An evaluation of the influence of passive ultrasonic irrigation on the seal of root canal fillings

L. W. M. van der Sluis, H. Shemesh, M. K. Wu & P. R. Wesselink

Department of Cariology Endodontology Pedodontology, Academic Centre for Dentistry Amsterdam (ACTA), Amsterdam, The Netherlands

Abstract

van der Sluis LWM, Shemesh H, Wu MK, Wesselink PR.
An evaluation of the influence of passive ultrasonic irrigation on the seal of root canal fillings. *International Endodontic Journal*, **40**, 356–361, 2007.

Aim To evaluate the influence of passive ultrasonic irrigation (PUI) on the seal of root canal fillings.

Methodology A total of 40 mandibular premolars were distributed equally into two groups and the root canals were cleaned and shaped; they were then filled with gutta-percha and AH26 (sealer) using the warm vertical compaction technique with the System B (Analytic Technology, Redmond, WA, USA) device. In one group PUI was applied, after completion of instrumentation and hand-irrigation. In the other group, PUI was not applied. Thereafter, leakage of glucose was evaluated by measuring its concentration once a week for a total period of 56 days using a glucose penetration model. Differences between the groups in terms of glucose concentrations were statistically analysed with the Mann–Whitney test; the level of significance was set at $P = 0.05$.

Results After the first month the root fillings in teeth where PUI had been used, sealed the root canal significantly better than in teeth where no PUI had been used ($P = 0.017$).

Conclusion Root fillings sealed the root canal better when PUI had been used.

Keywords: irrigation, passive, root fillings, sealing, ultrasonic.

Received 21 August 2006; accepted 18 October 2006

Introduction

During passive ultrasonic irrigation (PUI) a small ultrasonically oscillating file or smooth wire (e.g. size 15) is placed in the centre of the root canal following canal shaping (Ahmad *et al.* 1987). Because the root canal has been enlarged, the irrigant can flow in the root canal and the file or wire can vibrate relatively freely, which will result in more powerful acoustic streaming (Ahmad *et al.* 1987). PUI with sodium hypochlorite (NaOCl) as the irrigant, removes more dentine debris, planktonic bacteria and pulp tissue from the root canal than the syringe irrigation (Huque *et al.* 1998, Lee *et al.* 2004, Gutarts *et al.* 2005). During PUI,

more dentine debris can be removed from the isthmus, oval extensions in the root canal and irregularities from the root canal wall (Goodman *et al.* 1985, Lee *et al.* 2004).

It is generally accepted that relatively few dentists use PUI. Remaining dentine debris, which cannot be removed during hand-irrigation, will be packed into oval extensions and irregularities of the root canal (Wu & Wesselink 2001). If oval extensions are filled with dentine debris, the filling material cannot adapt to the canal wall and leakage may ensue (Wu & Wesselink 2001, van der Sluis *et al.* 2005a) because the filling material and sealer are not compacted against a clean root canal wall but against dentine debris particles, no matter which root filling technique or materials are used.

It is unclear whether root fillings, placed after PUI, seal the root canal better because more dentine debris is removed from the root canal. In the study of Wu *et al.*

Correspondence: L.W.M. van der Sluis, Department of Cariology Endodontology Pedodontology, ACTA, Louwesweg 1, 1066 EA Amsterdam, The Netherlands (Tel.: +31 20 5188651; fax: +31 20 6692881; e-mail: l.vd.sluis@acta.nl).

(2001), the quality of root fillings in oval canals was evaluated using the percentage of gutta-percha (PGP) in the root canal. The mean PGP was 86.6% varying from 47.1–100%. Many oval extensions were not prepared and became filled with dentine debris. PUI was not used for irrigation of the root canals. In another study, where a similar methodology was used, but with PUI, the mean PGP was 98.9% and varied from 94.5–100%. This indicated that PUI removed effectively dentine debris from the oval extensions and thus allowed the gutta-percha to fill more completely the root canal (Ardila *et al.* 2003).

Healing following root canal treatment is assured through effective infection control (Sjögren *et al.* 1990). However, it is not clear whether a better sealing root filling leads to less periapical inflammation. Yamauchi *et al.* (2006) demonstrated, in an animal experiment, that less periapical inflammation occurred when root fillings were protected against coronal leakage by application of an additional coronal plug of filling material. Because an additional coronal plug leads to less coronal leakage (Chailertvanitkul *et al.* 1997), these data indicate that less coronal leakage leads to less periapical inflammation.

Different leakage models were used to detect and measure leakage along root fillings (Wu & Wesselink 1993). Leakage tests are improving and recently Xu *et al.* (2005) reported a new model that measures the leakage of glucose molecules. This model consists of a tube where a concentrated glucose solution is placed and connected to the test element, whilst the apical side of the specimen is dipped in water. Glucose, which leaks through the root canal accumulates in the apical chamber and is measured using an enzymatic reaction with a spectrophotometer. Glucose has a low molecular weight, and may be used as an indication for toxins that might penetrate the canal.

The aim of this study was to evaluate the influence of PUI on the seal of root fillings.

Materials and methods

Digital radiographs from bucco-lingual and mesial-distal directions were made of extracted mandibular premolars that had been stored in water with added NaOCl for not more than 1 month. A total of 40 teeth with a single canal that had a long, oval shape at 5 mm coronal to the working length (WL), where the bucco-lingual diameter was more than twice as large as the mesio-distal diameter, were selected. The curvature of the roots was measured following Schneider's methodology (Schneider 1971). The 40 specimens were divided equally in two anatomically comparable groups taking into account the curvature and the oval shape of the root canals. Two teeth were used as negative controls (the roots were completely covered with nail varnish) and two as positive controls (canals were filled using lateral compaction of Gutta-percha cones without sealer).

The teeth were decoronated and all roots were reduced to a length of 12 mm. WL was determined by inserting a size 15 K-file into the canal until the tip of the file was just visible at the apical foramen. The canals were accessed and prepared to the apical foramen. The coronal aspect of each canal was flared using Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland) sizes 2–4. All the root canals were prepared with the GT rotary system (Dentsply Maillefer) in a crown-down sequence using a series of size 20 and 30, 0.10–0.04 taper. Between the instruments, each canal was irrigated with 2 mL of a 2% NaOCl solution, freshly prepared each day, using a syringe and a 27-gauge needle that was placed 1 mm short of the WL. The NaOCl solution was prepared by diluting a 10% NaOCl solution (Merck, Darmstadt, Germany) and its pH adjusted to 10.8 with 1 N HCl. The concentration of the NaOCl solution was measured iodometrically (Moorer & Wesselink 1982). The final file [master apical file (MAF)] for each root canal at the foramen was size 30, 0.06 taper. After preparation of the root canal, PUI was performed in group 1 ($n = 18$) with a piezoelectronic unit (PMax:Satelec, Meriganc Cedex, France). After the root canal was filled with 2% NaOCl, using a syringe and a needle, an ultrasonically activated smooth wire of stainless steel size 15, taper 0.02 was inserted in the root canal 1 mm short of WL (van der Sluis *et al.* 2005b). The irrigant was ultrasonically activated for 1 min. The root canal was then rinsed with 2 mL of 2% NaOCl, using a syringe and a 27-gauge needle that was placed 1 mm short of WL, and the irrigant was again activated ultrasonically for 1 min. This sequence was repeated thrice resulting in a total irrigation time of 3 min and a total irrigation volume of 6 mL. The oscillation was performed in bucco-lingual direction at power setting 'blue' three. According to the manufacturer, the frequency used under these conditions was approximately 30 kHz and the displacement amplitude was 28 μm. The teeth in group two ($n = 18$) were irrigated with 6 mL of 2% NaOCl by syringe irrigation in place of PUI for the same time period.

After irrigation, the canals were dried and filled with a warm vertical compaction technique. AH26 silver-free root canal sealer (De Trey Dentsply, Konstanz,

Germany) was mixed manually according to the recommendations of the manufacturer. The sealer was placed in the root canals using an EZ-Fill bi-directional spiral (EDS, Hackensack, NJ, USA), 1 mm short of WL in a pumping motion for 5 s. The complete spiral was coated with sealer. Before the filling procedure the tip of a medium sized non-standardized gutta-percha cone (Autofit, Analytic Endodontics, Glendora, CA, USA) was trimmed until tug-back was achieved 0.5 mm short of the full WL. The trimmed gutta-percha cone, lightly coated with sealer, was placed into the canal 0.5 mm short of the WL. At the level of the cementum–enamel junction the gutta-percha was seared off with the tip of an activated heat carrier at 260° (System B, Analytic Technology, Redmond, WA, USA) by placing it in the coronal section of the root canal. After deactivating the heat carrier, the cooled instrument was removed from the canal, bringing out an increment of gutta-percha. Vertical force was then applied with a cold size 11 handplugger (1.1 mm diameter, Dentsply Maillefer) to compact the gutta-percha in the coronal section of the canal. During the application of the plugger care was taken not to contact the canal wall. This procedure was repeated twice, first to a level 3–4 mm deeper than the cementum–enamel junction, vertically compacting the gutta-percha in the middle section of the canal using a cold size 7 plugger (0.7 mm diameter, Dentsply Maillefer), and secondly to the level 4 mm short of the full WL, vertically compacting the gutta-percha in the apical section of the canal using a cold size 5 plugger (0.5 mm diameter, Dentsply Maillefer). After the apical section the middle and the coronal section were filled using the same technique. During the filling procedure two roots of each group were fractured and discarded. The remaining teeth were stored in a moist sponge at 37 °C for 1 year.
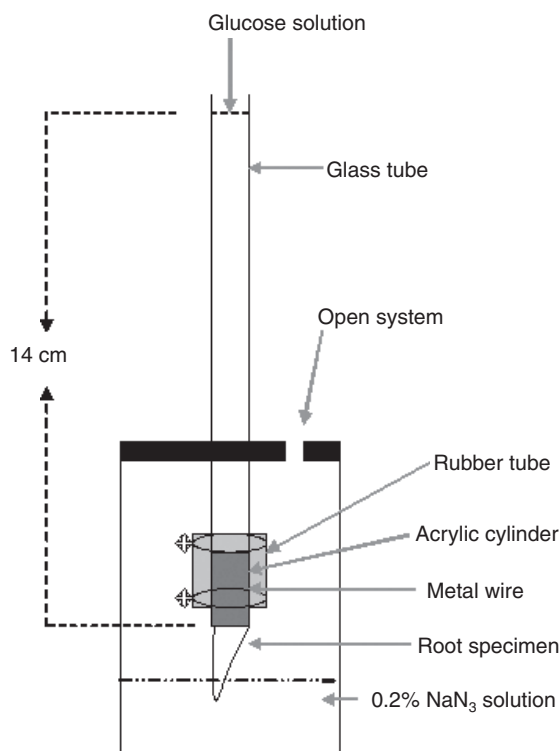
Glucose penetration model – preparation and measurements

All samples were examined under a microscope (Zeiss Stemi SV6, Jena, Germany) to exclude those with cracks. The coronal 4 mm of the root specimens were then embedded in Acryl (Vertex, Dentimex BV, Zeist, The Netherlands) to form an acrylic cylinder around the root and enable leak-free contact between the rubber tube and root specimen.

The difference between the current version of the glucose penetration model and the original model introduced by Xu *et al.* (2005) lies mainly in the environment where the models were stored: in order to prevent evaporation of fluids, the models were placed in a closed jar with 100% humidity. From a pilot study it was concluded that this method would eliminate the effect of fluid evaporation on glucose concentration measurements.

The resin block around the coronal part of each root was connected to a rubber tube and the adaptation improved with stainless steel wires. The other end of the tube was similarly connected to a 16-cm long pipette. The assembly was then placed in a sterile glass bottle with a screw cap and sealed with sticky wax, and a uniform hole drilled in the screw cap with a size 173 diamond bur (Horico, Berlin, Germany) to assure an open system at all times. Two mL of a 0.2% NaN_3 solution was added into the glass bottle, such that the root samples were immersed in the solution. NaN_3 was used to inhibit the growth of microorganisms that might influence the glucose readings. The tracer used in the present study was 1 mol L^{-1} glucose solution (pH = 7.0). Glucose has a low molecular weight and is hydrophilic and chemically stable. About 4.5 mL of the glucose solution, containing 0.2% NaN_3, was injected into the pipette until the top of the solution was 14 cm higher than the top of gutta-percha in the canal, which created a hydrostatic pressure of 1.5 kPa or 15 cm H_2O (Xu *et al.* 2005)(Fig. 1). All specimens were then returned to the incubator at 37 °C for the duration of the observation period. A 25 μL increment of solution was drawn from the glass bottle using a micropipette at 5, 14, 21, 37, 48 and 56 days. The same amount of fresh 0.2% NaN_3 was added to the glass bottle reservoir to maintain a constant volume of 2 mL. The sample was then analysed with a Glucose kit (Megazyme, Wicklow, Ireland) in a spectrophotometer (Molecular Devices, Spectra max 384 plus, Seattle, Wa, USA) at 340 nm wavelength. Concentrations of glucose in the lower chamber were presented in mg L^{-1} at that particular time after obturation. The lowest glucose level for which the current procedure is believed to be accurate is 0.663 mg L^{-1} which derives from an absorbance difference of 0.020 (D-Glucose – HK assay procedure, Megazyme International Limited, 2004). Below this level, the absorbance readings become relatively small, and results are subject to greater error from technique variables. Concentrations smaller than this were thus ignored. Similarly, once leakage exceeded 1.28 g L^{-1}, samples were no longer tested as the glucose concentration in the lower chamber at this stage was very high and significant leakage had occurred.

Figure 1 The glucose penetration model.

The positive control group ($n = 2$) was filled using lateral compaction of gutta-percha cones without any sealer. No warm vertical forces were used.

In the negative control group ($n = 2$) all roots were filled with laterally compacted gutta-percha and AH 26 and completely covered with nail varnish.

The data were statistically analysed with the Mann–Whitney test and P was set at 0.05.

Results

The results are shown in Table 1 and 2 and Fig. 2. After the first month, the root fillings in teeth where PUI had been used, sealed the root canal significantly better than in teeth where PUI had been not used ($P = 0.017$).

Discussion

The root fillings placed after PUI allowed significantly less leakage of glucose, which indicates it resulted in a better sealing of the root canal. This can be explained by the fact that more dentine debris can be removed from the oval extensions or irregularities (Lee *et al.* 2004) and/or more smear layer can be removed from the canal wall using PUI (Cameron 1983, 1987, Alaçam 1987, Cheung & Stock 1993, Huque *et al.* 1998). When oval extensions or irregularities of the root canal wall are free of dentine debris they can be filled, which is likely to result in a better seal of the root filling with probability of reduced or no coronal leakage.

Shaping of the root canal in combination with irrigation is more efficient in cleaning the canal than shaping alone (Baugh & Wallace 2005). The present study indicates, that efficient irrigation can also result in significant improvement of the sealing of a root filling. This would suggest that efficient irrigation could decrease coronal leakage of the root fillings and thus reduce the nutrition for the biofilm in the root canal with the potential to reduce the occurrence and severity of apical periodontitis (Yamauchi *et al.* 2006).

Glucose as a marker in leakage studies has clinical relevance because it is an important nutrient for microorganisms and even at very low concentrations a biofilm is able to survive (Siqueira 2001). Because it is impossible to remove completely the biofilm from the root canal (Ricucci & Bergenholtz 2003, Naïr *et al.* 2005) leakage of very small amounts of glucose could help the biofilm survive or promote its re-growth when left in the root canal after preparation (Siqueira 2001).

In this study, during PUI, 2% NaOCl was placed in the root canal using a syringe in place of a continuous flow. During 3 min of PUI, the 2% solution NaOCl was refreshed every minute using further 2 mL volumes of 2% NaOCl. The results of a previous study showed no significant difference between this method of administration and a continuous flow of irrigant when PUI was used for 3 min (van der Sluis *et al.* 2006).

Table 1 Mean $\pm$ SD of glucose leakage in g L^1 at different times

	Days					
Use PUI	5	14	21	37	48	57
No ($n = 18$)	0.19 ± 0.34	0.27 ± 0.37	0.35 ± 0.48	0.61 ± 0.46	0.69 ± 0.46	0.86 ± 0.37
Yes ($n = 18$)	0.05 ± 0.08	0.14 ± 0.21	0.20 ± 0.31	0.30 ± 0.42	0.40 ± 0.47	0.53 ± 0.40

PUI, passive ultrasonic irrigation.

Table 2 The *P*-values of statistic analysis after comparing leakage with and without passive ultrasonic irrigation at the different time intervals

Time (days)	P
5	0.440
14	0.274
21	0.970
37	*0.017*
48	*0.045*
57	*0.014*
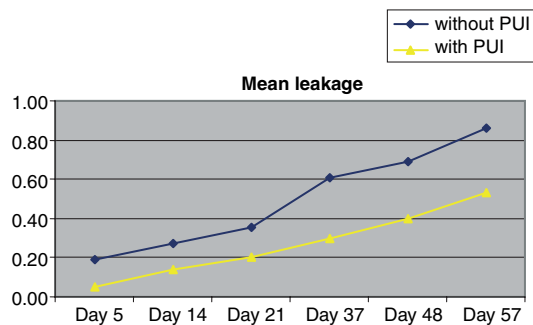
Figure 2 The mean leakage of glucose over time.

The standard deviation of the leakage results of both groups were large. This may have resulted because of the variation in the oval dimensions of the root canals. Although the MAF was standardized in all the teeth, the root canal dimension was not standardized; rather the specimens were distributed equally. Another explanation for the large standard deviations in the PUI group can be explained because it is difficult to standardize the positioning of the ultrasonically activated instrument in the centre of the root canal and to standardize the displacement amplitude as any constraint on the wire in the canal will change the amplitude. This will have a direct effect on the efficacy of PUI. This could be overcome by increasing the frequency of the ultrasound, which will reduce the influence of a variation in the displacement amplitude.

In the present study, the modified glucose penetration model was used (Xu *et al.* 2005, Shemesh *et al.* 2006). This test can be seen as a further development of the fluid transportation concept (Wu & Wesselink 1993). Both measure penetration of fluid through root fillings after subjecting them to constant pressure; however, the glucose model allows measurements of diffusion of the marker molecules as well. The glucose test might be more sensitive than the measurement of air-bubble movement, not only because the threshold measurement detected by the eye is larger than that of the spectrophotometer, but also because the convective fluid transport was combined with glucose molecule diffusion.

Time difference is an important factor when comparing the two different models. In the glucose penetration model the tooth is continuously subjected to the pressure of the glucose solution in the coronal chamber for a period of 2 months. The fluid penetration model detects leakage usually after subjecting the filling to pressure for 3 h (Shemesh *et al.* 2006). This enormous time difference might make the glucose test more sensitive, as it may result in detection of smaller voids in the filling.

Some authors claim that PUI removes the smear layer completely (Cameron 1983, 1987, Alaçam 1987, Huque *et al.* 1998) or partially from the root canal wall (Cheung & Stock 1993), whereas syringe irrigation of NaOCl does not remove the smear layer from the root canal wall (Cheung & Stock 1993, Huque *et al.* 1998). The improved sealing of the root canal filling could also be due to the removal of the smear layer by PUI. However, the reports in the literature on this subject are inconclusive (Sen *et al.* 1995, Torabinejad *et al.* 2002).

Leakage along root fillings may increase or decrease with the time following filling. Dissolution of sealer and the smear layer may result in a rise in leakage, whereas swelling of GP may result in diminished leakage (Sen *et al.* 1995, Kontakiotis *et al.* 1997). The leakage data measured some time after filling the root canals may be clinically more relevant.

Conclusion

Root fillings sealed the root canal better when PUI had been used.

References

Ahmad M, Pitt Ford TR, Crum LA (1987) Ultrasonic debridement of root canals: acoustic streaming and its possible role. *Journal of Endodontics* **14**, 490–9.

Alaçam T (1987) Scanning electron microscope study comparing the efficacy of endodontic irrigating systems. *International Endodontic Journal* **20**, 287–94.

Ardila CN, Wu MK, Wesselink PR (2003) Percentage of filled canal area in mandibular molars after conventional root-canal instrumentation and after a noninstrumentation technique (NIT). *International Endodontic Journal* **34**, 591–8.

Baugh D, Wallace J (2005) The role of apical instrumentation in root canal treatment: a review of the literature. *Journal of Endodontics* **31**, 333–40.

Cameron JA (1983) The use of ultrasonics in the removal of the smear layer: a scanning electron microscope study. *Journal of Endodontics* **9**, 292–8.

Cameron JA (1987) The synergistic relationship between ultrasound and sodium hypochlorite: a scanning electron microscope evaluation. *Journal of Endodontics* **13**, 541–5.

Chailertvanitkul P, Saunders WP, Saunders EM, MacKenzie D (1997) An evaluation of microbial coronal leakage in the restored pulp chamber of root-canal treated multirooted teeth. *International Endodontic Journal* **30**, 318–22.

Cheung GSP, Stock CJR (1993) In vitro cleaning ability of root canal irrigant with and without endosonics. *International Endodontic Journal* **26**, 334–43.

Goodman A, Reader A, Beck M, Melfi R, Meyers W (1985) An in vitro comparison of the efficacy of the step-back technique versus a step-back/ultrasonic technique in human mandibular molars. *Journal of Endodontics* **11**, 249–56.

Gutarts R, Nusstein J, Reader A, Beck M (2005) In vivo debridement efficacy of ultrasonic irrigation following hand-rotary instrumentation in human mandibular molars. *Journal of Endodontics* **31**, 166–70.

Huque J, Kota K, Yamaga M, Iwaku M, Hoshino E (1998) Bacterial eradication from root dentine by ultrasonic irrigation with sodium hypochlorite. *International Endodontic Journal* **31**, 242–50.

Kontakiotis EG, Wu M-K, Wesselink PR. (1997) Effect of sealer thickness on long-term sealing ability: a 2-year follow-up study. *International Endodontic Journal* **30**, 307–12.

Lee S-J, Wu M-K, Wesselink PR (2004) The effectiveness of syringe irrigation and ultrasonics to remove debris from simulated irregularities within prepared root canal walls. *International Endodontic Journal* **37**, 672–8.

Moorer WR, Wesselink PR (1982) Factors promoting the tissue dissolving capability of sodium hypochlorite. *International Endodontic Journal* **15**, 187–96.

Naïr PNR, Henry S, Cano V, Vera J (2005) Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after 'one visit' endodontic treatment. *Oral Surgery, Oral Medicine Oral Pathology, Oral Radiology and Endodontics* **99**, 231–52.

Ricucci D, Bergenholtz G (2003) Bacterial status in root-filled teeth exposed to the oral environment by loss of restoration and fracture or caries – a histobacteriological study of treated cases. *International Endodontic Journal* **36**, 787–97.

Schneider SW (1971) A comparison of canal preparations in straight and curved root canals. *Journal of Oral Surgery* **32**, 271–5.

Sen BH, Wesselink PR, Türkün M. (1995) The smear layer: a phenomenon in root canal therapy. *International Endodontic Journal* **28**, 141–8.

Shemesh H, Wu MK, Wesselink PR (2006) Leakage along apical root fillings with and without smear layer using two different leakage models: a two month longitudinal ex vivo study. *International Endodontic Journal* **39**, 968–76.

Siqueira JF (2001) Aetiology of root canal treatment failure: why well-treated teeth can fail. *International Endodontic Journal* **34**, 1–10.

Sjögren U, Hägblund B, Sundqvist G, Wing K (1990) Factors effecting the long-term results on endodontic treatment. *Journal of Endodontics* **16**, 498–504.

van der Sluis LWM, Wu MK, Wesselink PR (2005a) An evaluation of the quality of root fillings in mandibular incisors and maxillary and mandibular canines using different methodologies. *Journal of Dentistry* **33**, 683–8.

van der Sluis LWM, Wu MK, Wesselink PR (2005b) A comparison between a smooth wire and a K-file in removing artificially placed dentine debris from root canals in resin blocks during ultrasonic irrigation. *International Endodontic Journal* **38**, 593–6.

van der Sluis LWM, Gambarini G, Wu MK, Wesselink PR (2006) The influence of volume, type of irrigant and flushing method on removing artificially placed dentine debris from the apical root canal during passive ultrasonic irrigation. *International Endodontic Journal* **39**, 472–6.

Torabinejad M, Handysides R, Khademi AA, Bakland LK (2002) Clinical implications of the smear layer in endodontics: a review. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **94**, 658–66.

Wu MK, Wesselink PR (1993) Endodontic leakage studies reconsidered. Part: 1. Methodology, application and relevance. *International Endodontic Journal* **26**, 37–43.

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

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

Xu Q, Fan MW, Fan B, Cheung GS, Hu HL (2005) A new quantitative method using glucose for analysis of endodontic leakage. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **99**, 107–11.

Yamauchi S, Shipper G, Buttke T, Yamauchi M, Trope M (2006) Effect of orifice plugs on periapical inflammation in dogs. *Journal of Endodontics* **32**, 524–6.