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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

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Abstract

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Aim To determine the influence of volume, irrigant and method of flushing on the removal of artificially-placed dentine debris from the apical part of root canals during passive ultrasonic irrigation.

Methodology Access cavities were prepared in 15 canine teeth and their root canals instrumented to size 20, 0.10 taper. Each root was split longitudinally, forming two halves. A groove was cut in the canal wall 2–6 mm from the apex in each half which was then filled with dentine debris prior to the roots being reassembled. All canals were ultrasonically irrigated, using a size 15, 0.02 taper smooth wire to a length of 21 mm that was placed in the canal to the apical foramen. In group 1 the canal was flushed with a continuous flow of 50 mL 2% sodium hypochlorite (NaOCl). In group 2 the continuous flow was not used but the canal was flushed with 12 mL 2% NaOCl, at a rate of 2 mL 30 s^{-1} using a syringe. Group 3 was treated in the same way as group 2 but the canal was flushed with 6 mL 2% NaOCl, at a rate of 2 mL min^{-1}. Group 4 was treated in the same way as group 1 but water was used as the irrigant. Before and after irrigation, images of the grooves were captured and stored. The quantity of dentine debris in the groove was evaluated. The differences in debris scores between the experimental groups were analysed with the Kruskal–Wallis test and the Mann–Whitney *U*-test. The level of significance was set at $P = 0.05$.

Results The difference between all groups was statistically significant (K–W test $P < 0.001$).Groups 1, 2 and 3 differed significantly from group 4 ($P < 0.001$); there was no significant difference between groups 1, 2 and 3 ($P = 0.550$).

Conclusions Syringe delivery of 2% NaOCl (6 and 12 mL) was as effective as a continuous flow of 2% NaOCl (50 mL). Water was not effective in removing dentine debris from grooves in the apical portion of root canals.

Keywords: flushing, irrigant, irrigation, ultrasonic, volume, water.

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Introduction

It has been established that passive ultrasonic irrigation in combination with sodium hypochlorite (NaOCl) is more effective than conventional hand irrigation in removing dentine debris from the root canal (Goodman *et al.* 1985, Lee *et al.* 2004b). Other studies have shown that water is ineffective in removing dentine debris from the root canal during passive ultrasonic irrigation (Cameron 1987, Cheung & Stock 1993, Guerisoli *et al.* 2002). However, a controlled quantitative comparative study of the capacity to remove dentine debris from the root

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canal between water and NaOCl has never been performed.

Passive ultrasonic irrigation is the most efficient method of ultrasonic irrigation (Ahmad *et al.* 1987b). Passive ultrasonic irrigation implies that it will be performed following root canal preparation, irrespective of the preparation method used, up to the size of the master apical file. In this way the ultrasonic file can oscillate freely in the root canal and its cutting action reduced to a minimum. When the file oscillates freely, acoustic streaming and/or cavitation is more powerful (Roy *et al.* 1994).

Chlorine is responsible for the dissolution of organic tissue and the antimicrobial effect of NaOCl (Moorer & Wesselink 1982). However, chlorine is consumed rapidly during the first phase of tissue dissolution, probably within 2 min (Moorer & Wesselink 1982). Therefore regular replenishment and large volumes of NaOCl are required. However, it has not been determined how large the volume of NaOCl should be during passive ultrasonic irrigation.

With certain ultrasonic devices it is possible to use a continuous flow of irrigant during ultrasonic irrigation (Lee *et al.* 2004b). It is also possible to place NaOCl into the canal with a syringe and then activate the ultrasonic file (Cameron 1987). It is not known whether during ultrasonic irrigation a continuous flow of irrigant is more or less efficient in the removal of dentine debris from the root canal than syringe delivery of the irrigant. Syringe delivery of the irrigant allows full control of the procedure because the depth of needle penetration in the canal and the volume flushed through the canal are known. When using a continuous flow of irrigant, the volume through the root canal is not controlled as it is not measured or standardized.

The purpose of this study was to evaluate the effect of the volume, type of irrigant and the method of flushing the root canal on the removal of dentine debris from artificial extensions of the apical root canal during ultrasonic irrigation.

Materials and methods

Fifteen maxillary and mandibular canines were selected after bucco-lingual and mesio-distal radiographs indicated that their internal diameters at three points (3, 5 and 8 mm from the apex) were smaller than the corresponding diameters of a size 20, 0.10 taper GT instrument (Dentsply Maillefer, Ballaigues, Switzerland). Access cavities were prepared and the root canals shaped. Each canal was prepared to the apical foramen which was determined by inserting a size 15 K-file into the canal until the tip of the file was just visible. The coronal aspect of each canal was flared, using sizes 2–4 Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland); in the canal orifice only. The root canals were prepared to a size 20, 0.10 GT instrument. Between each instrument, the canals were irrigated with 2 mL of a freshly prepared 2% solution of NaOCl, using a syringe and a 27-gauge needle that was placed 1 mm short of the working length, resulting in a total volume of 30 mL. The NaOCl solution was prepared by diluting a 10% NaOCl solution (Merck, Darmstadt, Germany). Its pH was adjusted to 10.8 with 1 N HCl. The concentration of the NaOCl solution was measured iodometrically (Moorer & Wesselink 1982).

After root canal preparation each root was split longitudinally through the canal, forming two halves. A standard groove of 4 mm in length, 0.2 mm in width and 0.5 mm in depth was cut in one canal wall 2–6 mm from the apex (Fig. 1), to simulate uninstrumented canal extensions in the apical half (Lee *et al.* 2004a). Each groove was filled with dentine debris mixed with 2% NaOCl to simulate a situation when

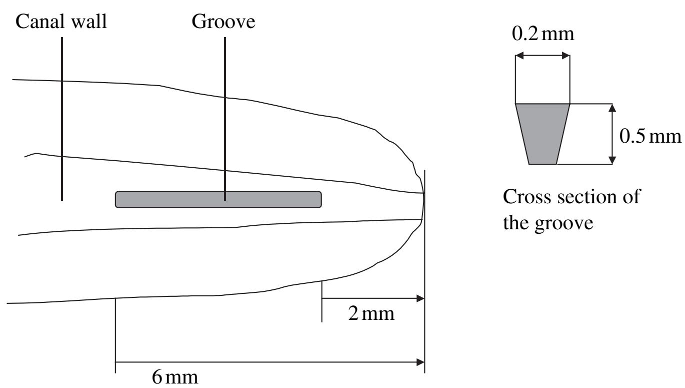

Figure 1 Schematic representation of specimen preparation. In one half of the instrumented root canal, a groove was cut 2–6 mm from the apex.

dentine debris accumulates in natural uninstrumented canal extensions. The amount of dentine debris and NaOCl and the time of application between mixing and placement were standardized. Images of each half of the canal with a groove were taken using a digital camera Konica Minolta Dimage Z10 (Konica Minolta, Mah Wah, NJ, USA), after which the images were loaded on a laptop, Asus M6 Boone (Dell Inc., USA), as jpg images with a USB cable. After reassembling the two root halves by means of wires and sticky wax, ultrasonic irrigation was performed with a piezoelectronic unit (PMax: Satelec, Meriganc, France). Four experiments were performed with the 15 teeth after a pilot study demonstrated that the smooth wire did not damage the root dentine or alter the form of the groove. In group 1 ($n = 15$) the root canals were ultrasonically irrigated for 3 min with a continuous flow of 50 mL 2% NaOCl. Group 2 ($n = 15$) was the same as group 1 with the exception that a continuous flow of irrigant was not used, rather the canal was flushed every 30 s with 2 mL 2% NaOCl using a syringe (total volume 12 mL). Group 3 ($n = 15$) was the same as group 2 with the exception that the canal was flushed every minute (total volume 6 mL). Group 4 ($n = 15$) was the same as group 1 with the exception that water was used as irrigant. After switching on the ultrasonic device, an activated 21 mm long stainless steel smooth wire with a 0.15 mm diameter and 0.02 taper (van der Sluis *et al.* 2005a) was placed in the canal as far as the apical foramen, the oscillation of the wire and irrigation began almost at the same time when the continuous flow was used. When no continuous flow was used, NaOCl was administered into the root canal by a syringe before inserting the ultrasonically activated wire. The oscillation of the wire was directed towards the groove and the intensity was set on speed 'blue 4'. In accordance with the manufacturer's, instructions the frequency employed under these conditions was approximately 30 kHz and the displacement-amplitude varied between 20 and 30 μm. The root halves were separated after the irrigation procedure in order to evaluate the removal of dentine debris. After irrigation, images of each half of the canal with a groove were taken using a digital camera Konica Minolta Dimage Z10, after which the images were loaded on a laptop, Asus M6 Boone, as jpg images with a USB cable. No extra magnification except for the magnification of the digital camera was necessary for the quanitification of the dentine debris.

The quantity of the debris in the groove before and after irrigation was scored independently by three calibrated dentists using the following scores: 0, the groove is empty; 1, less than half of the groove is filled with debris; 2, more than half of the groove is filled with debris; 3, the groove is filled completely with debris. With the scores before and after irrigation, the percentage of score reduction was calculated as follows:

$$\text{Percentage of score reduction} = \frac{\text{Score before irrigation} - \text{Score after irrigation}}{\text{Score before irrigation}} \times 100\%$$

The differences in debris scores between the different groups were analysed by means of Kruskal–Wallis test and the Mann–Whitney U-test. The level of significance was set at $P = 0.05$.

Results

The results of the study are shown in Table 1. The difference between all groups was statistically significant (K–W test $P < 0.001$). Groups 1, 2 and 3 differed significantly from group 4 ($P < 0.001$), but there was no significant difference ($P = 0.550$) between groups 1, 2 and 3.

Discussion

In a recent study (van der Sluis *et al.* 2005b) dentine debris removal from artificial extensions in the apical root canal was studied in canals of size 20, 0.06 taper, a taper 0.08 or a taper 0.1. The canals of size 20 and 0.1 taper had the greatest percentage of dentine debris removal (92.7%). Therefore, canals of size 20, 0.1 taper were used in this study.

It has been reported that uninstrumented extensions or irregularities in root canals were totally or partially filled with dentine debris following conventional hand irrigation (Goodman *et al.* 1985, Wu & Wesselink 2001). In the present study, a standard 4 mm groove was prepared, 2–6 mm from the apex and each groove was filled with dentine debris mixed with 2% NaOCl to simulate a situation where dentine debris accumulates

Table 1 Score of dentine debris before and after ultrasonic irrigation and the percentage of score reduction

Groups	Before	After Mean	After SD	% score reduction
Group 1	3.00	0.07	0.26	98
Group 2	3.00	0.07	0.26	98
Group 3	3.00	0.13	0.35	96
Group 4	3.00	1.67	1.11	44

in uninstrumented oval canal extensions. This methodology has the potential to score the dentine debris in the groove before and after the treatment and thus shows how much dentine debris had been removed by ultrasonic irrigation (Lee *et al.* 2004a,b, van der Sluis *et al.* 2005a).

From the results of this study it can be concluded that water as an irrigant during ultrasonic irrigation is not as effective as 2%NaOCl in removing dentine debris from extensions in the apical root canal. This confirms the results of other studies (Cameron 1987, Cheung & Stock 1993, Guerisoli *et al.* 2002). However, explanations for this enhanced cleaning effect are a matter of debate.

The significantly increased capacity of NaOCl to dissolve organic material when it is agitated by ultrasound (Moorer & Wesselink 1982) or when the temperature rises because of ultrasound energy (Cunningham & Balekjian 1980, Ahmad 1990) could explain the results.

During ultrasonic irrigation different processes can occur when NaOCl is used as irrigant. For example, the 'boiling point' of NaOCl is 40 °C, at which point the NaOCl will decompose. NaOCl can decompose and partially split into the sodium cation (Na^+), hypochlorite anion (ClO^-), sodium hydroxide (NaOH), hypochlorous acid (ClOH), chlorine (Cl_2), oxygen (O) or sodium chlorate (NaCl). During cavitation oscillating bubbles will form in the irrigant that will contain dissolved gas. When the bubble is in the expansion phase, gas will diffuse into the bubble; conversely, when the bubble is in the compression phase, gas will diffuse out of the bubble (Crum 1994). Chlorine could have an influence on this process by diffusing in the bubble. Bubbles can transport gas during cavitation (Leighton 1994). This could have an effect on the spread of chlorine through the irrigant. Bubbles formed in salt water tend to be more numerous, especially the smallest bubbles, and less prone to coalesce than bubbles in fresh water (Leighton 1994). These detailed factors could explain the difference in the action of water and NaOCl as irrigants. However, further research is required to explain the mechanism more clearly.

From the results it can be concluded that syringe delivery of irrigant during ultrasonic irrigation is as effective as a continuous flow of irrigant in the removal of dentine debris from extensions in the apical root canal. The maximum volume during 3 min of ultrasonic irrigation with the device employed in this study was 200 mL. A pilot study demonstrated that 50 mL during 3 min of irrigation (the minimum volume when continuous flow is possible) was as effective in dentine debris removal from an oval root canal as 200 mL. The results from the pilot study and the main study show that a continuous flow of 50 mL during 3 min of ultrasonic irrigation was sufficient to result in effective dentine debris removal from grooves cut in the wall of an oval root canal. It is not known if even less volume of irrigant during a continuous flow will result in efficient dentine debris removal.

During syringe delivery of the irrigant, the penetration depth of the needle and the volume that flows through the apical root canal are known. It is not possible to standardize the amount of NaOCl, which flows through the root canal during a continuous flow of irrigant because it is not known how much irrigant actually enters the root canal and flows through the apical part. During the procedure too many variables are involved which are impossible to standardize because the irrigant is always delivered outside the root canal. These variables include the placement of the suction tube, the width of the irrigant jet and the location and dimension of the root canal orifice.

From the results of this study it can also be concluded that 2 mL of 2% NaOCl delivered every minute by a syringe is as effective as 2 mL of 2% NaOCl delivered every 30 s during 3 min of ultrasonic irrigation in the removal of dentine debris from extensions in the apical root canal. When 2% NaOCl is refreshed every minute it is possible that sufficient free chlorine is present in the root canal to dissolve the organic component of dentine debris. In addition, the flushing effect seems adequate in the removal of inorganic dentine debris from the root canal when it is introduced ultrasonically every minute with 2 mL 2% NaOCl. It is not known if no refreshment of NaOCl during ultrasonic irrigation results in adequate dentine debris removal. It could be possible that 2 mL of 2% NaOCl contains enough free chlorine to dissolve the organic component of the dentine debris and that one refreshment of NaOCl has enough flushing effect to remove the inorganic component of dentine debris. This should be studied further.

Conclusion

Syringe delivery of 2% NaOCl (6 and 12 mL) was as effective as a continuous flow of 2% NaOCl (50 mL) during passive ultrasonic irrigation in removing dentine debris from artificial extensions in the apical root canal. Water, as irrigant during passive ultrasonic irrigation, was not effective in removing dentine debris from the apical root canal.

References

Ahmad M (1990) Measurements of temperature generated by ultrasonic file in vitro. *Endodontics and Dental Traumatology* **6**, 230–3.

Ahmad M, Pitt Ford TR, Crum LA, Walton AJ (1987b) Ultrasonic debridement of root canals: acoustic cavitation and its relevance. *Journal of Endodontics* **14**, 486–93.

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

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

Crum LA (1994) Sonoluminescence. *Physics Today* **9**, 22–9.

Cunningham WT, Balekjian AY (1980) Effect of temperature on collagen-dissolving ability of sodium hypochlorite as endodontic irrigant. *Oral Surgery, Oral Medicine, and Oral Pathology* **49**, 175–7.

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.

Guerisoli DM, Marchesan MA, Walmsley AD, Lumley PJ, Pecora JD (2002) Evaluation of smear layer removal by EDTAC and sodium hypochlorite with ultrasonic agitation. *International Endodontic Journal* **5**, 418–21.

Lee S-J, Wu M-K, Wesselink PR (2004a) The efficacy of ultrasonic irrigation to remove artificially placed dentine debris from different-sized simulated root canals. *International Endodontic Journal* **37**, 607–12.

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

Leighton TG (1994) *The Acoustic Bubble*. New York: Academic Press.

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

Roy RA, Ahmad M, Crum LA (1994) Physical mechanisms governing the hydrodynamic response of an oscillating ultrasonic file. *International Endodontic Journal* **27**, 197–207.

van der Sluis LWM, Wu MK, Wesselink PR (2005a) A comparison between a smooth wire and a K file in the removal of artificially placed dentine debris in plastic blocks. *International Endodontic Journal* **38**, 593–6.

van der Sluis LWM, Wu MK, Wesselink PR (2005b) The efficacy of ultrasonic irrigation to remove artificially placed dentine debris from human root canals prepared using instruments of varying taper. *International Endodontic Journal* **38**, 764–8.

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

