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Ultrasonic root-end preparation Part 2. Microleakage of EBA root-end fillings

W. P. SAUNDERS* E. M. SAUNDERS† & J. L. GUTMANN‡

Department of Adult Dental Care, Glasgow Dental Hospital and School, Glasgow G2 3JZ, †Department of Conservative Dentistry, The Dental School, University of Dundee, Dundee DD1 4HR, UK and ‡Department of Restorative Sciences, Baylor College of Dentistry, Dallas, Texas 75246, USA

Summary

The effect of three methods of root-end preparation, following apical resection, on the apical seal of root-end fillings, was studied *in vitro*. Root canals of 116 single-rooted teeth with mature apices were prepared chemo-mechanically and obturated with gutta-percha and sealer. The root ends were resected with a diamond bur under water coolant and were prepared as follows: group I a size 010 round bur was used to prepare an apical cavity 2–3 mm down the long axis of the root; group II treatment as per group 1 followed by a 60-s rinse with a solution of 10:3 (10% citric acid: 3% Fe_2Cl_3); and group III an ultrasonic retrotip was used to prepare a 2–3 mm deep apical cavity. The root end was restored with an EBA cement. Apical leakage was determined using India ink after 7 days and 7 months. The teeth were demineralized, rendered transparent and linear dye penetration was recorded. Results showed that there was no significant difference in leakage between the groups at each time interval ($P>0.05$) but there was increased leakage after 7 months ($P<0.01$). Cracking of the root surface was seen most often with the ultrasonically prepared roots ($P<0.001$).

***Keywords*: EBA cement, leakage, root-end filling, ultrasonics.**

If non-surgical retreatment of failed root canal therapy is impossible or impractical, periradicular surgery may be required. Such surgery usually involves resecting part of the root apex, preparation of an apical cavity, and improving the seal of the root canal by placing a root-end filling (Gutmann & Harrison 1985, 1991). There has been little evaluation, however, on the quality of the root-end preparation, with the majority of studies directed to the seal provided by the filling material.

Recent advances in root-end preparation techniques suggest that a superior root-end preparation can be created with an ultrasonic unit and specially devised retrotip (Carr 1992). Cited advantages for this technique are numerous (Carr 1992, Gutmann *et al.* 1994) and Part 1 of this study examined the quality of the root-end preparation created by using this type of preparation compared with a standard bur preparation technique and a bur preparation technique in which the cavity was rinsed with a cavity cleansing solution, 10% citric acid: 3% ferric chloride (Gutmann *et al.* 1994). While it was found that none of the preparation techniques resulted in a clean root-end preparation, the ultrasonic preparation resulted in the lowest amount of superficial debris. The least amount of smear layer, however, was identified in the apical preparations which were rinsed with the acid cleanser. Because cavity debris, in particular the smear layer, has been implicated in apical leakage and suggested as a source of bacterial sustenance during leakage (Pitt Ford & Roberts 1990), the evaluation of apical cavities, prepared under clinical conditions and obturated with an acceptable root-end filling material would be warranted.

A number of materials have been evaluated for use as apical filling materials. These include amalgam, gutta-percha, silver cones, zinc oxide–eugenol cements, composite resins, Cavit, polycarboxylate cements and glass polyalkenoate cements (Gutmann & Harrison 1991). While amalgam is the most commonly used material, it has been shown not to provide a good apical seal (Thirawat & Edmunds 1989), especially as it is not usually placed in a cavity that has been previously varnished (Tronstad *et al.* 1979). In addition, the biocompatibility of amalgam has been questioned, as has the use of mercury, on both toxicological and environmental grounds.

An EBA cement, Staline Super (Staident International, Staines, Middlesex, UK) was shown by Hendra

Correspondence: Professor William P. Saunders, Department of Adult Dental Care, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow G2 3JZ, UK.

(1970) to be suitable as a root-end filling material. This material consists of a powder of 60% zinc oxide, 34% silicon dioxide and 6% natural resin. This is mixed with a liquid consisting of 62.5% ortho ethoxybenzoic acid and 37.5% eugenol. The set cement has high compressive and tensional strength, neutral pH and low solubility. Even in moist conditions the material adheres to tooth structure. Stailine has been shown to produce a good healing response by Oynick & Oynick (1978). They found, using scanning electron microscope evaluation, that collagen fibres grew over the material and into the cracks present on the surface of the material.

In a number of *in vitro* leakage studies EBA cement has demonstrated less leakage compared with other retrograde filling materials (Beltes *et al.* 1988, King *et al.* 1990, Bondra *et al.* 1989). None of these studies have investigated leakage for longer than 8 weeks. In a further study retrofillings of EBA cement were shown to leak significantly more than glass ionomer, light-cured composite resin with and without dentine bonding agent, and dentine bonding agent alone (Thirawat & Edmunds 1989). However, this was an *in vitro* study and it is generally accepted that glass ionomer cements and composite resins may be more difficult to manipulate clinically at the root end (Pitt Ford & Roberts 1990). Clinically, the use of EBA cement has produced acceptable results. Dorn & Gartner (1990) found that success rates, over a 10-year period, were significantly better with EBA cement (95% with 65 cases) compared with a non-zinc high-copper amalgam (75% with 294 cases).

The purpose of Part 2 of this study was to evaluate, *in vitro*, the apical seal, both in the short and long term, created by EBA root-end fillings placed in cavities created with a bur only, a bur followed by acid cleanser rinse, and ultrasonic retrotips.

Materials and methods

One-hundred and twenty single-rooted extracted human teeth with fully developed apices and straight roots were used in this study. The teeth were stored in deionized water, with a few crystals of thymol, prior to use. Each tooth was sectioned at the amelo-cemental junction using a water-cooled diamond bur, and the crown discarded. The root canals were prepared chemo-mechanically using the modified double-flared technique (Saunders & Saunders 1992), rinsed with 2.5% sodium hypochlorite, and dried with paper points. The root canals were then obturated with gutta-percha using the hybrid technique as described by Tagger (1984) using Sealapex (Kerr, Romulus, MI, USA) as the sealer. The teeth were then stored in physiological saline for 2 months.

One-hundred and sixteen of the root-filled teeth were divided into two groups, of 59 and 57 teeth. These were to be tested for leakage after 7 days and 7 months, respectively. The remaining four teeth were to act as controls and were divided into two groups of two teeth each. Root ends were resected at a 45° angle using a high-speed diamond with water spray and apical cavities were prepared as in Part 1 of this study.

Group I

A size 010 round bur in a slow-speed handpiece with water cooling was used to prepare a cavity 2–3 mm down the long axis of the canal. All visible gutta-percha was removed from the cavity walls. Cavities were rinsed with water and dried with paper points.

Group II

Following cavity preparation as in group I, a solution of 10% citric acid and 3% ferric chloride (10:3) (pH = 1.62) was used to lightly flush the apical cavity and resected root surface for a period of 60s. Subsequently, the cavity was rinsed with water and dried with paper points.

Group III

A 2–3 mm deep apical cavity was cut using an ultrasonic retrotip on the ENAC ultrasonic system (Osada Electric Co., Los Angeles, CA, USA), at a power setting of 10 under water spray. All cutting occurred in a range of 3–5 min. Cavities were dried with paper points.

All cavities in the experimental groups of teeth were restored with Stailine EBA cement. This was mixed according to the manufacturer's instructions and placed into the cavity in the root-end with a plastic instrument. A fine round-ended amalgam plugger (Shofu, Tokyo, Japan) was used to pack the material to the full depth of the cavity. Each tooth was placed in a cotton gauze square which had been dampened with physiological saline solution. The teeth were stored in an incubator at 37°C and 100% relative humidity and the quality of the apical seal was evaluated after the appropriate time.

Apical leakage was detected using a dye. Each tooth was coated with two layers of nail varnish (Boots No. 7, Boots Manufacturing Co, Nottingham, UK) except for the resected root end. As soon as the varnish had dried the teeth were suspended in India ink (Windsor and

Newton, London, UK) at 37°C for 90 h. Excess dye was rinsed from the roots and the varnish removed with a sharp scalpel. The teeth were then demineralized in 11% nitric acid for 48 h. At the end of this time a pin could be passed through an unimportant part of the root, indicating that demineralization was complete. Following thorough rinsing with water, dehydration was carried out sequentially in 70%, 95% and 100% iso-propyl alcohol, and the teeth rendered transparent by storage in methyl salicylate.

The root ends of one of the groups of control teeth were also restored with Stailine following cavity preparation of the root end with a bur. In the second group, however, the cavity was left unfilled after preparation of the Class I cavity with a bur. In the first group of teeth nail varnish was applied to the complete tooth surface, including the root end. This was the negative control group. In the second group the varnish was applied to all surfaces except the root end. These teeth were the positive controls. The control teeth were tested for leakage in the same way as the experimental groups, after storage for 7 days.

The amount of dye leakage was measured using a stereoscopic microscope at ×6 magnification. The maximum depth of penetration of dye from the resected root end was measured with the aid of a calibrated eyepiece graticule. The degree of leakage was measured according to the following criteria: 0 = no leakage; 1, up to 0.5 mm; 2, > 0.5–1.0 mm; 3, > 1.0–2.0 mm; and, 4, > 2.0 mm. These data were analysed using the Kruskal-Wallis test, corrected for ties, to determine if there were statistically significant differences between the groups, at each time interval. Leakage for groups of teeth that had been subjected to the same root-end preparation but stored for different times was compared using the Mann–Whitney U test.

Results

Tables 1 and 2 show the frequency of leakage scores for each of the experimental groups. In the controls there was no leakage detected in the negative control group, while there was leakage along the length of the Class I cavity in the positive group. In the latter group this extended into the gutta-percha root filling in both specimens.

Statistical analysis showed that there were no significant differences in leakage between the groups stored for 7 days (P=0.41) or for 7 months (P=0.13). Comparison between the 7 month and 7 day groups, for each root-end preparation technique, showed that there was significantly more leakage after 7 months than after 7 days (P<0.01).

It was noted that in a number of teeth there was cracking of the root end, and in some cases of the surface of the root (Table 3). Statistical analysis, using the χ^2 test showed that there was significantly more cracking of the teeth where the root end had been prepared with the ultrasonic instrument (P<0.001).

Table 1. Leakage scores for teeth stored for 7 days

Root-end preparation	Number of specimens	Leakage scores				
		0	1	2	3	4
Bur only	20	10	8	1	1	0
Bur/10:3 solution	20	7	7	2	3	1
Ultrasonic	19	11	2	1	4	1

Table 2. Leakage scores for teeth stored for 7 months

Root-end preparation	Number of specimens	Leakage scores				
		0	1	2	3	4
Bur only	20	0	11	1	1	7
Bur/10:3 solution	18	0	4	5	4	5
Ultrasonic	19	0	4	2	2	11

Discussion

The results of this study indicate that the method by which the root end is prepared, following resection, does not affect the apical leakage of a root-end filling using the super EBA cement, Stailine. There was, however, an increase in leakage between those teeth stored for 7 days and those where leakage was tested after 7 months storage.

The technique for clearing teeth to assess dye penetration has been used in other studies (Tagger *et al.* 1983, Zetterqvist *et al.* 1988, Saunders & Saunders 1990). It allows the specimens to be examined in three dimensions. This was important in the present study as a number of teeth prepared using the ultrasonic unit showed cracking on the resected root surface (Fig. 1)

Table 3. Number of teeth demonstrating cracks at the root end

Root-end preparation	Number of 7-day specimens	Number of 7-month specimens
Bur only	0	1
Bur/10:3 solution	1	1
Ultrasonic Prep	10	11

which allowed the ingress of dye. This leakage was not in association with the root-end filling but occurred within the dentine of the root end. The origin of these cracks is unknown but they could have arisen as a result of the energy generated by the ultrasonic instrument, which was used at a power setting of 10. In two specimens fine cracking could be seen extending across the surface of the root of the tooth. Such damage to the root may lead to failure of the treatment *in vivo*, as leakage of microorganisms could occur along these cracks. Further research is required into the effect ultrasonic root-end cavity preparation has on tooth structure.

The use of the 10:3 combined solution of citric acid and ferric chloride has been shown to both clean and demineralize dentine and stabilize the exposed collagen fibres (Wang & Nakabayashi 1991). This, combined with the fact that the surface of EBA cement allows the deposition of collagen fibers (Oynick & Oynick 1978) may promote healing of the periradicular tissues. Some of the teeth that had been treated with this solution showed leakage within the dentinal tubules at the root end, indicating that the smear layer, produced during resection, had been removed (Figs 2 and 3). Six teeth showed this penetration of dye in both the 7-day and 7-month groups, respectively. The clinical significance of these open tubules is speculative and may be of concern if there are residual microorganisms present in the tubules (Brannstrom 1984), or if leakage occurs, bacteria may lodge in these openings. Hence, there is a great need to identify a root-end filling material which will either penetrate and seal these tubules or bond to the dentine and eliminate the possibility of leakage.

The sealing ability of the EBA cement deteriorated with time, with significantly more leakage after 7 months. If good healing and adaptation of the periapical tissues takes place within this time then, provided that the coronal seal of the root filling remains intact, the increased leakage may not be of clinical significance. Oynick & Oynick (1978) reported a clinical study where EBA had been used as a retrograde filling material in 200 cases over a 14-year period. Sixty of these cases were recalled and the success rate was considered to be high. Dorn & Gartner (1990) stated that it was important to burnish the margins of the EBA with a ball burnisher to improve adaptation. In the present study the cavity was packed using a round-tipped

Fig. 1. Cracks seen in the root structure following ultrasonic root-end preparation. Original magnification ×25.

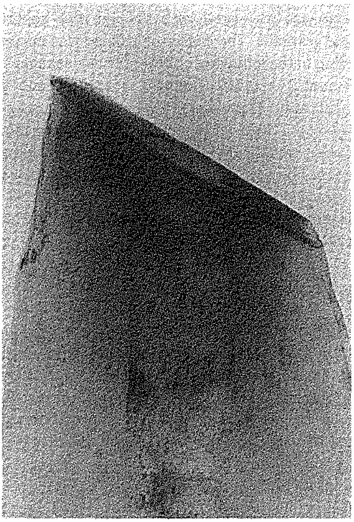

Fig. 2. Dye penetration into patent tubules following smear layer removal with a solution of 10:3 citric acid and ferric chloride. Original magnification ×9.

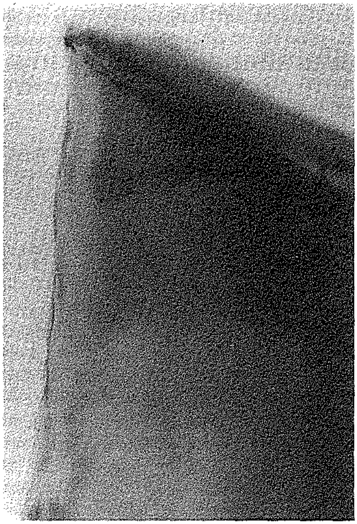

Fig. 3. Enlargement of apical section of Fig. 2 showing dye penetration from both the cleaned root canal face and the canal wall of the preparation. Original magnification ×18.

amalgam plugger which would have had the same effect. Although two studies have reported the efficacy of using EBA cement as a root-end filling further *in vivo* studies are required to ascertain long-term performance of this material.

Conclusions

Within the parameters of this study the following conclusions can be drawn.

1. Leakage of EBA root-end fillings occurred with all methods of apical cavity preparation. There was no significant difference in the amount of leakage among the groups at each time interval ($P>0.05$).
2. There was increased leakage with EBA root-end fillings over the 7-month evaluation period, with all techniques of root-end preparation used ($P<0.001$).
3. Root ends prepared with the ENAC ultrasonic unit showed a significant amount of cracking on the root surface ($P<0.001$).

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