The efficacy of ultrasonic irrigation to remove artificially placed dentine debris from different-sized simulated plastic root canals

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Abstract

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Aim To investigate the influence of diameter and taper of root canals on the effectiveness of ultrasonic irrigation to remove artificially placed dentine debris from simulated uninstrumented extensions in simulated root canals.

Method Three groups of standard canals were cut in resin blocks using either size 20, .04 taper ProFile instruments, size 20, .06 Greater Taper (GT) rotary instruments or size 20, .08 GT instruments, respectively. Each resin block was then split longitudinally through the canal, forming two halves. In one canal wall, a standard groove 4 mm in length was cut 2–6 mm from the apical end of the canal, to simulate uninstrumented canal extensions. Each groove was filled with dentine debris mixed with 2% NaOCl to simulate a situation when dentine debris accumulates in the uninstrumented canal extensions. Each canal was reassembled by joining the two halves of the resin block by means of wires and sticky wax. In each canal ultrasonic irrigation was performed for 3 min using 2% NaOCl as irrigant. Before and after irrigation, images of each half of the canal with a groove were taken using a microscope and a digital camera, after which they were scanned into a PC as TIFF images. The quantity of dentine debris in the groove was evaluated using a scoring system: the higher the score, the larger the amount of debris remaining. The score data were analysed by means of Kruskal–Wallis and Mann–Whitney *U*-tests.

Results After ultrasonic irrigation, the debris score for the size 20, .04 taper group was significantly higher than that for the size 20, .06 group ($P = 0.040$) and the size 20, .08 group ($P = 0.006$) groups. However, no significant difference was found between the size 20, .06 and the size 20, .08 groups ($P = 0.320$).

Conclusion In simulated plastic root canals, the diameter and taper of root canal influenced the effectiveness of ultrasonic irrigation to remove artificially placed dentine debris.

Keywords: uninstrumented extension, ultrasonic irrigation, dentine debris

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Introduction

Both the ability of irrigant to dissolve tissue and its mechanical flushing action contribute to the cleaning of the root canal system (Chow 1983). Through the flushing action organic and dentinal debris and micro-organisms are mechanically removed from the canal. Baker *et al.* (1975) compared the cleaning efficacy of different irrigating solutions with or without the ability to dissolve tissue. They found no apparent difference in the effectiveness of the solutions in removing root canal debris and suggested that the flushing action may be more important than the ability to dissolve tissue. As most of the dentine is inorganic matter that cannot be dissolved by sodium hypochlorite (NaOCl) solution, the removal of dentine debris probably relies on the flushing action only.

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The mechanical flushing action of conventional hand syringe irrigation is dependent on the depth of placement and the diameter of the needle (Abou-Rass & Piccinino 1982, Chow 1983, Walters *et al.* 2002). The efficacy of syringe irrigation by hand to remove dentine debris from root canal is not ideal, suggesting that its flushing action is not powerful enough (Cunningham *et al.* 1982a, Goodman *et al.* 1985, Wu & Wesselink 2001, Walters *et al.* 2002). Indeed, Baker *et al.* (1975) concluded that 'Even when teeth were thoroughly instrumented and irrigated, significant amounts of debris remained in the prepared root canals'.

Enhancing the flushing action of irrigant solution by using ultrasound is well documented (Cunningham & Martin 1982b, Cunningham *et al.* 1982a,c, Stock 1991, Lumley *et al.* 1993, Lee *et al.* 2004). The ultrasound device is designed to allow endodontic irrigant to pass along the ultrasonic files. The irrigant is activated by the ultrasonic energy imparted from the energized instruments producing acoustic streaming and eddies (Ahmad *et al.* 1987, Krell & Johnson 1988, Stock 1991). Cunningham & Martin (1982b) and Cunningham *et al.* (1982a,c) compared the efficacy of hand irrigation and ultrasound to remove debris or bacterial spores from root canals and found that (i) after hand irrigation debris remained in canal irregularities while after ultrasound the irregularities were free of debris; (ii) after hand irrigation using saline 62% of bacterial spores was removed while after ultrasound using saline 86% of spores was removed; and (iii) after ultrasonic irrigation the canal wall was cleaner with visible dentinal tubules. The superior cleaning by ultrasonic irrigation was later confirmed in curved mesial roots of mandibular molars (Goodman *et al.* 1985, Ardila *et al.* 2003). However, in a study by Abbott *et al.* (1991), the ultrasonic technique was less effective at removing the smear layer when compared with other techniques.

Small root canals may restrict the flushing action of irrigant (Usman *et al.* 2004), with the result that such canals should be enlarged to allow effective irrigation. It has been reported that hand syringe irrigation was less effective when the canal was enlarged to less than a size 40 at the apex (Senia *et al.* 1971, McComb *et al.* 1976, Ram 1977, Wu & Wesselink 1995). Narrow canals may also compromise the effectiveness of ultrasonic irrigation (Druttman & Stock 1989, Stock 1991). The transverse oscillation of the ultrasonically activated file consists of nodes where the oscillation is minimal, and antinodes where the oscillation is greatest (Stock 1991). Krell *et al.* (1988) found that the irrigant would not penetrate beyond the first node until the canal was wide enough to allow free movement of the instrument.

Apical master files size 35–70 have been recommended for different tooth groups (Tronstad 2003). Recently, Greater Taper (GT) (Dentsply Maillefer, Ballaigues, Switzerland) and ProFile (Dentsply Maillefer) instruments of different tapers have been developed (Hata *et al.* 2002, Schäfer & Lohmann 2002). It has been recommended that using GT rotary instruments size 20, .10 taper should be the shaping objective in large root canals while size 20, .06 taper has been recommended in small roots (Buchanan 2001). Unfortunately, it is not known what diameter or taper will a root canal allow good ultrasonic irrigation and which restrict its effectiveness.

The purpose of this study was to investigate the influence of the diameter and taper of root canals on the effectiveness of ultrasonic irrigation to remove dentine debris from artificially made grooves simulating uninstrumented canal extensions in simulated plastic root canals.

Materials and methods

Thirty-six resin blocks (Endo Training Block, REFA0177; Dentsply Maillefer) were used. The portion of each block containing the canal was removed, leaving a shortened resin block 15 mm in length without a canal.

Three groups ($n = 12$) of straight canals 11 mm in length were prepared in the plastic blocks, using size 20, .04 ProFile (Dentsply Maillefer), size 20, .06 rotary GT (Dentsply Maillefer) and size 20, .08 rotary GT instrument (Dentsply Maillefer) respectively, in a hand piece rotating at approximately 8000 rpm. After two grooves were cut in each block along the long axis of the canal, they were split longitudinally through the canal using a chisel, forming two halves.

The working portion of a hand spreader (A60; Dentsply Maillefer) was removed and the end of the shank was sharpened. In the wall of one half of each canal, a standard groove of 4 mm in length was created 2–6 mm from the apex using the modified hand spreader (Fig. 1); the groove simulated an uninstrumented canal extension. The groove was 0.5 mm deep and 0.2 mm wide; the width of the groove is comparable with the width of the short diameter of narrow oval canals (Wu *et al.* 2000).

To produce dentine debris, a number of teeth with single canals were split longitudinally and debris was

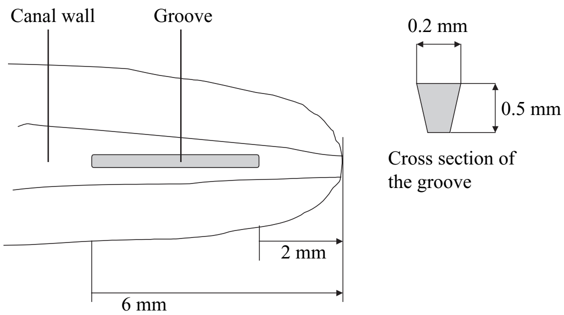

Figure 1 Schematic representation of specimen preparation. In one half of the instrumented root canal a groove was cut 2–6 mm from the apex.

ground off from the canal wall with round burs from the pulpal to the cementum side. Five minutes before use, the dentine debris was mixed with 2% NaOCl; a wet sand-like mixture was prepared. Using a paper point, each groove was filled with debris, taking care not to compact it.

To reassemble the tooth, the two halves of each block were reconnected using wires and sticky wax. Irrigation was performed in each canal with a piezo-electronic ultrasonic unit (P MAX; Satelec, Meriganc Cedex, France) using 2% NaOCl as the irrigant. The concentration of the NaOCl solution was measured iodometrically (Moorer & Wesselink 1982). Each canal was then irrigated with approximately 200 mL of 2% NaOCl along an ultrasonically activated size 15 file 1 mm short of the apical end of the canal, and oscillating in the direction towards the groove at speed 3 for 3 min. According to the manufacturer, the frequency employed under the above-mentioned conditions was approximately 30 kHz.

Before and after irrigation, photographs of the two halves of the canal were taken using a Photomakroskop M400 microscope with digital camera (Wild, Heerbrugg, Switzerland) at ×40 magnification; the photos were then scanned as tagged-image file format images. The amount of the dentine debris in the grooves was evaluated prior to treatment, using a scoring system, in order to examine whether all grooves were filled with debris at the time of irrigation. The second scoring was performed after irrigation. A higher score indicated a greater amount of debris: score 0: the entire groove was free of debris; score 1: less than half of the groove was filled with debris; score 2: half or more than half of the groove was filled with debris; and score 3: the entire groove was filled with debris. The canal width was measured at 3, 7 and 11 mm from the apical end of the canal, using a KS100 Imaging system 3.0 (Carl Zeiss Vision GmbH, Hallbergmoos, Germany).

The differences in debris scores after irrigation between the three groups were analysed by means of Kruskal–Wallis and Mann–Whitney *U*-tests. The level of significance was set at $\alpha = 0.05$.

Results

The canal width measured at 3, 7 and 11 mm from the apical end is shown in Table 1, demonstrating that standard canals were produced in the resin blocks. The average width at the different levels was comparable with those of the three instruments used to drill the canals. Before irrigation, the groove score was 3 for all specimens. The debris scores after irrigation are shown in Table 2. The Kruskal–Wallis test showed that between the groups a significant difference existed ($P = 0.012$). The Mann–Whitney *U*-test revealed that the debris score for the size 20, .04 group was significantly higher than those for the size 20, .06 ($P = 0.040$) and size 20, .08 ($P = 0.006$) groups. However, no significant difference was found between size 20, .06 and size 20, .08 groups ($P = 0.320$).

Discussion

Instruments of different diameters and tapers have been used in root canal treatment (Buchanan 2001, Hata *et al.* 2002, Schäfer & Lohmann 2002). The size of a prepared root canal may be similar to the size of the instruments used in the root canal preparation.

Table 1 Diameters of standardized simulated canals at 3, 7 and 11 mm from the apical end correspond to the diameters of the GT files

	Average canal diameter in mm ± SD (diameter of the GT file)		
Group (n = 12)	3 mm	7 mm	11 mm
20-04	0.32 ± 0.02 (0.32)	0.47 ± 0.03 (0.48)	0.60 ± 0.04 (0.64)
20-06	0.38 ± 0.02 (0.38)	0.61 ± 0.04 (0.62)	0.82 ± 0.05 (0.86)
20-08	0.42 ± 0.04 (0.44)	0.72 ± 0.05 (0.76)	0.99 ± 0.04 (1.00)

Table 2 The debris scores after ultrasonic irrigation

n	Debris scores for different-sized canals		
	20-04	20-06	20-08
1	0	0	0
2	1	0	0
3	0	0	0
4	0	0	0
5	3	1	1
6	2	1	1
7	1	0	0
8	2	2	0
9	2	0	0
10	0	0	0
11	2	0	0
12	2	2	0
Sum	15 (58.3% reduction*)	6 (83.3% reduction*)	2 (94.4% reduction*)

*As each specimen had a score of 3 (full with debris) before irrigation, the sum score before irrigation was 36 ($n = 12$). % Reduction=[(36–sum score after irrigation)/36] × 100%.

Because the purpose of this study was to investigate the size and taper that allowed effective ultrasonic irrigation and which size and taper restricted the effectiveness of ultrasonic irrigation, it was desirable to have three groups of root canals of which the size was standardized. Although it would be more realistic to conduct the experiment in natural teeth, it would have been impossible to create standard-sized root canals in natural teeth considering the enormous variation in canal diameters at all different levels especially in the bucco-lingual direction within natural teeth (Wu *et al.* 2000). Because of the nature of the plastic experimental model a degree of caution should be exercised in the interpretation of the data.

In some studies (Weller *et al.* 1980), simulated plastic canals were compared with extracted teeth as models for measuring the efficiency of root canal instrumentation and irrigation techniques; similar results were obtained in both models. However, dentine, due to its porous nature (by having dentinal tubules), may act differently than a solid plastic material.

It has been reported that uninstrumented extensions or irregularities were totally or partially filled with debris following conventional hand irrigation (Cunningham *et al.* 1982a, Goodman *et al.* 1985, Wu & Wesselink 2001). In this study, a standard groove of 4 mm in length was cut, 2–6 mm from the apex and each groove was filled with dentine debris mixed with 2% NaOCl to simulate a situation when dentine debris accumulates in the uninstrumented canal extensions.

The size 20, .04 canals may be too small to allow effective ultrasonic irrigation (Table 2). By contrast, in 10 (83%) of size 20, .08 canals, the groove was free of debris after ultrasonic irrigation, while in the other two a very small amount of debris remained (Table 2). These data suggest that a certain amount of canal enlargement and taper is necessary to allow the oscillation of the file to remove debris effectively.

In this study standardized canals created to a size 20, .08 taper had sufficient shape to allow effective irrigation. A size 20, .08 instrument is 0.2, 0.28, 0.36, 0.44, 0.52 and 0.6 mm wide at 0, 1, 2, 3, 4, and 5 mm from its tip, respectively (Fig. 2). The diameters of the apical 5 mm of the canal prepared using size 20, .08 GT instrument correspond to the diameters of ISO sizes 20, 30, 35, 45, 50 and 60 (i.e. 20–60) at the corresponding apical levels, as shown in Fig. 2. It is likely that using ISO size files (20–60) stepping back with 1 mm increments can also create a size 20, .08 shape within the apical portion of root canal (Fig. 2). Good cleaning was achieved in the canals prepared using size 20, .08 taper GT instrument (Table 2), suggesting that canals prepared to these diameters (0.2–0.6 mm) allowed the ultrasonic file to oscillate sufficiently.

In large roots the original apical canal may be wider than the instrument used in this study (Fig. 2)

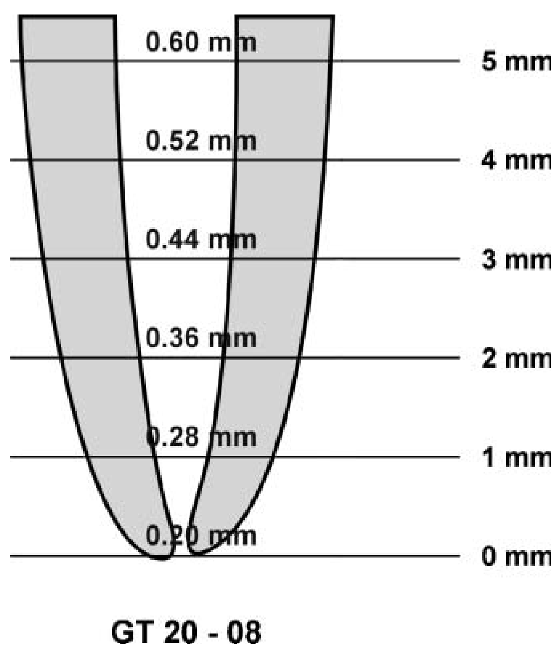

Figure 2 Illustration of the diameters of the apical 5 mm of the canal cut by GT 20-08.

(Wu *et al.* 2000, Tronstad 2003). Such large canals may not need further enlargement by instrumentation to ensure free oscillation of the ultrasonic file. However, a large root can also have a small canal (Wu *et al.* 2000). Therefore, it seems justified that at least a series of instruments size 20–60 should be used as measuring or preparation instruments, in order to ensure that the necessary diameter is present at different levels (taper) to allow effective oscillation.

Conclusion

In simulated plastic root canals, the diameter and taper of root canal influenced the effectiveness of ultrasonic irrigation in removing artificially placed dentine debris.

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