International Endodontic Journal (1993) 233, 273–283

Management of the resected root end: a clinical review

J. L. GUTMANN & T. R. PITT FORD*

*Department of Restorative Sciences, Baylor College of Dentistry, Dallas, Texas, USA; and *Department of Conservative Dental Surgery, United Medical and Dental Schools, Guy's Hospital, London, UK*

Summary

Careful management of the resected root end during endodontic surgery is critical to the overall success of the case. After resection, the root structure presents with multiple anatomical variations and considerations at both a macroscopic and microscopic level. These include root outline, canal anatomy, dentinal tubule configuration, presence of a smear layer and root canal filling material. Proper assessment of these variables will dictate the best methods for root-end management, along with the attainment of an anatomically compatible root face for optimal healing of the periradicular tissues.

Keywords: **dentine, endodontic surgery, resection, root end, smear layer.**

Introduction

Endodontic surgery encompasses multiple specific procedures designed to manage the compromised root system and periradicular tissues. A commonly performed procedure is root-end resection, often referred to as apicoectomy or apicectomy (Gutmann & Harrison 1991). The term root-end resection refers specifically to the removal of the apical portion of the root. The purpose of, and indications for, root-end resection are varied, and the rationale for its use resides in each individual case.

From an historical perspective, the surgical literature since the late 1800s has supported the following rationales for this procedure, although many of those cited may or may not be valid in contemporary endodontics.

Removal of pathological processes

This has included root resorption, fractured root tips, reactive or pathological tissues and potentially infected cementum and dentine at the root apex (Weaver 1947, Buch & Waite 1962, Leubke *et al.* 1964, Cummings *et al.* 1985). Little support presently exists for these rationales as the sole determinants for root-end resection.

Correspondence: James L. Gutmann DDS, Professor and Chairman, Department of Restorative Sciences, Baylor College of Dentistry, 3302 Gaston Avenue, Dallas, Texas 75246, USA.

Removal of anatomical variations

Commonly cited entities include severe canal curves, lateral and accessory canals, apical bifurcations or deltas, and calcifications (Johns 1977, Oliet & Grossman 1983, Barnes 1984, Nicholls 1984). These indications exist only when the anatomical variations have been implicated in case failure or are strongly suspected as potential contributors to failure. The validity of their rationale occurs only after attempts at quality non-surgical root canal treatment have failed.

Removal of operator errors in canal preparation

Despite the skill of the clinician, it is not uncommon for ledges, blockages, zips, perforations and separated instruments to occur (Nicholls 1962, di Lauro *et al.* 1980, Van Welsenes & Van der Kwast 1983, Panzoni 1985). These errors will only serve as valid rationales for surgical intervention if there is failure following attempts to non-surgically rectify the problem and patient signs or symptoms persist.

To enhance removal of the soft tissue lesion

Often, root-end resection will facilitate access to deeply placed granulation or cystic tissues (Gerstein 1985, Gutmann & Harrison 1985).

Access to the canal system

Curettage alone will not allow apical entry into a canal system which requires thorough cleaning, shaping and obturation, when it has not been properly managed through the crown (Vasiliu 1977, Oliet & Grossman 1983, Messing & Stock 1988). Therefore, a variable amount of the root apex must be removed to achieve this purpose, depending on root and canal anatomy.

Evaluation of the adaptation of the canal filling material

Removal of the root apex allows the clinician to assess three dimensionally the quality of the adaptation and nature of the root canal filling material (Leubke 1974, Harrison & Todd 1980) and to determine the need for a root-end filling.

To enhance the adaptation of the root canal filling material

This is probably the most commonly cited reason for root-end resection, especially when the canal system cannot be cleaned, shaped and obturated through the crown of the tooth (Herd 1968, Leubke 1974, Johns 1977).

Reduction of root apices which have fenestrated the bone

This occurs primarily in maxillary premolars and molars. With pulpal demise, the periosteum, which overlies roots with fenestrated bone, becomes inflamed. Root-end resection contours the root tip to lie within its bony housing (Gerstein 1985, Ruiz de Termino Malo *et al.* 1986).

Exploration for aberrant canal anatomy or root fractures

The resection of the root end enables direct vision of any canal aberrances or unsuspected root fractures (Taylor & Bump 1984, Gutmann & Harrison 1985, Kirschner 1987).

Consequences of root-end resection

Whilst substantial reasons exist for root-end resection, many controversies surround this procedure, especially as it relates to the amount of root removed. Historically, some authors have discouraged root-end resection because it opened dentinal tubules which might house bacteria, tooth stability in the alveolus would be compromised, and cemental healing might not occur on the exposed dentine. Whilst the validity of these arguments against resection were suspect, periradicular curettage was still advocated as a terminal, definitive procedure. In essence, the real cause of the periradicular problem was invariably not being addressed, as the soft tissue surrounding the root was only the result of continued irritation coming from the root canal system. Even in cases which appear radiographically acceptable, cleaning and shaping of the canal system is often below acceptable levels. Therefore, contemporary views support the need for root-end resection in most cases as being necessary to achieve the goals of the surgical procedure. The extent to which the removal of the root end should occur, will be dictated by the following factors (Gutmann & Harrison 1991).

(1) Access and visibility to the surgical site.
(2) Position and anatomy of the root within the alveolar bone.
(3) Anatomy of the cut root surface relative to the number of canals and their configuration.
(4) Need to place a root-end filling into sound root structure.
(5) Presence and location of procedural errors, e.g. perforation.
(6) Presence of an intra-alveolar root fracture.
(7) Presence of any periodontal defects.
(8) Anatomical considerations, such as root proximity to adjacent teeth, or level of remaining crestal bone.
(9) The presence of significant accessory canals. Roots with a likelihood of these anatomical aberrances would be likely to receive more extensive resection.

Resection technique

The technique of root-end resection uses a lingual to labial bevel, angled to the coronal aspect of the tooth. This is designed for surgical access and visibility. Angles for root bevels have been suggested to range from 30° to 45° in the line of sight, although variables in each case will determine the exact degree of cut (Luks 1956, Rud & Andreasen 1972, Cambruzzi & Marshall 1983, Gutmann & Harrison 1985). From the anterior to the posterior, the angle of the bevel will gradually go from a direct coronal–buccal cut to one that is accentuated coronally and mesio–buccally placed. These angles of resection and their use will also be determined by the root inclination and curvature, number of roots, thickness of bone and position of the root in the bone and arch.

The root end can be resected and bevelled in one of two ways. Once the root end has been exposed, the bur and handpiece are positioned at the desired angle and the root is shaved away, beginning from the apex, cutting coronally. The bur is moved from mesial to distal at the desired angle, shaving the root smooth and flat, and exposing the entire canal system and root outline. This approach allows for continual observation of the root end during the cut.

The second technique of resection is to predetermine the amount of root end to be resected. This approach however may remove more root structure than is essential. If chosen, the bur and handpiece are positioned at the ideal angle and the apex is resected by cutting through the root from mesial to distal. Once the segment is removed, the root face is gently shaved with the bur to smooth the surface and ensure complete resection and visibility of the root face. This technique works well when an apical biopsy is desired or to gain access to significant amounts of soft tissue located lingual to the root.

Anatomy of the resected root surface—macroscopic considerations

The appearance of the root face following root-end resection will vary, depending upon the type of bur used, the external root anatomy, the anatomy of the canal system exposed at the particular angle of resection chosen, and the nature and density of the root canal filling material.

Bur type

Various types of bur have been recommended for root-end resection, such as round burs, straight fissure burs, diamond burs, and cross-cut fissure burs (Gutmann & Harrison 1991). Each will leave a characteristic anatomical imprint on the root face, from rough-grooved and gouged to regularly-grooved and smooth. To date, no study has clearly defined the advantages of one type of bur over the other, with regard to surface morphology or tissue healing response. For years, however, clinical practice has favoured a smooth flat root surface (Moorehead 1927, Sommer 1946, Trice 1959, Gutmann 1986).

External root anatomy

The external root anatomy will determine the ultimate shape of the cut root end, as oval, round, dumb-bell shaped, kidney-bean shaped, or tear-drop shaped. Outlines will vary depending on the tooth, angle of the bevel and position of the cut on the root. Once cut, however, the entire surface must be visible. If visibility or access is impaired, or the root possesses an unusual cross-sectional outline, 1% methylene blue dye can be placed on the root surface to help identify the periodontal ligament that surrounds the root (Cambruzzi & Marshall 1983). A small cotton pellet containing dye is wiped over the root face for 5–10 s. Subsequently the area is flushed with sterile water or saline. The dye will stain the periodontal ligament dark blue, highlighting the root outline (Fig. 1). A potential drawback to this technique may be the deposition of cotton fibres on the resected surface or in the osseous wound. Residual remnants of cotton fibres have been shown to induce a foreign-body reaction in the healing tissues (Gutmann & Harrison 1991).

Anatomy of the canal system

The shape of the exposed canal system will vary depending on the angle of the bevel and the canal anatomy at the level of the cut. Canal systems will generally assume a more elongated and accentuated shape as the angle of the bevel is increased buccally (Fig. 2). Often, canals will be irregular and extend further than anticipated, thus, additional root structure may have to be removed to ensure exposure of the entire system.

Root canal filling material

In addition to the variations with different materials, e.g. gutta-percha, silver cones, pastes, the nature of the filling technique, e.g. lateral condensation, vertical condensation, or thermoplastic fillings, will provide a different view of the canal contents and their adaptation to the root canal walls (Fig. 3). Likewise, the different burs advocated for resection will create discrepancies in the surface of the filling material and adaptation to the canal walls. For example, coarse diamond burs will tend to rip and tear at the gutta-percha root canal filling, spreading the gutta-percha over the edge of the canal aperture and onto the resected root face (Fig. 4). Invariably this will create gaps between the originally adapted gutta-percha and the root canal wall. Similar findings are noted with fissure burs and round burs (Gutmann & Harrison 1991). In order to prevent this, surface finishing with an ultra-fine diamond is recommended (Ultrafine No. 862-012 diamond bur; Brasseler, Savannah, GA, USA; Komet, Lemgo, Germany).

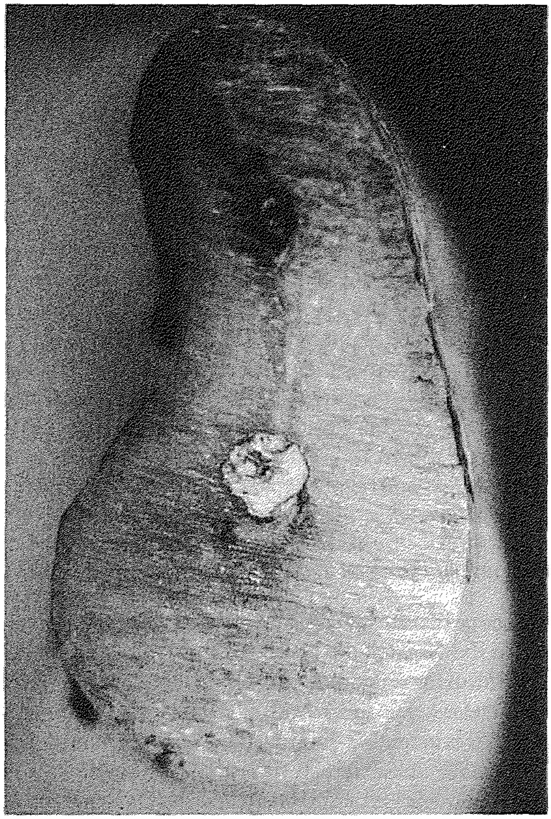


Fig. 1. Outline of resected root, *in vitro*, delineated by staining of the periodontal ligament with methylene blue.

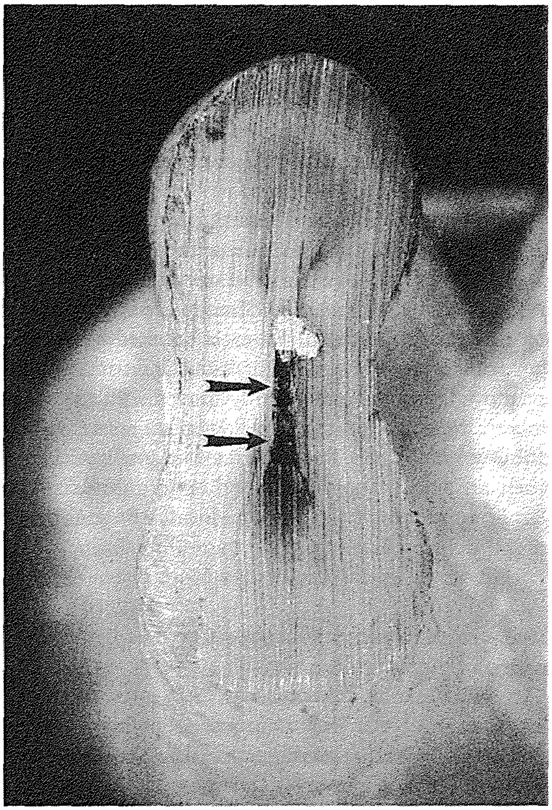


Fig. 2. Elongated canal on resected root surface delineated with methylene blue. Note extension (arrows) beyond gutta-percha filling.

Clinical considerations

The complete root face must be identified and examined subsequent to resection. The examination is done with a fine, sharp probe, e.g. DG 16/17 (Hu Friedy, Chicago, IL, USA), guided around the periphery of the root and the root canal. The presence of additional foramina, anastomoses between foramina, fracture lines, and the quality of the apical adaptation of the root canal filling must be checked (Fig. 5). If methylene blue has been used, it will also have a tendency to stain the periphery of the canal system and highlight fracture lines. Nitromersol, a dental disinfectant which stains reddish-brown, can also be used when examining the root face or a fibre-optic light can be aimed at or behind the root end to enhance visibility (Arens *et al.* 1981). If these methods do not work, it may be necessary to remove additional root structure to identify the canal system or, in the case of a fracture line, to enhance its direction and extent. Once the surface extent of the canal system has been identified, and it is determined that there is uncleaned or unfilled space, a root-end preparation is made with a bur or with an ultrasonic tip to clean the apical extension of the canal space and to create a cavity for obturation.

Anatomy of the resected root surface—microscopic considerations

Dentinal tubules

The consequence of exposing resected dentinal tubules to the periradicular tissues has been a controversial issue for many years. Claims were made that ideal healing could not occur against the tubules in the form of layered cementum and periodontal ligament (Barron *et al.* 1947, Pearson 1949, Curson 1966, Wakeley & Simon 1977). However, it has been shown that cementum can reform over the resected tubules and that a periodontal encapsulation with varying degree of fibre attachment can

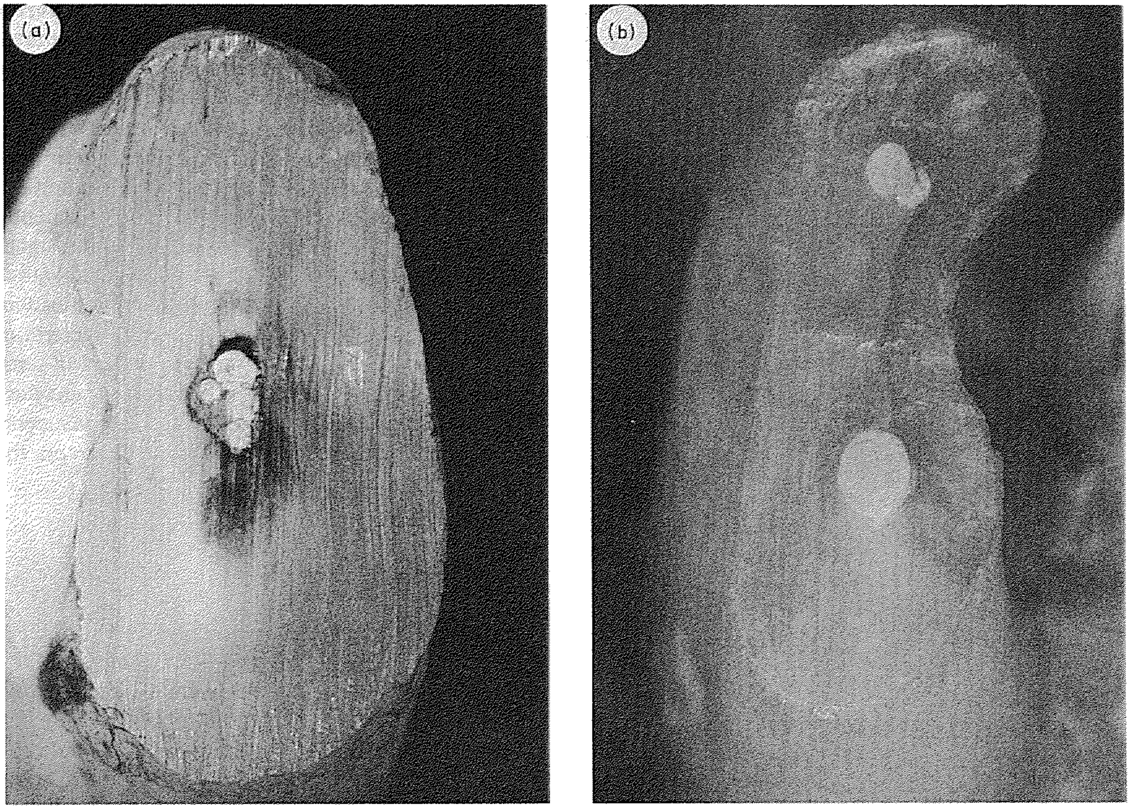


Fig. 3. (a) Appearance of laterally condensed gutta-percha cones after resection. Note lack of condensation and large amount of root canal sealer. (b) Resection of vertically condensed thermoplasticized gutta-percha.

occur (Coolidge 1930, Herbert 1941, Blum 1945, Smith 1967, Rowe 1967, Andreasen 1973, Craig 1990).

A second controversy is that exposure of the dentinal tubules would expose the periradicular tissues to bacteria entrapped in the tubules (Fawn 1927, Ross 1935, Castenfeldt 1939). However, no correlation could be shown by Andreasen & Rud (1972) between the presence of micro-organisms in the dentinal tubules and the degree of periradicular inflammation. Likewise, because the number of tubules in the apical third would be significantly reduced in both number and patency, with ageing and sclerosis (Fig. 6) (Carrigan *et al.* 1984, Ichesco *et al.* 1991), coupled with root-end resection, this would tend to reduce the number of bacteria in the region significantly, especially since the majority of bacteria in the apical third have been shown to be located immediately adjacent to the root canal system (Jolly & Sullivan 1956, Shovelton 1964) and good canal cleaning and shaping would tend to eliminate them from this area. Although bacteria retained in the root canal system has been implicated in endodontic failure (Lin *et al.* 1991) and may, therefore, have access to the periradicular tissues following resection, Nicholls (1965) has taken an opposite view stating that, 'the exposure of dentinal tubules which may have been contaminated at their pulpal ends, although sometimes constituting a criticism of apicectomy in the past, is probably of little or no significance.'

A third area of concern following tubule exposure is the possibility that these channels may serve as a direct course of contamination from unclean root canals into the periradicular tissues, especially if there is coronal leakage into the root canal system. Tidmarsh & Arrowsmith (1989) have shown that root ends resected from 45° to 60° have as many as 28 000 tubules mm^{-2} at a point immediately adjacent to the canal. At the cemental–dentine junction, an area which may communicate with the root canal even in the presence of a root-end filling, an average of 13 000 tubules mm^{-2}

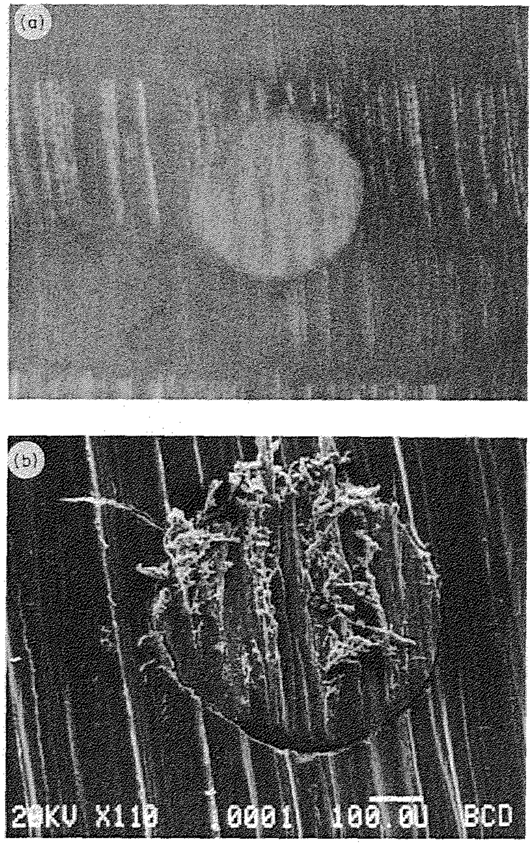


Fig. 4. (a) Root end resected with coarse diamond bur. Note smearing of the gutta-percha onto the resected surface. (b) SEM shows smearing of gutta-percha tags and gaps between the root canal filling and wall (bar = 0.1 mm).

were found. Likewise, owing to angular changes in the tubules at the apex, there could be patent communication with the main canal if the depth of the root-end preparation in the buccal aspect of the cavity was insufficient to compensate for these anatomical variations (Vertucci & Beatty 1986, Beatty 1986). Recently, Ichesco *et al.* (1991) have shown that root-end resections in older teeth evidenced less leakage than that seen in teeth from younger patients; this corroborates with the findings of sclerosis and reduced patency in the apical dentinal tubules (Carrigan *et al.* 1984). It was suggested that if the apical ramifications commonly found in young teeth could be dismissed as a rationale for root-end resection, the resection would be inadvisable owing to the patency of the apical dentinal tubules.

Fourth, the presence of a contaminated smear layer, containing microorganisms and tissue debris, over the resected root end may serve as a source of irritation to the periradicular tissues, primarily preventing the intimate layering of cementum against the resected tubules. While this concern is primarily clinical in nature and has not been demonstrated in human specimens, short term animal studies in which vital, uncontaminated teeth were treated endodontically followed by root-end resection and smear layer removal have shown favourable cemental apposition (Craig 1990). At the same time, the smear layer may actually block the tubules and serve as a source of obturation of the potential avenues of communication, especially with tubules contaminated with bacteria or those exposed to oral fluids over long periods of time. Experiments designed to evaluate these parameters are essential, because there is no unequivocal data to support the proper management of the smear layer on the resected root surface.

Clinical considerations

Depth and type of root-end preparation

In order to seal the potential avenues of communication from the resected root end to the canal system adequately, a root-end preparation should be made into the root to the coronal extent of the resected apical tubules. This will vary from case to case, but generally a depth of 2–4 mm would be sufficient (Taylor & Doku 1961, Rud & Andreasen 1972, Barry *et al.* 1975). This can either be made with a rotary bur, such as inverted cone or round bur (ISO size 008) at high- or low-speed, or with specially angulated tips adapted for use on an ultrasonic unit (ENAC, Osada Electric Co., Los Angeles, CA, USA). This approach to root-end preparation assumes that a standard type of filling material, such as amalgam with varnish, will be placed. However, the approach to and the design of the preparation may vary if other contemporary restorative materials are used. While the purpose of the paper is not to address these materials, the practitioner must take these potential variations into account during root-end preparation.

Recent enhancements in apical root-end preparation have resulted from the development of 'ultrasonic retrotips' (Excellence in Endodontics, San Diego, CA, USA) (Carr 1990). These small, angled tips have been advocated for the ultrasonic development of apical preparations parallel to the long axis of the root after minimal root-end resection. Their use in the debridement and enlargement of canal anastamoses and irregularities commonly found in molar roots has received particular

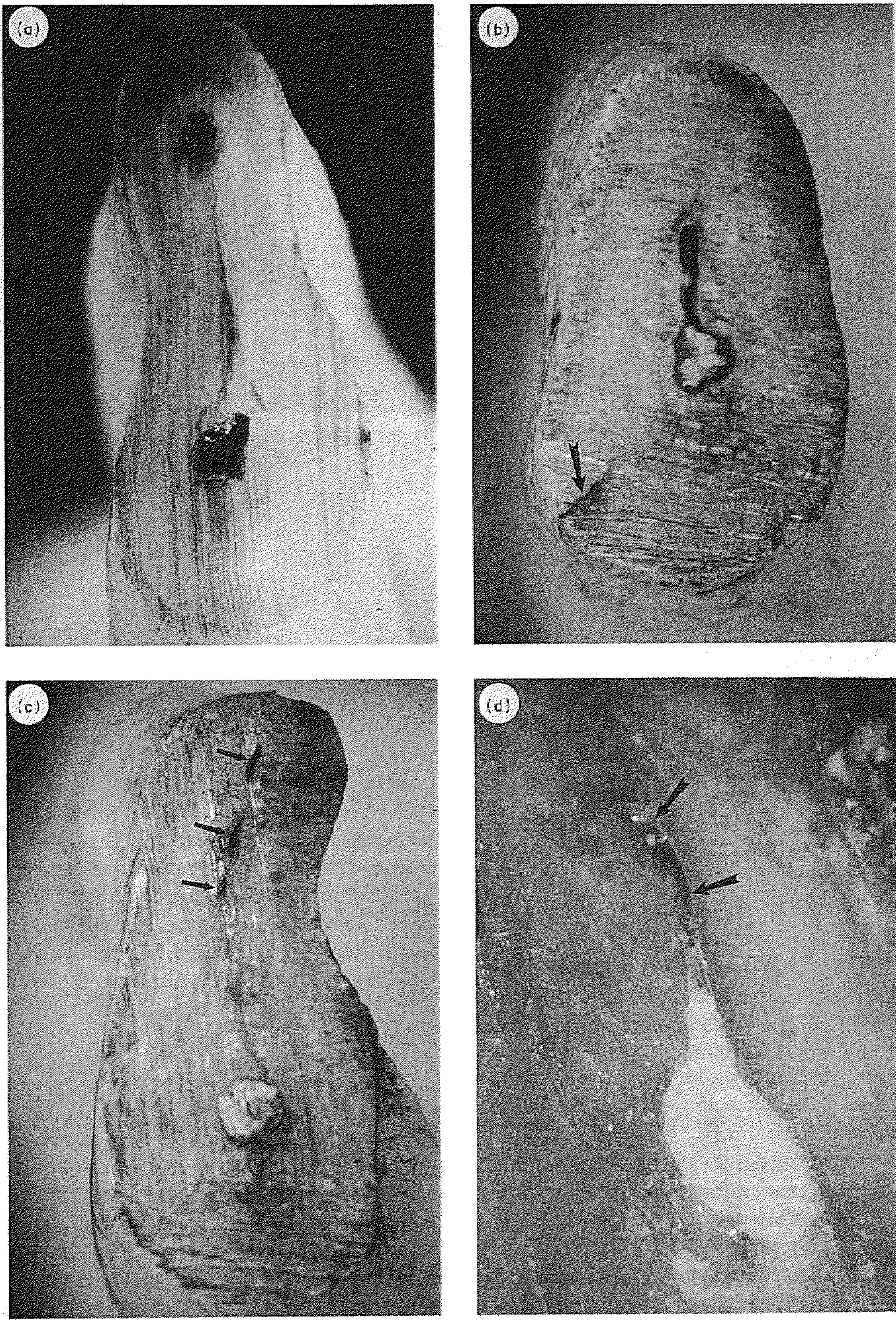


Fig. 5. Resected root ends showing anatomical variations. (a) Canals and anastomosis visible. (b) Poor gutta-percha condensation and canal extension; fracture visible in the root (arrow). (c) Palatally extended canal space (arrows) of mesial buccal root of a maxillary first molar. (d) Gutta-percha filling of canal and small portion of anastomosis. Note necrotic tissue debris in canal extension (arrows).

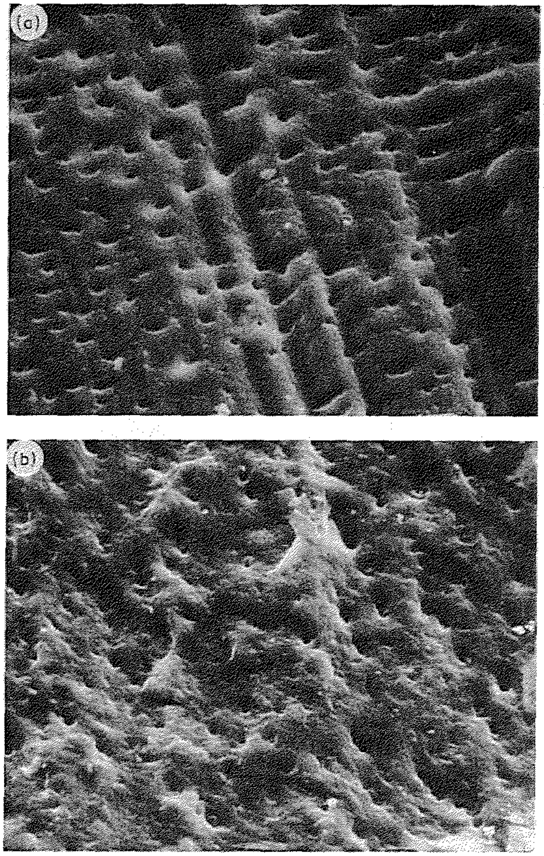


Fig. 6. (a) Apically resected dentine with smear layer removed. Note small numbers of dentinal tubules and variations in their patency. (b) Apically resected dentine with smear layer removed. Note amount of tubular sclerosis.

attention. While empirical experience favours their usage, there were no studies or evaluations published to provide the complete parameters of their efficiency and effectiveness, at the time of submission of this paper.

Methods of resecting the root surface—smear layer

The technique of resection from a macroscopic level has been discussed. From a microscopic level, resection which removes dentinal debris and irregularities is favoured (Fig. 7). Eick *et al.* (1970) have shown that debris generated during the cutting of tooth structure, i.e. the smear layer, is similar with diamond or tungsten carbide burs when prepared wet or dry. Gwinnet (1984) reported that with tungsten carbide burs, gaps occurred in the smear layer due to tearing and brittle fracture of the dentine by the cutting edges of the bur. Also, Gwinnet

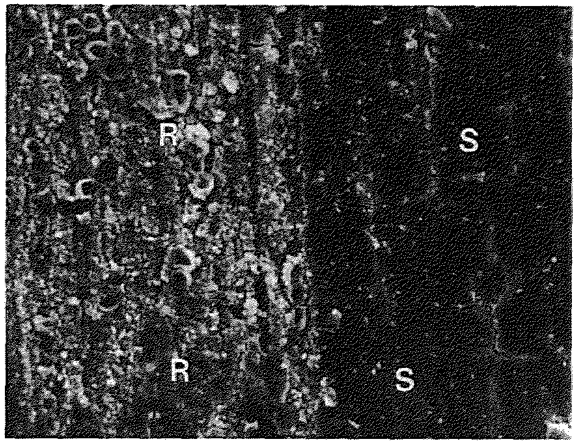
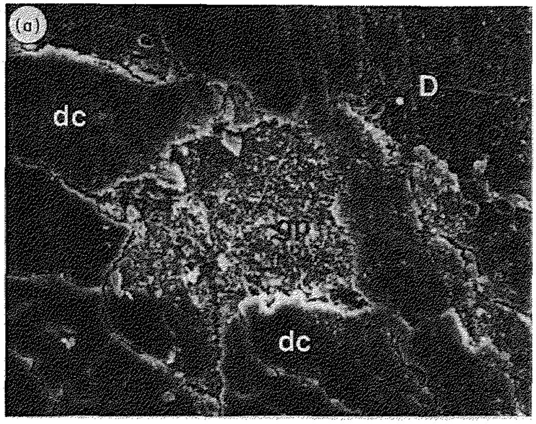


Fig. 7. Variations in appearance of smear layer on apically resected dentine from smooth (S) to rough (R) with accumulations of dentinal debris.

(1984) noted that there was little difference in appearance of the smear layer when tungsten carbide burs were run at high speed with or without water. However, when diamond burs were used, the water appeared to significantly reduce the smear layer compared with dry cutting. In this regard, Pashley (1984) has also indicated that a thicker smear layer is usually created by cutting without waterspray than with a heavy air–waterspray. Brannstrom *et al.* (1979) also noted that coarse diamond burs generally created a thicker smear layer than tungsten carbide burs. Therefore, it is recommended that root-end resection be performed under constant irrigation, which assists the partial removal of the dentinal smear layer from the surface. Also, if diamond burs are used to resect the root, a medium grit is preferred, followed by a fine or ultrafine grit diamond. If there is a gutta-percha root canal filling resection without irrigation may promote the lodging of dentine chips in the gutta-percha, which could serve as a source of irritation if contaminated. These chips may not be removable during the elimination of the smear layer with a dentinal cleanser (Fig. 8).

Removal of smear layer and dentine demineralization

In common with procedures in operative dentistry and periodontics, removal of the smear layer and exposure of the apical collagen fibres is recommended after root-end resection, primarily to remove potentially contaminated debris and to enhance the healing environment for cemental deposition. However, the nature of the dentine



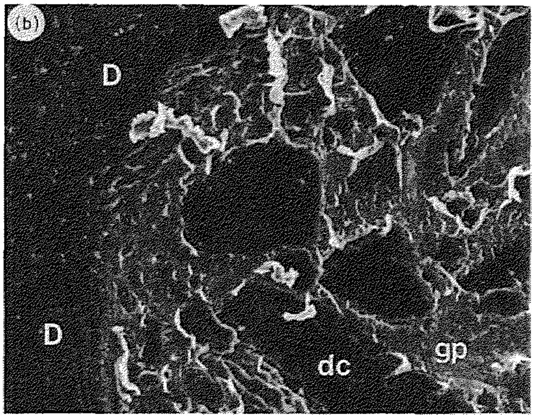


Fig. 8. (a) Apical dentine resected without water. Note dentine chips (dc) embedded in gutta-percha (gp); dentine (D). (b) Removal of smear layer shows clean dentine chips with exposed patent tubules and no evidence of dentinal debris (dc) embedded in gutta-percha (gp); dentine (D).

cleanser to achieve this ideal is uncertain, as various agents have been recommended, such as phosphoric acid (Passanezi *et al.* 1979, Goldberg 1984), ethylenediamine tetra-acetic acid (Boyko *et al.* 1980), hydrochloric acid (Register 1973, Ruse & Smith 1991), and citric acid (Register & Burdick 1975, Crigger *et al.* 1983, Bostanci *et al.* 1990). Also, times of exposure and demineralization have been highlighted, as has the optimal pH for activity. Codelli *et al.* (1991) indicated that the optimal exposure of collagen and demineralization occurred with a burnishing application of citric acid (pH 1.0) for 3 min. Longer applications resulted in collagen denaturation. However, Sterrett *et al.* (1991) have shown that the peak activity pH of citric acid was 1.42, beyond which effective dentinal demineralization diminished. Craig (1990) showed that demineralization of resected root ends with

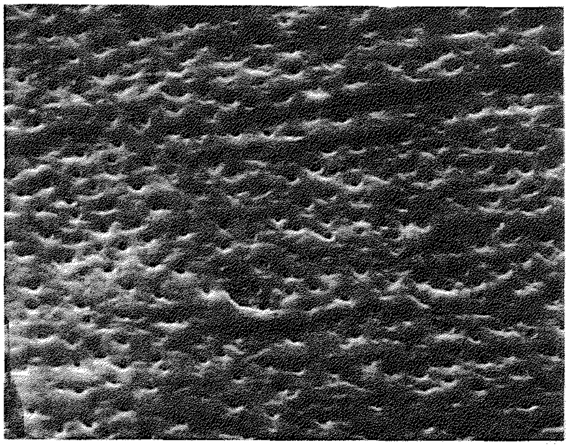


Fig. 9. Removal of smear layer from resected root end with 10% citric acid and 3% ferric chloride. Dentine is clean and tubules are patent.

a 2-min burnishing of a 50% citric acid solution at pH 1.0 consistently resulted in a rapid and predictable layering of a cementoid type of material on the resected surface of dogs' teeth after 45 days. No direct application to human teeth, under similar circumstances, has been studied.

What appears to be crucial to ultimate healing and cemental deposition is the stabilization of the exposed collagen fibres along with minimal demineralization. Failure to do such may account for the discrepancies seen in the periodontal literature regarding the use of different concentrations of citric acid at various times. Likewise, the exact benefits of the citric acid are still considered speculative and in need of further research (Nery *et al.* 1990). In essence, all that may be necessary to accomplish the ideal healing at the resected root end may be the removal of the smear layer and retention of the smear plugs, as proposed by Brannstrom (1984), with the use of Tubulicid (Tubulicid Blue Label, Tubulicid Red label; Dental Therapeutics AS, Nacka, Sweden) in coronal cavities. However, Pashley (1984) believes that this may be difficult to achieve clinically.

Recent studies by Mizunuma (1986) and Wang & Nakabayashi (1991) have identified the use of the Fe^{3+} ion, in the form of an aqueous solution of 10% citric acid and 3% ferric chloride (10:3), to stabilize dentine collagen during the demineralization process (Fig. 9). However, applications were limited to less than 30 s, as longer exposure increased demineralization and denaturation of the collagen. This approach has enhanced the bonding that occurs with restorative materials, and may also stimulate adhesion of the exposed, intact collagen with fibrin and fibronectin

(Polson & Proye 1983) and the splicing of collagen with newly formed collagen fibrils (Ririe *et al.* 1980) during the wound healing process. Further work with this material and other potential dentinal cleansers on the resected root end are warranted prior to their wholesale recommendation.

Summary

There is substantial rationale for root-end resection in periradicular surgery. Once resected, the root end poses a myriad of concerns relative to the management of the root canal filling and the exposed dentinal tubules. Procedures designed to minimize local irritational factors and to enhance true periradicular healing are recommended from both a clinical and biological standpoint. Areas requiring further investigation have been highlighted in an attempt to stimulate research into these clinically relevant issues.

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