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The evaluation of removal of calcium hydroxide paste from an artificial standardized groove in the apical root canal using different irrigation methodologies

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Abstract

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Aim To evaluate the capacity to remove a calcium hydroxide ($Ca(OH)_2$) paste from the root canal and to evaluate the efficacy of $Ca(OH)_2$ removal during passive ultrasonic irrigation using either sodium hypochlorite (NaOCl) or water as an irrigant.

Methodology Sixteen mandibular premolars were used. Each root was prepared to the apical foramen using GT instruments of size 30, 0.06 taper. Each root was split longitudinally. In one half of the root, a groove was cut in the canal wall 2–6 mm from the apex which was then filled with a $Ca(OH)_2$ paste. Subsequently the roots were reassembled. In group 1 ($n = 16$), the teeth were ultrasonically irrigated using 50 mL 2.0% NaOCl as the irrigant. Group 2 ($n = 16$) was treated in the same manner as group 1, but using 50 mL water in place of the NaOCl. In group 3 ($n = 16$), the teeth were irrigated by syringe injection of 50 mL 2.0% NaOCl. The quantity of remaining $Ca(OH)_2$ in the groove was scored and the data analysed with Kruskal–Wallis and Mann–Whitney tests.

Results The difference in remaining $Ca(OH)_2$ between all groups was statistically significant ($P < 0.001$). Group 1 had significantly lower scores than group 2 ($P < 0.001$) and group 3 ($P = 0.002$), but there was no significant difference between groups 2 and 3 ($P = 0.765$).

Conclusions Passive ultrasonic irrigation with 2% NaOCl was more effective in removing $Ca(OH)_2$ paste from artificial root canal grooves than syringe delivery of 2% NaOCl or water as irrigant.

Keywords: calcium hydroxide, passive ultrasonic irrigation, sodium hypochlorite, syringe delivery, water.

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Introduction

Calcium hydroxide ($Ca(OH)_2$) in a nonsetting paste form is used widely as an intracanal medicament during root canal treatment because of its antimicrobial properties (Siqueira & Lopes 1999, Law & Messer 2004). The most frequently described method for removal of $Ca(OH)_2$ from the root canal is instrumentation of the root canal with the master apical file in combination with copious irrigation of sodium hypochlorite (NaOCl) and EDTA (Lambrianidis *et al.* 2006). EDTA has the ability to neutralize $Ca(OH)_2$ residues, which could prevent a chemical reaction with the sealer, or chelate $Ca(OH)_2$ residues, which could make them easier to remove by irrigation (Margelos *et al.* 1997). However, it has been reported that removal of $Ca(OH)_2$ from the apical root canal wall, when this

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method is used, is difficult (Margelos *et al.* 1997, Lambrianidis *et al.* 1999, 2006). This can be explained because instrumentation and irrigation alone cannot completely clean the entire root canal wall (Wu *et al.* 2003). When $Ca(OH)_2$ is removed from the main canal with a file, remnants will remain in canal extensions or irregularities. From these canal extensions or irregularities it is only possible to remove the $Ca(OH)_2$ by irrigation. Passive ultrasonic irrigation (PUI) is more effective in dentine debris removal from the root canal wall than syringe delivery of the irrigant (Goodman *et al.* 1985, Lee *et al.* 2004b). However, whether PUI can remove $Ca(OH)_2$ from the root canal wall is not known.

Passive ultrasonic irrigation is based on the transmission of energy from an ultrasonically oscillating instrument to the irrigant in the root canal (van der Sluis *et al.* 2005a). In the irrigant solution, acoustic streaming and/or cavitation will occur that is more powerful when the root canal wall is not touched deliberately with the oscillating instrument (Ahmad *et al.* 1988, Roy *et al.* 1994). Therefore, PUI is undertaken after the root canal is prepared up to the master apical file and without instrumenting the root canal wall during the ultrasonic irrigation.

Calcium hydroxide remnants left in the root canal can result in a thicker nonhomogenous appearance of root canal sealers (Margelos *et al.* 1997, Kim & Kim 2002, Hosoya *et al.* 2004). The sealer thickness could have an effect on the sealing ability of root canal fillings (Kontakiotis *et al.* 1997). The $Ca(OH)_2$ remnants could also result in a chemical reaction with the sealer resulting in a reduction of flow or working time (Margelos *et al.* 1997, Hosoya *et al.* 2004). Cracks were visible in zinc-oxide eugenol sealer after the use of $Ca(OH)_2$ (Kim & Kim 2002) which can be explained by the faster setting of the sealer under the influence of $Ca(OH)_2$ (Margelos *et al.* 1997). Calcium hydroxide remnants could also prevent sealer from penetrating the dentinal tubules resulting in a potential reduction in sealer adaption (Çalt & Serper 1999). The dimensional instability of $Ca(OH)_2$ and its potential to dissolve in water and dissociate into hydroxide and calcium ions (Cohen & Burns 2002) could influence the leakage of root fillings on the long term. In the past, leakage studies have been undertaken to evaluate the influence of the above-mentioned phenomena on the leakage of a root canal filling *ex vivo*. However, most of these were passive dye leakage studies which are not reliable because $Ca(OH)_2$ discolours methylene blue (Wu *et al.* 1998), which is often used as a colouring agent for dye leakage. Furthermore, dye leakage is a passive leakage test which can hinder the penetration of dye when air bubbles are present between the root filling and the root canal wall (Wu *et al.* 1994). Because the studies were performed directly after filling the root canals, the effect on the long term could not be evaluated. Therefore, a negative effect of $Ca(OH)_2$ remnants on leakage of subsequently placed root fillings on the short and long term has never been demonstrated.

In a study by Lee *et al.* (2004a), a standardized groove was cut in the apical part of the root canal to simulate an oval extension of the apical root canal. The dimensions of the groove were determined using the data of the anatomy of the apical root canal as described by Wu *et al.* (2000). Using this methodology the removal of calcium hydroxide paste packed in an apical extension, which cannot be removed by endodontic files, but can only be removed by irrigation, could be evaluated while the situation before irrigation is controlled.

The purpose of the study was to evaluate the capacity to remove $Ca(OH)_2$ from an artificial standardized groove in the apical root canal and to evaluate the efficacy of $Ca(OH)_2$ removal during PUI between NaOCl and water.

Materials and methods

Sixteen mandibular single-rooted premolars were selected after bucco-lingual and mesio-distal radiographs indicated that their internal diameters at three points (2, 4 and 6 mm from the apex) were smaller than the corresponding diameters of a size 30, 0.06 taper GT instrument (Dentsply Maillefer, Ballaigues, Switzerland). The crowns of the teeth were removed 12 mm from the apex to standardize the length of the roots and eliminate the variation in dimension of the pulp chamber. The root canals were shaped with GT root canal instruments, to a size 30, 0.06 taper GT instrument as the master apical file. Each canal was prepared to the apical foramen which was determined by inserting a size 10 K-file into the canal until the tip of the file was just visible. 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, to simulate uninstrumented canal extensions in the apical half (Lee *et al.* 2004a) (Fig. 1). Each groove was filled with calcium hydroxide paste (Ultracal® XS; Ultradent products, Jordan, UT, USA) using paper points 30–40, to simulate a situation when calcium hydroxide paste remains in natural canal extensions after instrumentation. Care was taken to consistently apply the calcium hydroxide paste in the groove. The teeth were reassembled with wires and stored for 1 week at 37 °C in 100% relative humidity to simulate the clinical situation when $Ca(OH)_2$ is used as an intermediate root filling between two treatment visits. After 1 week of storage, images of each half of the canal with a groove were taken using a Photomakroskop M 400 microscope with a digital camera (Wild, Heerbrugg, Switzerland) at ×40 magnification to detect the amount of $Ca(OH)_2$ just before irrigation; the photos were then scanned as tagged-image file format images. The two root halves were reassembled by means of wires and sticky wax, and the apical foramen was sealed with wax. Three different types of irrigation were tested with the 16 teeth; a pilot study had demonstrated that the smooth wire used during ultrasonic irrigation did not damage the root dentine or alter the form of the groove. In group 1 ($n = 16$), the root canals were ultrasonically irrigated for 3 min with a continuous flow of 50 mL 2.0% NaOCl. Group 2 ($n = 16$) was the same as group 1 with the exception that water was used as the irrigant in place of 2% NaOCl. In group 3 ($n = 16$), the canals were irrigated with 50 mL of 2.0% NaOCl using a syringe with a 27-gauge Therumo needle (Terumo Europe N.V., Brussels, Belgium) which was inserted just short of the apical foramen. Ultrasonic irrigation was performed with a piezoelectronic unit (PMax; Satelec, Meriganc, France). After switching on the ultrasonic device, an activated 21-mm-long stainless steel smooth wire with a diameter of 0.15 mm and a 0.02 taper (van der Sluis *et al.* 2005a) was placed in the canal just short of the apical foramen, the oscillation of the wire and irrigation began almost at the same time. The oscillation of the wire was directed towards the groove and the intensity was set on speed 'blue 4'. According to the manufacturer, the frequency employed under these conditions was approximately 30 kHz, and the displacement-amplitude varied between 20 and 30 μm. Between the different irrigation procedures the root halves containing the groove were cleaned with brushes and air under high pressure. The grooves were examined under a microscope to ensure that all $Ca(OH)_2$ remnants were removed from the grooves. The root halves were separated after each irrigation procedure to evaluate the removal of $Ca(OH)_2$. After irrigation, images of each half of the canal with a groove were taken using a Photomakroskop M 400 microscope with a digital camera (Wild) at ×40 magnification; the photos were then scanned as tagged-image file format images.

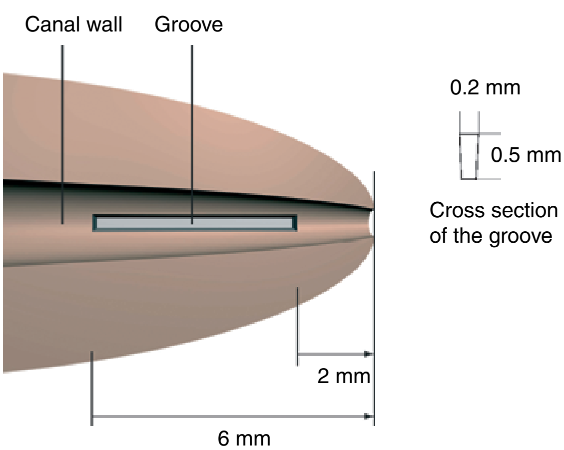

Figure 1 Schematic representation of specimen preparation. In one half of the instrumented root canal, a groove was cut 2-6 mm from the apex.

The quantity of $Ca(OH)_2$ in the groove before and after irrigation was scored double-blind and independently by three calibrated dentists using the following scores: score 0, the groove is empty; score 1, less than half of the groove is filled with $Ca(OH)_2$; score 2, more than half of the groove is filled with $Ca(OH)_2$ and score 3, the groove is filled completely with $Ca(OH)_2$. 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 $Ca(OH)_2$ scores between the different groups were analysed by means of the Kruskal–Wallis and Mann–Whitney tests. The level of significance was set at $\alpha = 0.05$.

Results

The results of the study are shown in Table 1. The $Ca(OH)_2$ score was reduced by 63.3% in group 1, 6.7%

Table 1 Score of calcium hydroxide before and after irrigation and the percentage of score reduction

Groups	Before	After Mean	After SD	Percentage of score reduction Mean	Percentage of score reduction SD
1	3.00	1.1	1.1	63.3	36.7
2	3.00	2.8	0.5	6.7	16.7
3	3.00	2.5	1.0	16.7	33

in group 2 and 16.7% in group 3. The difference between all groups was statistically significant (Kruskal–Wallis test, $P < 0.001$). Group 1 differed significantly from group 2 ($P < 0.001$) and group 3 ($P = 0.002$), but there was no significant difference between groups 2 and 3 ($P = 0.765$).

Discussion

The results indicate that PUI with NaOCl as irrigant was more effective in removal of $Ca(OH)_2$ paste from an artificial standardized groove in the apical root canal than PUI with water or irrigation by means of syringe delivery of NaOCl.

During PUI, acoustic microstreaming and cavitation can occur which cause a streaming pattern within the root canal from the apical to the coronal (Ahmad *et al.* 1987, Roy *et al.* 1994). Because of this microstreaming, more dentine debris can be removed from the root canal compared with syringe delivery of the irrigant (Lee *et al.* 2004a), even from remote places in the root canal (Goodman *et al.* 1985). Probably the same mechanisms are responsible for the more effective removal of $Ca(OH)_2$ during PUI in comparison with syringe delivery of the irrigant.

Sodium hypochlorite as irrigant is more effective in removing dentine debris from the root canal during PUI than water (Huque *et al.* 1998, van der Sluis *et al.* 2006). As 30% of dentine debris is an organic material, the excellent organic tissue dissolution properties of NaOCl were suggested as an explanation (van der Sluis *et al.* 2006). To examine if the organic tissue dissolution properties are really of importance for the effectiveness of PUI with NaOCl as irrigant, the removal of a nonorganic substance from a standardized groove in a root canal during PUI could give an answer. The capacity to remove a nonorganic substance from a standardized groove in a root canal during PUI can evaluate the importance of the tissue-dissolving effect of NaOCl during PUI. Sodium hypochlorite as an irrigant during PUI is also more effective in removing $Ca(OH)_2$ from an artificial groove in the apical root canal than water, as it is during the removal of dentine debris. The results of PUI with water were comparable with the results of irrigation by means of syringe delivery of NaOCl indicating that the extra capacity to remove matter from the root canal of PUI with NaOCl as irrigant does not occur when water is used. Because $Ca(OH)_2$ is an inorganic substance the tissue dissolving capacity of NaOCl cannot play a role in the process. There are several explanations for differences between water and NaOCl as irrigant during PUI. First the physical properties of NaOCl are different from water, NaOCl is a salt water suspension, normal water not. Bubbles formed in salt water tend to be more numerous, particularly regarding the smallest bubbles and are less prone to coalesce than bubbles in fresh water (Leighton 1994). Because the smallest bubbles are more numerous, the acoustic microstreaming will be different and could perhaps be more powerful. Another explanation is that gas will dissolve in the bubble during cavitation and the oscillations of the bubble depend on the concentration of the gas dissolved in the liquid, the temperature of the liquid and small amounts of surface active impurities (Brenner *et al.* 2002). During PUI with NaOCl as irrigant, chlorine gas will be present in the irrigant which can dissolve in the bubble. The chlorine gas in the irrigant will also have an influence on the oscillation of the bubbles. This will influence the acoustic microstreaming. Whether the temperature and surface active impurities during PUI are different with NaOCl or water as an irrigant is not known. All these items remain for further research.

In this study, the most successful method of $Ca(OH)_2$ removal was PUI with NaOCl as irrigant; an average of 63.3% of $Ca(OH)_2$ removal was recorded. In earlier studies, higher percentages of dentine debris removal and more samples with a completely empty groove were recorded (Lee *et al.* 2004b, van der Sluis *et al.* 2005b, 2006) (Table 2). However, root canals of different sizes and tapers were used varying from apical sizes 50, 30 and 20 and tapers of 0.10–0.06. It is more difficult to remove dentine debris from the root canal when the size and taper of the root canal are smaller (Lee *et al.* 2004a, van der Sluis *et al.* 2005b). However, the average removal of $Ca(OH)_2$ from a size 30 taper 0.06 was even lower than the scores of dentine debris removal from a smaller root canal of size 20 and taper 0.06. This could indicate that it is more difficult to remove $Ca(OH)_2$ from the root canal wall than dentine debris. The remaining 36.7% $Ca(OH)_2$ residue could

Table 2 Percentage of dentine debris or $Ca(OH)_2$ removal from an artificial groove in the apical root canal in different studies

Study	Size	Taper	Irrigation	Reduction (%)	Score 0 (%)
Lee *et al.* (2004b), dentine debris	50	SB	US NaOCl	88	75
	50	SB	S NaOCl	25	0
van der Sluis *et al.* (2005b), dentine debris	20	0.10	US NaOCl	92.7	87
van der Sluis *et al.* (2006), dentine debris	20	0.10	US NaOCl	98	93
	20	0.10	US water	44	20
$Ca(OH)_2$	30	0.08	US NaOCl	63.3	37.5
	30	0.08	US water	6.7	0
	30	0.08	S NaOCl	16.7	6.25

have a negative effect on the sealing abilities of sealers, prevent sealers from penetrating the dentinal tubules or dissolve with time (Margelos *et al.* 1997, Çalt & Serper 1999, Cohen & Burns 2002, Kim & Kim 2002, Hosoya *et al.* 2004).

No irrigation with EDTA was used in this study. EDTA may neutralize $Ca(OH)_2$ residues to prevent chemical influence on the sealer; however, the interference from the mechanical point of view is still present (Margelos *et al.* 1997). Çalt & Serper (1999) reported complete removal of $Ca(OH)_2$ from the root canal after irrigation with EDTA and NaOCl in comparison with NaOCl alone. It is likely that EDTA may chelate residual $Ca(OH)_2$ which is then more easily removed by irrigation with NaOCl (Margelos *et al.* 1997). However, other studies using the same irrigation regime (EDTA and NaOCl) could not confirm these results and still found extensive remnants of $Ca(OH)_2$ (Tatsuta *et al.* 1999, Lambrianidis *et al.* 2006). There is no evidence that EDTA can completely dissolve $Ca(OH)_2$ placed superficially on the canal wall or from deeper layers of the root canal. However, it could be interesting to study if pre-treatment of $Ca(OH)_2$ with EDTA removes $Ca(OH)_2$ more easily from the root canal during PUI than no pre-treatment of EDTA.

In this study, Ultracal® XS was used as the calcium hydroxide paste. UltraCal® XS is an aqueous radiopaque paste with a pH of 12.5. The approximate $Ca(OH)_2$ concentration is 35%. If another type of calcium hydroxide paste would have given different results is not known, but as this is an aqueous solution of $Ca(OH)_2$ no influence from the vehicle is expected.

Conclusion

Passive ultrasonic irrigation with 2% NaOCl is more effective in removing $Ca(OH)_2$ from the root canal than syringe delivery of 2% NaOCl or water as irrigant during PUI.

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