The influence of root-end resection and root-end cavity preparation on microleakage of root filled teeth *in vitro*

E. G. Kontakiotis, T. A. Lagoudakos & M. K. Georgopoulou
Department of Endodontics, Dental School, University of Athens, Athens, Greece

Abstract

Kontakiotis EG, Lagoudakos TA, Georgopoulou MK. The influence of root-end resection and root-end cavity preparation on microleakage of root filled teeth *in vitro*. *International Endodontic Journal*, **37**, 403–407, 2004.

Aim To investigate *in vitro* the influence of root-end resection and root-end cavity preparation on leakage of root filled teeth.

Methodology The root canals of 48 roots, 16 mandibular premolars (G1), 16 mandibular incisors (G2) and 16 maxillary incisors (G3), 12 mm in length, were enlarged using a modified 'balanced force' technique and filled with gutta-percha and sealer using lateral compaction. After setting, leakage along the canal was measured using a fluid transport model. Root-end resection and root-end cavity preparation were then performed, leaving roots 10 mm in length with root fillings of 7 mm (groups R1, R2 and R3, respectively). Fluid transport was measured again along the remaining root fillings of all groups using the same experimental conditions. Results of leakage before and after root-end resection were analysed statistically using the Kruskal–Wallis and Wilcoxon tests.

Results A total of 31% of the roots leaked before and 54% after root-end preparation; the difference was significantly different ($P < 0.001$). No significant differences were found either among groups G1, G2, G3 ($P = 0.565$) or among groups R1, R2, R3 ($P = 0.2628$). Significant differences, however, were shown between groups G1–R1 ($P = 0.0053$), G2–R2 ($P = 0.0089$) and G3–R3 ($P = 0.0461$).

Conclusions Root-end resection and root-end cavity preparation compromised the seal of 7 mm root fillings in all tooth groups. Increased leakage was recorded in the following order: mandibular incisors > mandibular premolars > maxillary incisors.

Keywords: apicectomy, cross-section, leakage, root-end, root-end filling.

Received 28 July 2003; accepted 5 March 2004

Introduction

The rationale for a root-end filling is to prevent leakage after apicectomy. None of the various materials used provides an impervious seal, which may explain why periapical surgery is not always successful (Dorn & Gartner 1990, Rud *et al.* 1991, Zetterqvist *et al.* 1991, Frank *et al.* 1992, Pantschev *et al.* 1994, Testori *et al.* 1999). Friedman (1991) collected material from 36 studies and concluded that success was higher when surgical treatment was combined with conventional root canal treatment. Grung *et al.* (1990) also reported that the success rate of periapical surgery was higher (by 24%) when it followed retreatment of a failed root filling. Thus, better cleaning of the root canal will improve the success rate of periapical surgery, combined with a high quality root-end filling.

Recent studies have investigated the effect of canal cross-sectional shape on the quality of root fillings (Wu *et al.* 2001a,b, Wu & Wesselink 2001). Certain tooth groups appear to have canals of more oval cross-sections. Oval canals may be made round apically during shaping, but this is usually not possible in the coronal third of the root (Wu *et al.* 2000). Chemomechanical preparation and obturation of oval canals are often inadequate, because uninstrumented areas

Correspondence: Maria K. Georgopoulou, Xenias 32, 15771 Zografou, Greece (Fax: +30 210 7795526; e-mail: anifan@otenet.gr).

remain (Wu & Wesselink 2001). Additionally, apicectomy results in the exposure of an oval canal shape, which may, combined with root shortening, result in increased leakage. In a recent study, root-end cavity preparation led to leakage in 67% of the samples despite the use of a thermoplasticized gutta-percha filling technique (Wu *et al.* 2001b). On the contrary, in another study (Wu *et al.* 1998) using maxillary central incisor teeth with rounder cross-section, the leakage was almost half of that recorded for mandibular incisors. It is likely that root-end resection and cavity preparation influence the leakage of various teeth.

The purpose of the present study was to determine the impact of root-end resection and root-end cavity preparation on leakage of different tooth groups.

Materials and methods

The crowns of 16 mandibular premolars (G1), 16 mandibular incisors (G2) and 16 maxillary incisors (G3) were removed using a low speed saw (Isomet 11–1180; Buehler Ltd, Evanston, IL, USA), leaving roots 12 mm long. Another 12 teeth, four from each tooth category were used as controls; two positive and two negative controls for each experimental group.

The working length was established at 11 mm. The patency of each root canal was confirmed by inserting a size 20 file through the apical foramen both at the onset and the end of chemomechanical preparation. All canals were enlarged with Flexofiles (Dentsply Maillefer, Ballaigues, Switzerland) using a balanced force technique of manipulation (Roane *et al.* 1985). The preparation began with a size 15 file and continued successively up to a file size 45, which was selected as the master apical instrument (MAF). Between each successive instrument, irrigation was performed with 2.5 mL of freshly prepared 2.5% sodium hypochlorite solution and use of a syringe and a 27-gauge irrigation needle (Endo-Eze; Ultradent Products, Salt Lake City, UT, USA). A final irrigation with 10 mL of 2.5% sodium hypochlorite was used in each sample at the end of chemomechanical preparation.

Canal flaring was accomplished using Gates Glidden drills (Dentsply Maillefer). Ten millimetres were enlarged with Gates No. 1 (size 50), followed by Gates No. 2 (size 70) at 8 mm, Gates No. 3 (size 90) at 6 mm and Gates No. 4 (size 110) at 4 mm.

The root canals of all groups were dried with paper points (Dentsply Maillefer) and filled with gutta-percha (Dentsply Maillefer) and Roth 601 sealer (Roth International, Chicago, IL, USA), applied with a size 40 K file used in a counterclockwise rotation. A size 45 gutta-percha cone was used as a master cone, covered with sealer and inserted to the working length. Cold lateral compaction was performed with five additional size 25 gutta-percha cones using a size C non-standardized finger spreader (Dentsply Maillefer) with a 0.28 mm tip diameter. A heated instrument was used to remove the excess gutta-percha and then vertical force was applied with a hand plugger of 0.8 mm tip diameter (Dentsply Maillefer) to compact the gutta-percha in the coronal portion of the canal. The root filling of each sample was 11 mm. Six teeth, two from each group, were filled with laterally compacted gutta-percha without sealer. This group served as positive control. The negative control group consisted of another six teeth, two from each group that was filled with gutta-percha and sealer and were covered entirely with two coats of nail varnish.

All roots were kept in wet sponges at 100% humidity and 37 °C for 48 h in order to allow the sealer to set. Leakage along all samples was measured using a fluid transport model (Wu *et al.* 2001b). With a headspace pressure of 30 kPa (0.3 Atm), distilled water was forced through a plastic tube attached to the coronal end of the root specimen. The apical end of the root was tied to another plastic tube that was connected to a 20 μL glass capillary tube 170 mm long (Haak; Waller-Graf & Co., Werlheim, Germany). An air bubble about 3 mm long was introduced through the open end of the capillary. All connections were closed tightly by twisting pieces of stainless steel wire. Fluid conduction through the root filling was performed by applying pressure for 2 h after an interval period of 24 h necessary for air bubble stabilization. The fluid transport results (F) were expressed in $\mu L\ h^{-1}$ and divided to three categories: $F = 0$, $0 < F < 20$ and $F > 20$.

Following the initial assessment of leakage, 2 mm of root-end was resected without bevel (0°), using a cylinder diamond (Komet; Brasseler GmbH, Lemgo, Germany) with water irrigation. Three millimetre deep apical root-end cavities were prepared with a round bur No. 2 (Dentsply Maillefer) mounted on a low speed handpiece. The final samples (groups: R1, R2 and R3) were thus 10 mm long with 7 mm gutta-percha and sealer fillings (Figure 1). The composition of experimental groups is illustrated in Table 1. Fluid transport along the remaining root fillings was measured again using the same experimental conditions.

Statistical analysis of the results was performed as follows: the Kruskal–Wallis test was used to compare leakage in groups G1, G2 and G3 (samples prior to

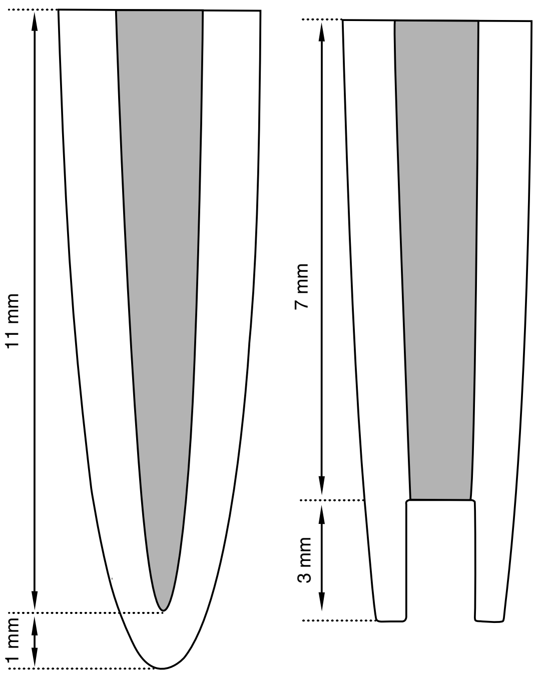

Figure 1 Illustration of the samples before apicectomy and after root-end cavity preparation.

Table 1 Composition of the six experimental groups

Group	Sample preparation before measurement	Number of samples
G1	Mandibular premolars	16
	Root filling length 11 mm	
	Root length 12 mm	
G2	Mandibular incisors	16
	Root filling length 11 mm	
	Root length 12 mm	
G3	Maxillary incisors	16
	Root filling length 11 mm	
	Root length 12 mm	
R1	Mandibular premolars	16
	Root filling length 7 mm	
	Root length 10 mm	
R2	Mandibular incisors	16
	Root filling length 7 mm	
	Root length 10 mm	
R3	Maxillary incisors	16
	Root filling length 7 mm	
	Root length 10 mm	

apicectomy) as well as among groups R1, R2 and R3 (samples after root-end cavity preparation) (Table 1). The Wilcoxon test was applied between the groups G1–R1, G2–R2 and G3–R3 in pairs. The same test was performed in pooled samples before and after apicectomy (G1, G2, G3 – R1, R2, R3). The level of statistical significance was 5% ($P < 0.05$).

Results

Gross leakage was recorded in the positive control group ($L > 20$ μL h^{-1}), while in the negative control group no leakage was recorded ($L = 0$ μL h^{-1}). The fluid transport results are illustrated in Tables 2 and 3.

Analysis of the pooled results before and after apicectomy showed a statistically significant increase in leakage after apicectomy: G1, G2, G3 versus R1, R2, R3: $P = <0.001$. Analysis of measurements for each tooth group separately showed significant differences as well:
G1 versus R1: $P = 0.0053$ (<0.05)
G2 versus R2: $P = 0.0089$ (<0.05)
G3 versus R3: $P = 0.0461$ (<0.05).

No significant differences were found among the experimental groups prior to apicectomy: G1 versus G2 versus G3 ($P = 0.565$, >0.05) or among experimental groups after apicectomy: R1 versus R2 versus R3 ($P = 0.2628$, >0.05).

Discussion

Leakage in filled root canals has been studied extensively. Bacterial leakage has been shown to occur in all filled root canals (Torabinejad *et al.* 1990, Khayat *et al.*

Table 2 Transport fluid results (F in μL h^{-1}) prior to apicectomy

	$L = 0$		$0 < L < 20$		$L > 20$	
	No. of samples	%	No. of samples	%	No. of samples	%
G1 ($n = 16$)	11	69	4	25	1	6
G2 ($n = 16$)	10	63	2	12	4	25
G3 ($n = 16$)	12	75	3	19	1	6
Total ($n = 48$)	33	69	9	19	6	12

Table 3 Transport fluid results (F in μL h^{-1}) after apicectomy and root-end cavity preparation

	$L = 0$		$0 < L < 20$		$L > 20$	
	No. of samples	%	No. of samples	%	No. of samples	%
R1 ($n = 16$)	7	44	2	12	7	44
R2 ($n = 16$)	5	31	4	25	7	44
R3 ($n = 16$)	10	63	2	12	4	25
Total ($n = 48$)	22	46	8	16	18	38

1993). On the contrary, Wu & Wesselink (1993) reported that dye leakage did not exceed 5 mm along the filling in 80% of 44 dye measurements, performed in 34 studies published from 1980 to 1990. In the present study, for the measurement of leakage in roots of various cross-sections before and after apicectomy a fluid transport device was selected, which has been shown to give reproducible quantitative results (Georgopoulou *et al.* 1995, Wu *et al.* 1995).

Results showed that 31% of the teeth leaked prior to apicectomy but 54% after apicectomy and root-end cavity preparation. Pooled results obtained from previous studies concerning central incisors, of both the maxilla and mandible, using the same fluid transport device, showed leakage in 57% of the samples after apicectomy (Wu *et al.* 1998, 2001b), a value that is almost identical to the present findings. Statistical analysis revealed consistent significant differences between all tooth groups separately, as well as in terms of the total number of teeth, before and after apicectomy, thus suggesting that apicectomy and root-end cavity preparation compromised the seal provided by a root filling 7 mm in length.

However, no significant differences were shown among the tooth groups, either before or after root-end resection. This can be attributed to the capacity of lateral compaction to produce consistent root fillings independently of tooth category.

Mandibular incisors were the teeth mostly affected by apical resection, while the maxillary incisors were the least influenced (Tables 2 and 3). This may be attributed to the possible different cross-sections of the three tooth groups. According to Wu *et al.* (2000), who investigated anatomical diameters of different teeth, at a level 5 mm short of the apical end, long oval cross-sections were present in 27% of mandibular premolars with one root canal, 5% for maxillary central incisors and 56% for mandibular central incisors, respectively.

Root filling consisted of cold lateral compaction of gutta-percha. When lateral compaction is performed in oval cross-sectioned root canals, the proportion of sealer to gutta-percha is greater when compared with the thermoplasticized gutta-percha techniques, at a distance of 4 mm from the apex (Wu *et al.* 2001a). This level coincides approximately with the apical preparation limit in this study. Furthermore, Wu & Wesselink (2001), in a study conducted on mandibular incisors, reported that uninstrumented recesses may remain and that it is not always possible to fill these recesses by lateral compaction of cones. In addition, the root filled proportion was smaller when they performed great enlargement, such as performed in the present study.

The increase of leakage noted in all groups after apicectomy is likely in part to be due to the exposure of the gutta-percha cones and sealer, that allowed the fluid transport system to identify gaps extending the full length of a specimen; shortening the filling would likely lead to an increased probability of a gap extending from the coronal to the apical end. In roots with a more pronounced oval cross-section, the microleakage was greater, probably due to the coexistence of uninstrumented recesses at the filling borders.

From the present study, root-end resection and root-end cavity preparation produced increased leakage values in all cases, compared with a full length root filling. In order to counterbalance this increased leakage, it is imperative to place a high quality root-end filling. Root-end filling materials that create good seals such as MTA, bonded composites or EBA cement may provide an efficient apical seal (Fogel & Peikoff 2001). Additionally, a suitable coronal restoration should be placed prior to apical surgery, in order to maintain the least leakage possible during the process.

In this study the criterion that determined the selection of teeth was that each group represented a different type of long oval cross-section. The results confirm that even teeth with rounder cross-sections, such as maxillary incisors, are susceptible to increased leakage when the length of root filling is reduced during apical surgery.

Conclusions

Apicectomy and root-end cavity preparation resulted in significantly increased leakage. This increase may be related to the frequency of roots with oval cross-sections, that is: mandibular incisors > mandibular premolars > maxillary incisors.

References

Dorn SO, Gartner AH (1990) Retrograde filling materials: a retrospective success-failure study of amalgam, EBA and IRM. *Journal of Endodontics* **16**, 391–3.

Fogel HM, Peikoff MD (2001) Microleakage of root-end filling materials. *Journal of Endodontics* **27**, 456–8.

Frank AL, Glick DH, Patterson SS, Weine FS (1992) Long-term evaluation of surgically placed amalgam fillings. *Journal of Endodontics* **18**, 391–8.

Friedman S (1991) Retrograde approaches in endodontic therapy. *Endodontics and Dental Traumatology* **7**, 97–107.

Georgopoulou MK, Wu M-K, Nikolaou A, Wesselink PR (1995) Effect of thickness on the sealing ability of some root canal sealers. *Oral Surgery Oral Medicine Oral Pathology* **80**, 338–44.

Grung B, Molven O, Halse A (1990) Periapical surgery in a Norwegian country hospital: follow-up findings of 477 teeth. *Journal of Endodontics* **16**, 411–7.

Khayat A, Lee S-J, Torabinejad M (1993) Human saliva penetration of coronally unsealed obturated root canals. *Journal of Endodontics* **19**, 458–61.

Pantschev A, Carlsson A-P, Andersson L (1994) Retrograde root filling with EBA cement or amalgam. A comparative clinical study. *Oral Surgery Oral Medicine Oral Pathology* **78**, 101–4.

Roane JB, Sabala CL, Duncanson MG (1985) The 'balanced force' concept for instrumentation of curved canals. *Journal of Endodontics* **11**, 203–11.

Rud J, Munksgaard EC, Andreasen JO, Rud V (1991) Retrograde root filling with composite and a dentin-bonding agent 2. *Endodontics & Dental Traumatology* **7**, 126–31.

Testori T, Capelli M, Milani S, Weinstein RL (1999) Success and failure in periradicular surgery. A longitudinal retrospective analysis. *Oral Surgery Oral Medicine Oral Pathology* **87**, 493–8.

Torabinejad M, Ung B, Kettering JD (1990) In vitro bacterial penetration of coronally unsealed endodontically treated teeth. *Journal of Endodontics* **16**, 566–9.

Wu M-K, Wesselink PR (1993) Endodontic leakage studies reconsidered. Part I. Methodology, application and relevance. *International Endodontic Journal* **26**, 37–43.

Wu M-K, Wesselink PR (2001) A primary observation on the preparation and obturation of oval canals. *International Endodontic Journal* **34**, 137–41.

Wu M-K, Wesselink PR, Boersma J (1995) A 1-year follow-up study on leakage of four root canal sealers at different thicknesses. *International Endodontic Journal* **28**, 185–9.

Wu M-K, Pehlivan Y, Kontakiotis EG, Wesselink PR (1998) Microleakage along apical root fillings and cemented posts. *Journal of Prosthetic Dentistry* **72**, 264–9.

Wu M-K, Roris A, Barkis D, Wesselink PR (2000) Prevalence and extent of long oval canals in the apical third. *Oral Surgery Oral Medicine Oral Pathology* **89**, 739–43.

Wu M-K, Kaăstkovà A, Wesselink PR (2001a) Quality of cold and warm gutta-percha fillings in oval canals in mandibular premolars. *International Endodontic Journal* **34**, 485–91.

Wu M-K, de Schwartz FBC, van der Sluis LWM, Wesselink PR (2001b) The quality of root fillings remaining in mandibular incisors after root-end cavity preparation. *International Endodontic Journal* **34**, 613–9.

Zetterqvist L, Hall G, Holmlund A (1991) Apicoectomy: a comparative clinical study of amalgam and glass ionomer cement as apical sealants. *Oral Surgery Oral Medicine Oral Pathology* **71**, 489–91.