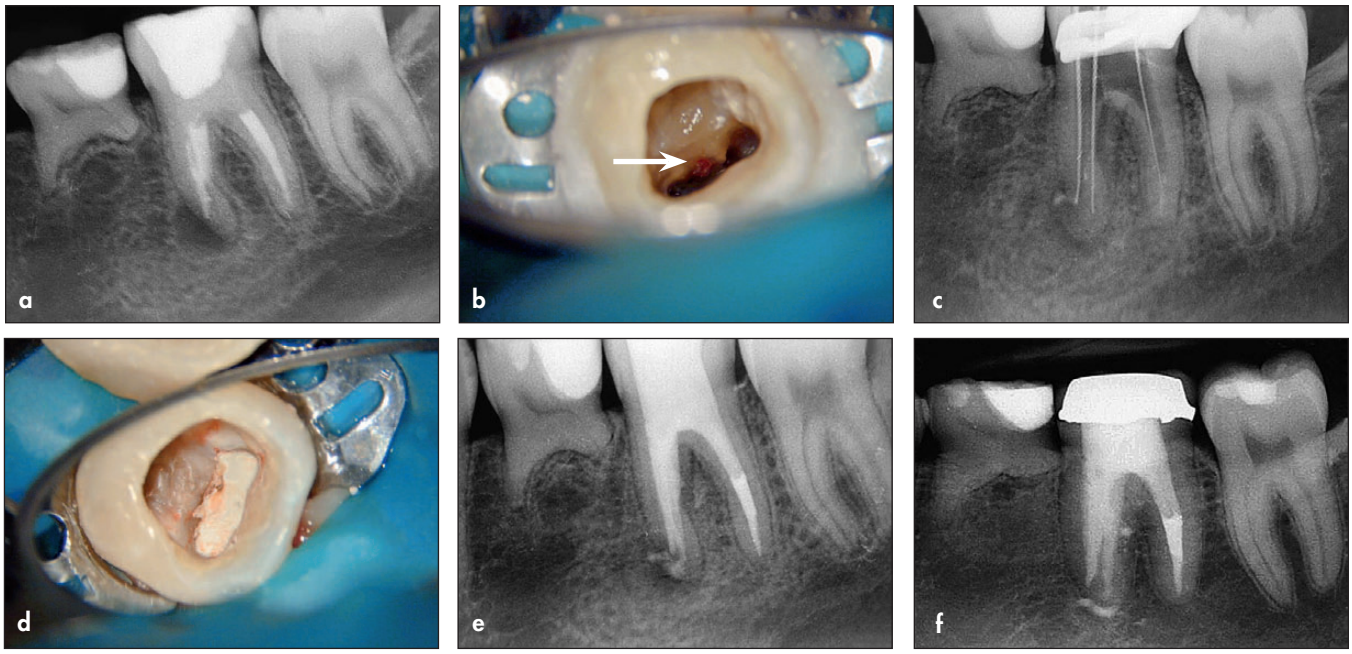

Fig 12-8 *(a)* Mandibular left first molar with a mesial root periapical radiolucency in a 13-year-old asymptomatic girl. The molar exhibits both strip and apical perforations from previous root canal treatment. *(b)* Strip perforation visible under the DOM at the furcal side of the mesial root *(arrow)*. *(c)* Working length determination after removal of previous obturation material. *(d)* White MTA canal obturation to the level of the pulpal floor. *(e)* Final radiograph of obturation and the fiber post and bonded core. *(f)* Radiograph at 7 years, showing the complete-coverage restoration and complete periradicular healing. The patient is asymptomatic with the molar in full function. (Courtesy of Dr Marga Ree, Amsterdam.)

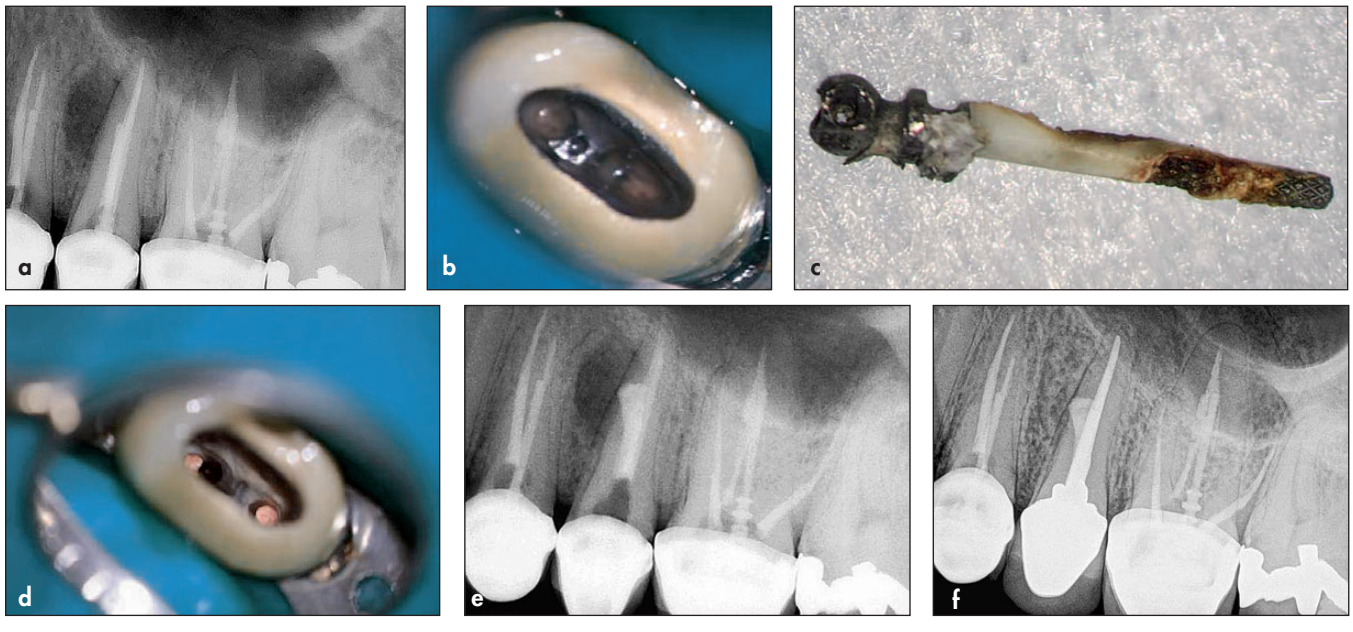

Fig 12-9 *(a)* Maxillary left second premolar in a symptomatic 24-year-old man with a suspected post perforation to the mesiobuccal root aspect. Note the well-circumscribed periradicular radiolucency adjacent to the perforation. *(b)* Completed access through the metal-ceramic crown. The coronal aspect of the post has been uncovered. *(c)* Post following removal. *(d)* Chamber after debridement of the perforation site and preparation for MTA placement. *(e)* Immediate postoperative radiograph following MTA perforation repair and subsequent completion of nonsurgical endodontic retreatment. *(f)* Ten-month radiographic review showing complete resolution of the periradicular pathosis. The patient is asymptomatic. (Courtesy of Dr Ryan M. Jack, Colorado Springs, CO.)

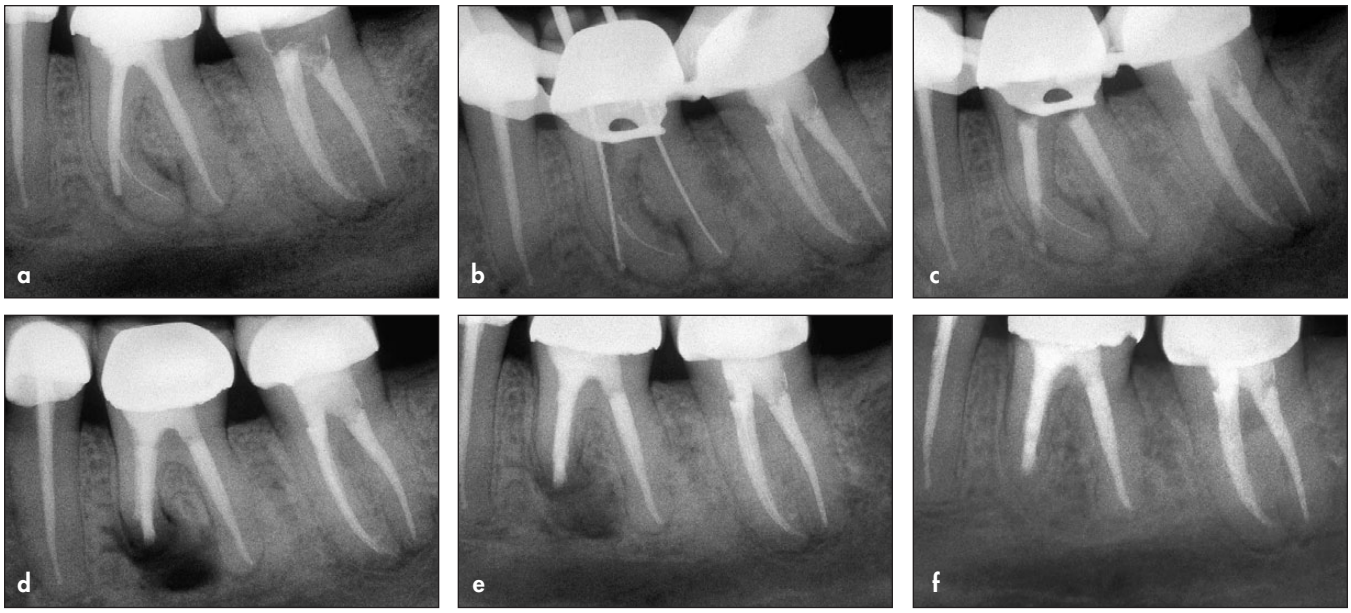

Fig 12-10 *(a)* Mandibular left first molar in a symptomatic 32-year-old man. Note the presence of a separated file at the mesial root apex and concomitant transportation and perforation of the mesial root canal during previous treatment. *(b)* Identification of the perforation site. *(c)* Canal obturation with gray MTA. *(d)* Surgical resection of the mesial roots, removal of the separated file, and MTA retrofill. *(e)* Nine-month radiographic review. *(f)* Three-year recall radiograph showing complete remineralization of the osteotomy site.

calcium hydroxide followed by placement of gutta-percha as a perforation repair and filling technique.[5,128–132] MTA can be placed with or without a matrix barrier; however, root-end resection may be indicated if the original canal is not accessible after the repair.[11] Where apical surgery is not an option, advanced techniques can also provide dedicated channels for conventional obturation after MTA placement and hardening.

Hemorrhage at the perforation site can be challenging when nonobservable subcrestal perforations are being prepared apically or beyond the view of the DOM. Once the perforation is identified, 1.25% to 6.0% NaOCl provides an environment that removes inflammatory tissue, controls hemorrhage, disinfects the perforation site, and conditions the surrounding dentin.[133–137] However, the solution must not be propelled into perforation areas because this can often cause severe tissue damage and paresthesia.[138–143] Sodium hypochlorite should always be delivered passively, using pipette carriers or cotton pellets, or placed in the pulp chamber and gently transported along the main canal using hand files, avoiding penetration at the wound site. The solution may also be delivered by inserting a small suction cannula into the canal beyond the perforation and then placing the liquid in the chamber to be passively drawn into the canal to beyond the defect. If the perforation does not include the main canal, then NaOCl is gently brought to the limit of the defect interface and frequently replenished until hemostasis is achieved.

Retrograde management of perforations

The goal of surgical repair of root perforations is to provide a reliable seal so that bacteria and their by-products are prevented from entering the periodontium through the root canal system. This procedure should encourage an environment that promotes regeneration of the damaged periodontal tissues and maintains immune cell surveillance. The indications for surgical treatment include excessive extrusion of the repair material, combination (orthograde and retrograde) therapies, perforations inaccessible by nonsurgical means, and failure of nonsurgical repairs[3,5,15,23,106] (Fig 12-10). The location of the perforation is the prime determinant in the strategy and material used in the surgical approach.[144]

According to Gutmann and Harrison,[106] certain aspects of the case must be considered before surgical treatment can be initiated:

- The amount of remaining bone and any surrounding osseous defects
- The overall periodontal status
- The duration and size of the defect
- The surgical accessibility
- The soft tissue attachment level
- The patient's oral hygiene and medical status
- The surgeon's soft tissue management expertise

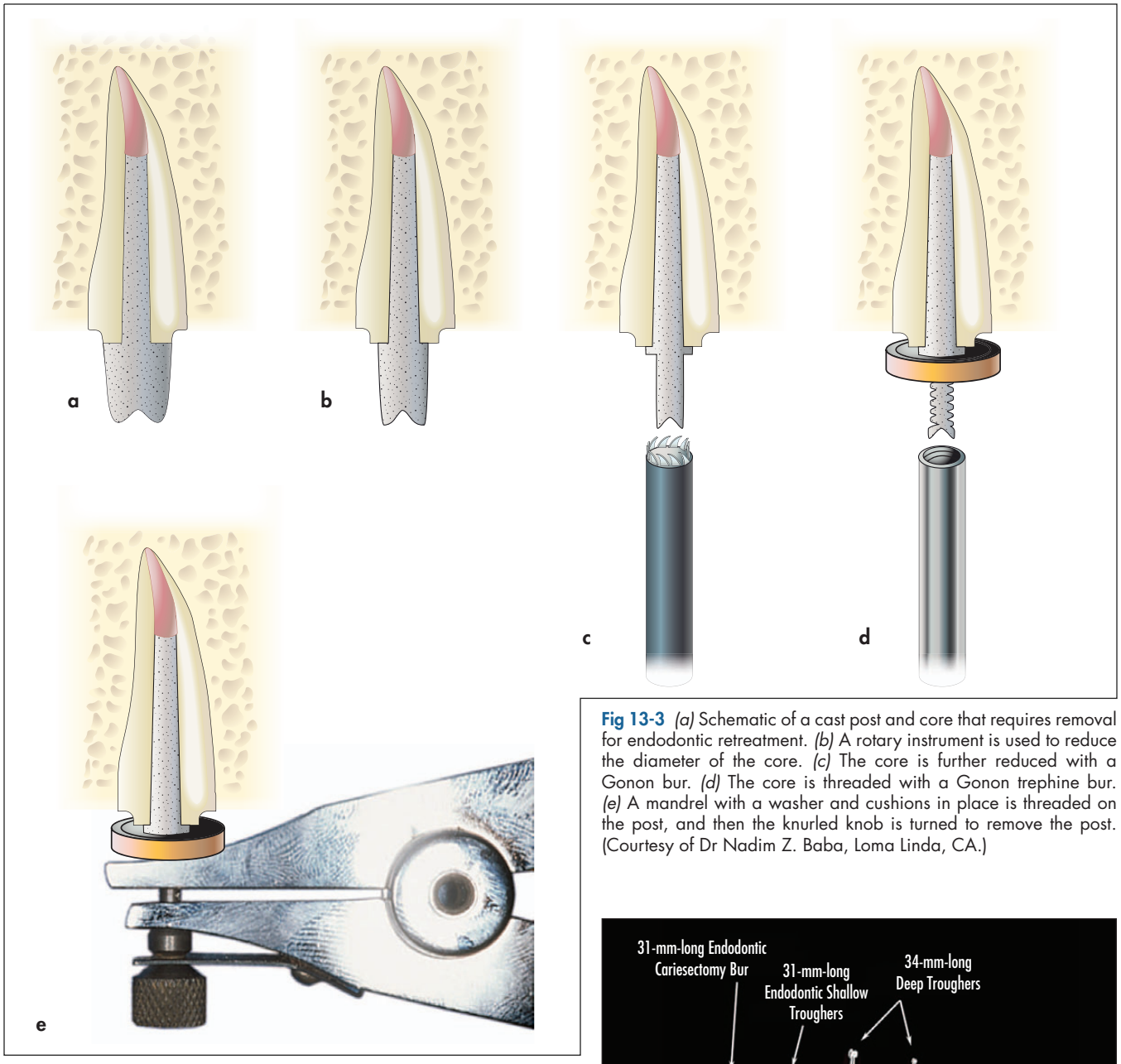

Fig 13-3 *(a)* Schematic of a cast post and core that requires removal for endodontic retreatment. *(b)* A rotary instrument is used to reduce the diameter of the core. *(c)* The core is further reduced with a Gonon bur. *(d)* The core is threaded with a Gonon trephine bur. *(e)* A mandrel with a washer and cushions in place is threaded on the post, and then the knurled knob is turned to remove the post. (Courtesy of Dr Nadim Z. Baba, Loma Linda, CA.)

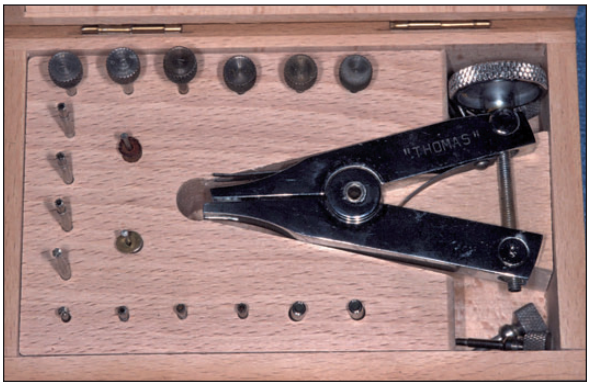

Fig 13-4 Gonon post puller device.

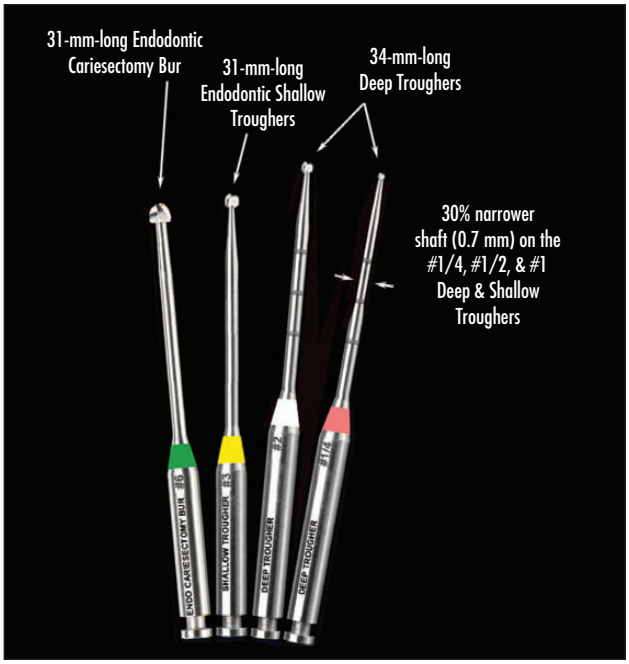

Fig 13-5 Munce Discovery Burs (CJM Engineering).

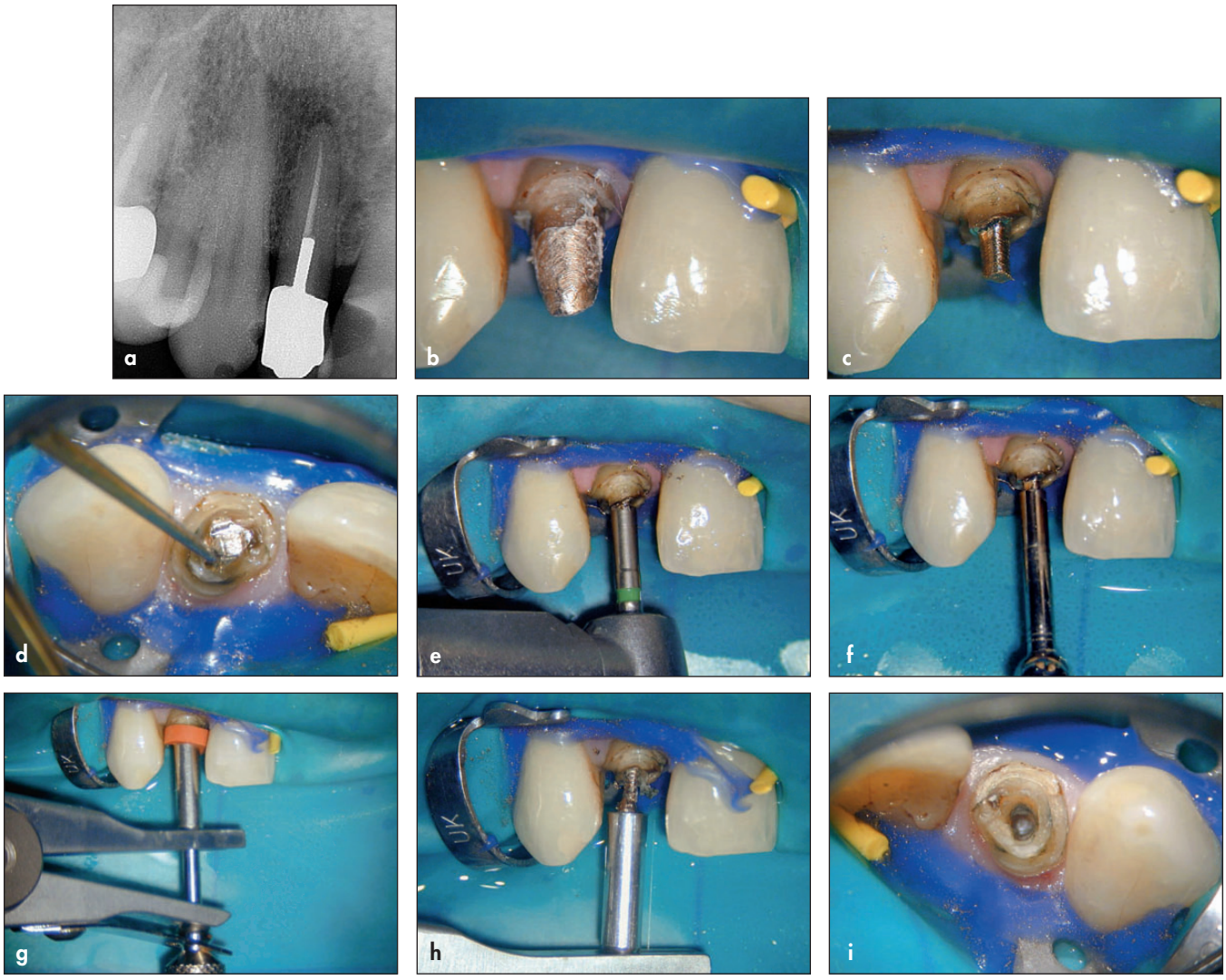

Fig 13-6 *(a)* Radiograph of a maxillary right lateral incisor with an apical lesion requiring the removal of a cast post and core and endodontic retreatment. *(b)* The cast post and core is isolated with rubber dam. *(c)* The cast post and core is shaped into a roughly cylindric shape. *(d)* A Munce Discovery Shallow Troughers (CJM Engineering) is used to remove the cement around the post. *(e)* A special bur is used to thread the head of the cast post and core. *(f)* Application of counterclockwise rotational force using the wrench. *(g)* Gonon post in place and ready to be used. *(h)* The screw is turned to open the jaws and create an extraction force. *(i)* Removal of post and preservation of the tooth structure. *(j)* Postoperative radiograph showing the endodontically retreated root canal and the definitive restoration. (Courtesy of Dr Marga Ree, Amsterdam.)

post to protect the tooth from the lifting action of the pliers (Fig 13-6). Should the post be successfully removed at this point, the retreatment of the tooth may proceed following inspection of the root to verify its integrity.

The Gonon post removal system is less invasive then the Masserann Kit and the LGPP and requires less removal of tooth structure.[11,38]

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