Calcium hydroxide dressings using different preparation and application modes: density and dissolution by simulated tissue pressure

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Abstract

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Aim To study the effect of different apical shapes in prepared simulated root canals on the application of a commercially prepared calcium hydroxide paste by a syringe or lentulo spiral.

Methodology Three different types of root canal preparation were performed in 90 simulated canals: group A to an apical size 20 and a 0.10 taper using hand and rotary instruments, group B to an apical size 30 and a 0.08 taper using GT rotary instruments and group C to an apical size 40 and a 0.04 taper using ProFile 0.04 instruments. The insertion of calcium hydroxide [$Ca(OH)_2$] paste was accomplished using either a lentulo spiral or a syringe. After 1 week of simulated fluid pressure applied to the apical end of the canal using physiological saline solution, the solution was evaluated for released $Ca(OH)_2$. The specimens were weighed initially, after preparation, after insertion of $Ca(OH)_2$ paste, after temporization with Cavit and after 1 week of simulated fluid pressure. Digital radiographs of the filled canals were taken and canal areas in mm^2, gray values of the $Ca(OH)_2$ dressings, total area of voids in mm^2, as well as location of voids in the apical, middle or coronal thirds of the root canals were measured. Analyses of variance, with Scheffe's *post-hoc* tests, as well as chi-square tests were performed.

Results Canals in group C had significantly fewer ($P < 0.01$) radiographic voids than canals in groups A and B. Using a lentulo spiral resulted in significantly ($P < 0.05$) fewer voids compared with the injection technique. More voids were detected coronally compared with middle and apical root canal thirds ($P < 0.05$).

Conclusions Canal shape and method of application had an impact on the amount and radiodensity of calcium hydroxide dressings in simulated root canals. Canals prepared to an apical size 40 and a taper of 0.04 had the least number of voids; $Ca(OH)_2$ was placed with significantly fewer voids using a lentulo spiral compared with the injection technique.

Keywords: calcium hydroxide, canal shape, dissolution, fill, radiodensity.

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Introduction

It has been shown that successful disinfection of root canals with negative cultures results in high rates of healing (Sjögren *et al.* 1997). Mechanical instrumentation alone reduces intracanal bacteria counts and creates space for subsequent placement of irrigating solutions. However, even after mechanical instrumentation and irrigation with antimicrobial solutions, bacteria can survive (Byström & Sundqvist 1981, Gomes *et al.* 1996). Placement of intracanal medicaments has therefore been recommended (Byström *et al.* 1985, Peters *et al.* 1995, Shuping *et al.* 2000, Siqueira 2001).

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Calcium hydroxide [$Ca(OH)_2$] is widely used as an interappointment intracanal disinfectant and has a pH of 11–12. It has antibacterial, tissue dissolving (on surface contact) and hygroscopic properties (Hasselgren *et al.* 1988, Zehnder *et al.* 2003); it also represents a physical barrier to prevent bacterial recontamination (Siqueira & Lopes 1999). $Ca(OH)_2$ increases the pH not only inside root canals but also in surrounding dentine and periradicular tissues (Cvek 1973, Tronstad *et al.* 1980, Nerwich *et al.* 1993).

Nickel–titanium (NiTi) rotary instrumentation is an important adjunct in root canal instrumentation, allowing more centered preparations and minimizing complications such as ledging, perforations and apical zipping (Short *et al.* 1997, Peters 2004). Some new instrumentation techniques advocate smaller apical diameters combined with greater tapers than traditional hand instrumentation; under these conditions, a dense filling with $Ca(OH)_2$ apically may be difficult to achieve and consequently, antimicrobial efficacy may be reduced. The placement of sealer in narrow apical canal diameters may also be more difficult than in wider apical preparations.

Placement of calcium hydroxide into shaped canals without voids can be difficult to accomplish but may be verified on postoperative radiological examination. A large amount of $Ca(OH)_2$ slurry placed initially is desirable to create a sufficient pH rise and antibacterial conditions (Fava & Saunders 1999, Staehle *et al.* 1997). A lentulo spiral was efficient in filling root canals with $Ca(OH)_2$ (Dumsha & Gutmann 1985, Sigurdsson *et al.* 1992, Staehle *et al.* 1997) but other authors state that if moderately curved root canals were shaped to a larger size of at least size 50, dense $Ca(OH)_2$ fillings are possible by means of a syringe system (Staehle *et al.* 1997).

These factors may also be influenced by tissue fluid that gains access to the root canal from the periapical region. This fluid supplies liquid to further dissolve $Ca(OH)_2$ but may also lead to physical dissolution and ultimately removal of $Ca(OH)_2$ (Beeler *et al.* 1989, Heyeraas & Kvinnsland 1992, Rehman *et al.* 1996).

Therefore, it is possible that the quality of $Ca(OH)_2$ placement as well as the ingress of fluid diluting the medicament and providing nutrition for multiplication of bacteria remaining in root canals may influence clinical outcomes. The aim of this study was to investigate the effect of apical diameter and taper in prepared simulated root canals on the radiodensity of intracanal dressings comprising of a commercially prepared $Ca(OH)_2$ paste. The efficacy of two methods of application was also compared along with the effects of simulated apical fluid pressure.

Materials and methods

Specimens

The lengths of 90 simulated canals in plastic blocks (50° curvature with a 6.5 mm radius, Ref. A 0177; Dentsply Maillefer, Ballaigues, Switzerland) were determined with size 15 K-files that were introduced into the root canal until just visible at the apical terminus. The canals were randomly divided into three groups of 30. A small metal sleeve made out of a needle was glued (Sekundenkleber 1733; Renfert, Hilzingen, Germany) to the side of the plastic block, with the sleeve encircling the apical terminus. Specimens were covered with sterilization tape during canal preparation and placement of medication.

Canal preparation

After initial canal negotiation with stainless steel hand instruments, a handpiece and an electrical motor (AEU-20; Dentsply Tulsa, Tulsa, OK, USA) were used to prepare 30 canals each using a hybrid technique with either engine-driven NiTi ProSystem GT instruments (GT) and hand stainless steel K-flexofiles, with rotary GT instruments alone or with ProFile rotary instruments (all instruments by Dentsply Maillefer).

Thirty canals (group A, Table 1) were prepared in a crowndown approach with GT instruments to size 30, 0.10 taper inserted to 14.5 mm. Using the balanced force technique (Roane *et al.* 1985) and K-flexofiles (batch no. 6713061), canals were prepared by hand to full canal length minus 0.5 mm to an apical size 20. A

Table 1 Summary of conditions in the three experimental groups

Group	Canal preparation
A ($0.032\ mm^2$)	
Lentulo	Apical size no. 20, stepback in 0.5 mm
Injection	increments, K-files
B ($0.071\ mm^2$)	
Lentulo	Apical size no. 30 and continuous 0.08 taper,
Injection	no stepback, GT files
C ($0.126\ mm^2$)	
Lentulo	Apical size no. 40, no stepback, ProFile 0.04
Injection	instruments

Numbers in parentheses indicate apical cross-sectional areas of contact between fluid and calcium hydroxide fill.

stepback preparation to size 40 in 0.5 mm increments followed. The specimens were then randomly divided into two groups of 15 canals each, groups A1 and A2.

Canals in group B ($n = 30$, Table 1) were prepared by hand to an apical ISO size 20 using K-files and the balanced force technique, working length was to the full canal length minus 0.5 mm. A crowndown preparation was carried out up to working length with engine-driven GT instruments. Root canals were enlarged to an apical size 30, 0.8 taper. The specimens were then randomly divided into two groups of 15 canals each, groups B1 and B2.

The remaining 30 canals (group C, Table 1) were hand-prepared to an initial apical size 15 using K-files and the balanced force technique, to full canal length minus 1 mm. This working length definition corresponds to recommended clinical practice for the use of rotary instruments to shape an apical stop or matrix (Kast'akova *et al.* 2001). A crowndown preparation was carried out to working length with rotary ProFile 0.04 instruments. The root canals were enlarged to an apical size 40. The specimens were then randomly divided into two groups of 15 canals each, groups C1 and C2.

Patency was confirmed in all groups by introducing a size 10 K-file just past the prepared working length. During preparation the canals were copiously irrigated with tap water and files were coated with a lubricant (Glyde, Dentsply Maillefer). Canals were dried with paper points and the plastic blocks were weighed after shaping (see below).

Depending on the shape of the preparation, and the instruments used, the volume of an idealized prepared canal can be calculated as volume of a cone or a combination of cones and cylinders. The geometrical dimensions and tolerances of the files used were known and when used in rotary motion, these instruments would ideally produce shapes of corresponding geometry. Depending on the individual working length of each specimen, canal volumes can thus be calculated. Accordingly, shapes in groups A to C produced theoretical idealized canal volumes of 8.763, 9.879 and 8.217 mm^3, respectively (Table 2).

$Ca(OH)_2$ application

The plastic blocks remained covered with tape to conceal the canals during the canal dressing procedure. In groups A1, B1 and C1, $Ca(OH)_2$ paste (Pulpdent; Pulpdent Corporation, Watertown, MA, USA; specific density 1.555 g mL^{-1}) was applied by coating a lentulo paste carrier (No. 2, ISO size 30, Dentsply Maillefer) to 1 mm shorter than the binding point and rotating the paste into the root canal at 1000 rpm. The procedure was repeated until canals were filled to the orifice; the medicament was then condensed at the orifice using paper points.

In groups A2, B2 and C2, Pulpdent was injected into the root canals using a syringe and an 18 gauge, 1 1/4 inch needle provided by the manufacturer (18 gauge corresponds to an outer diameter of 1.27 mm). The medicament was then condensed at the orifice level using paper points. The orifices were closed with Cavit (Espe, Seefeld, Germany) to a depth of approximately 3 mm.

Weight

The specimens were weighed to the nearest 0.1 mg (Ohaus Explorer Balance E00640; Ohaus Corporation, Pine Brook, NJ, USA) at the following stages: before preparation, after preparation, after application of $Ca(OH)_2$ paste (prior to placement of Cavit), after placement of Cavit and after 1 week of simulated fluid pressure.

Table 2 Void areas (means ± SD) before and after specimens in groups A to C (total canal areas in parentheses) were subjected to simulated fluid pressure

Group	Significance	Initial area (mm^2)	Significance	Area after 1 week (mm^2)	Significance
A (7.7 ± 1.0 mm^2)					
Filled with lentulo spiral	1	1.19 ± 0.54		1.56 ± 0.60	
Filled by direct injection	2	1.14 ± 0.90		1.36 ± 0.90	
B (8.7 ± 0.7 mm^2)					
Filled with lentulo spiral	1	0.48 ± 0.27		0.61 ± 0.31	
Filled by direct injection	2	1.91 ± 1.96		2.15 ± 2.11	
C (7.6 ± 0.6 mm^2)					
Filled with lentulo spiral	1	0.09 ± 0.09		0.22 ± 0.10	
Filled by direct injection	2	0.49 ± 0.29		0.78 ± 0.32	

$n = 15$ in each subgroup. Bars indicate statistically different scores (ANOVA, $P < 0.05$).

Simulated fluid pressure and $Ca(OH)_2$ analysis

A thin rubber tube was placed over the metal sleeve attached around the canal terminus and connected to a plastic 3 mL syringe containing 3 mL of physiological saline solution. The fluid level of each syringe was maintained 15 cm above the specimens to create a fluid pressure of 150 mm H_2O (Pommel & Camps 2001). The saline solution was collected by lifting up the block, detaching the rubber tube, then lowering the tube into a plastic container (3 mL volume), letting the fluid empty passively and sealing the container airtight.

A sample was analyzed for dissolved Pulpdent paste. The quantity of Ba^{2+} and Ca^{2+} in Pulpdent paste was determined by atomic absorption spectrometry. The amount of Pulpdent that dissociated and was released into the simulated periapical space after 1 week was measured using the fluorescent indicator calcium green 2 (CG2; Molecular Probes, Eugene, OR, USA) (Erne & Eberhard 1991). Fluorescent probes such as CG2, that show a spectral response upon binding Ca^{2+}, allow free Ca^{2+} concentrations to be determined using fluorescence spectroscopy. For each sample, baseline fluorescence intensity was measured at 535 nm (irradiating at 488 nm) for 1.80 mL of 0.42 μmol L^{-1} CG2 in deionized water. The intensity increases in fluorescence for subsequent additions of 10 μL aliquots of the saline solution collected and 10 μL of 10 mmol L^{-1} $CaCl_2$ were measured. Pulpdent content in the aliquot was determined using the linear portion of a standard curve for μg Pulpdent versus fluorescence intensity and adjusted for dilution to obtain the amount of Pulpdent in the solution. Physiological saline and a solution saturated with Pulpdent paste served as negative and positive controls, respectively.

Radiographs

Radiographs of the specimens were taken digitally (Dexis; Provision Dental Systems Inc., Redwood City, CA, USA), at 12 ms, 65 kV and 20 cm distance before and after exposure to simulated fluid pressure. The images were saved as tiff files and analyzed using NIH image 1.61 (NIH, Bethesda, MD, USA). Depths of the temporary fillings were measured, including any voids directly underneath the restoration. Canal areas in mm^2, mean gray values of the $Ca(OH)_2$ dressings, total areas of voids in mm^2, and location of voids in the apical, middle or coronal thirds of the root canals were measured (Fig. 1) and noted.

Statistical analysis

Data were normally distributed and are presented as means ± standard deviations. $Ca(OH)_2$ mass and void areas were compared using ANOVA, with Scheffe's *post-hoc* tests, whilst chi-square tests were performed to compare void distribution (Stat View 4.5; Abacus Inc., Berkeley, CA, USA). The level of significance was set at $\alpha = 0.05$.

Results

Amount of $Ca(OH)_2$ placed

Overall, mean weight of $Ca(OH)_2$ placed into simulated canals in groups A to C was 12.8 ± 0.7 mg. Analysis of variance indicated that canals in group B, that had the largest theoretical canal volumes after shaping, received significantly more $Ca(OH)_2$ ($P < 0.005$). However, there were no differences in the amounts of $Ca(OH)_2$ by weight with respect to application mode ($P = 0.35$). It was not possible to compare weights before and after the application of simulated fluid pressure because of the possibility of water sorption into the root canals.

Analysis of radiographically detectable voids

Mean canal areas measured radiographically were 7.7 ± 1.0 mm^2 for group A, 8.7 ± 0.7 mm^2 for group B and 7.6 ± 0.6 mm^2 for group C. Initially, void areas ranged between 0 and 6.8 mm^2. Table 2 shows mean void areas by canal preparation and $Ca(OH)_2$ application. Two-way ANOVA indicated a significant effect of preparation and application modes on void areas ($P < 0.01$) and *post-hoc* analysis revealed that canals in group C had significantly fewer voids than canals in groups A and B (Table 2). Overall, $Ca(OH)_2$ was placed with significantly fewer voids using a lentulo spiral compared with the injection technique. Regarding the distribution of voids into root canal thirds, significantly more voids were detected coronally (74/90) than in the middle (46/90) and apical (47/90) thirds, respectively ($P < 0.05$, chi-square test).

Effects of simulated fluid pressure

After 1 week of exposure to simulated tissue fluid pressure, the amount of $Ca(OH)_2$ dressing that was removed through dissociation or dissolution from each canal was calculated for each group. The mass of Pulpdent that diffused from the root canal into the

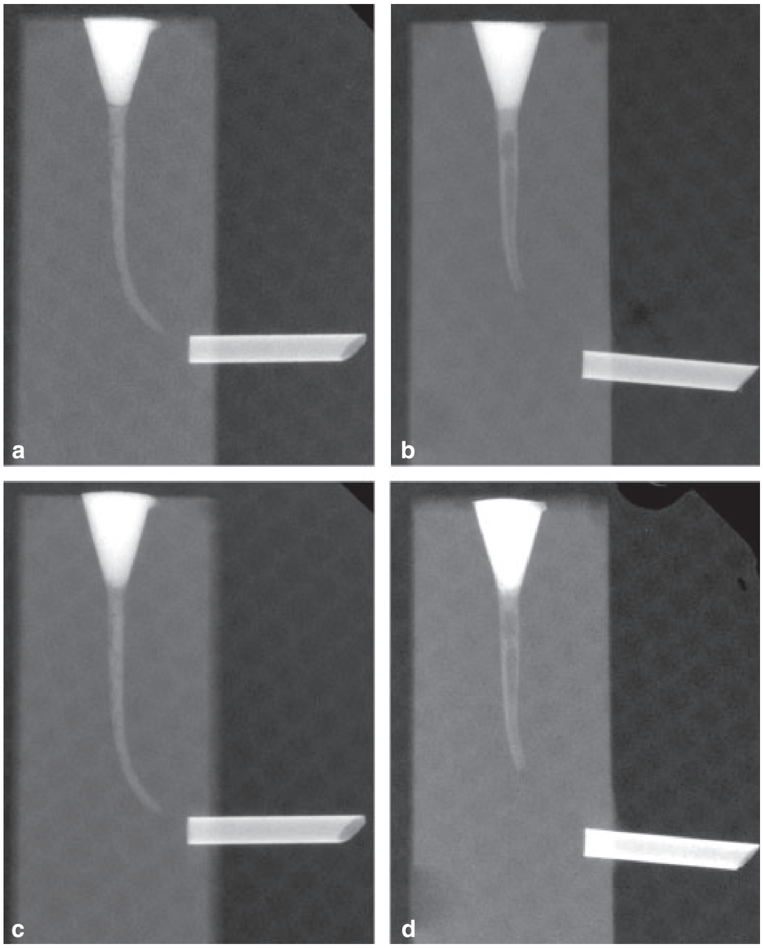

Figure 1 Representative radiographs of simulated canals filled with calcium hydroxide paste: (a) dense initial fill (example from group 3); (b) poor initial fill (example from group 1); (c) no change in radiodensity after simulated fluid pressure [same specimen as in (A)]; (d) deterioration of quality of fill after simulated fluid pressure [Same specimen as in (b)].

saline bath were 385 ± 138 ng, 390 ± 117 ng and 380 ± 117 ng for sample preparations A, B and C, respectively. There were no significant differences between subgroups.

Discussion

Calcium hydroxide remains the medication of choice for root canals treated in more than one visit (Byström *et al.* 1985, Shuping *et al.* 2000). In particular in teeth with periapical lesions, an inter-appointment medication of at least 1 week is recommended to eliminate bacteria remaining in the root canal after chemo-mechanical preparation (Peters *et al.* 1995, Siqueira 2001, Card *et al.* 2002). In order to obtain the maximum benefit of $Ca(OH)_2$ dressings, the entire canal should be filled densely (Dumsha & Gutmann 1985).

There are several commonly used placement techniques for medicaments, including injection and lentulo spiral application (Staehle *et al.* 1997, Deveaux *et al.* 2000, Torres *et al.* 2004). It was stated that in canals prepared using K-files, lentulo spirals consistently produced an even fill throughout the entire length of the root canal, whereas the injection technique only reached working length in half of the cases (Sigurdsson *et al.* 1992). Root canals in the latter study were shaped with stainless steel instruments in a standard preparation technique to a size 25, suggestive of a narrow parallel shape.

Artificial canals in plastic blocks were used in the present study to eliminate the effect of variations in canal anatomy (Torres *et al.* 2004) and to allow a high degree of standardization; the material was of sufficient radiodensity for radiographic comparison. However, the effect of dentine acting as a buffer and the surface tension of dentine were not mimicked (Haapasalo *et al.* 2000).

Two different application modes were utilized in the present study to insert $Ca(OH)_2$ paste into the prepared canals, namely lentulo spirals and a syringe delivery using a needle provided by the manufacturer. Both systems are commonly advocated and used clinically. Counterclockwise rotation of K-files did not result in acceptable fills (Sigurdsson *et al.* 1992) and was consequently not used in the present study.

As expected, differences in preparation technique resulted in variations in the weight of Pulpdent in the various canal shapes. These differences were not significant but canals in group C with an apical size 40 had significantly less area occupied by voids compared with the two narrower shapes in group A and B. However, most voids occurred in the coronal half. Other studies demonstrate more voids apically (Deveaux *et al.* 2000) or no significant difference in empty spaces (Staehle *et al.* 1997). It is not known if a lentulo spiral smaller than size 30 as used in groups A and B would have led to fewer voids.

Earlier studies had indicated that a lentulo spiral was effective in filling root canals with $Ca(OH)_2$ (Dumsha & Gutmann 1985, Sigurdsson *et al.* 1992, Staehle *et al.* 1997) and the present results are in agreement with those findings. However, it had been suggested that if straight or slightly curved root canals were prepared up to at least size 50, high quality $Ca(OH)_2$ fillings could be placed with a syringe system (Staehle *et al.* 1997).

In the second phase of the experiment specimens were subjected to simulated fluid pressure (Beeler *et al.* 1989, Heyeraas & Kvinnsland 1992, Rehman *et al.* 1996) to demonstrate the physical effects of available water on $Ca(OH)_2$ dressings. There was a measurable but insignificant increase in void areas after 7 days of simulated fluid pressure.

The amounts of Ca^{2+} ions that migrated into the physiological saline solution used to simulate fluid pressure were not significantly different and there were no significant differences between application with a lentulo spiral or a syringe. In accordance with other studies, the fact that an exchange took place; however, confirmed the availability of Ca^{2+} and OH^- ions in the periradicular environment (Hosoya *et al.* 2001, Metzger *et al.* 2001). Although the indicator CG2 is insensitive to monovalent cations and to Mg^{2+}, it is sensitive to several other divalent cations, including Ba^{2+}, present to 0.43% in Pulpdent as $BaSO_4$ to provide radio-opacity. However, $BaSO_4$ is insoluble under physiological conditions and may not contribute substantial amounts of Ba^{2+}. Other divalent cations, if present in Pulpdent, are likely to be at negligible levels compared with >20 mmol L^{-1} free Ca^{2+}.

As stated before, this study in simulated canals can only give an estimate of clinical $Ca(OH)_2$ balance, as $Ca(OH)_2$ paste hydrolyzes over time and can penetrate not only the apical foramen but to a lesser degree dentinal tubules and lateral canals, which were not reproduced in this study (Ørstavik & Haapasalo 1990, Nerwich *et al.* 1993). In addition, the antibacterial effect of $Ca(OH)_2$ slurry is negated by dentine powder becacuse of its buffering capacity (Haapasalo *et al.* 2000).

Conclusion

Tapered preparations to an apical size 30 resulted in the largest canal space and received most $Ca(OH)_2$ slurry as measured by weight, whilst specimens with an apical size 40 and less taper had the least area of voids. Application with a lentulo spiral was more homogenous than injection of $Ca(OH)_2$ paste.

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