Removal efficacy of various calcium hydroxide/chlorhexidine medicaments from the root canal

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Abstract

Lambrianidis T, Kosti E, Boutsioukis C, Mazinis M. Removal efficacy of various calcium hydroxide/chlorhexidine medicaments from the root canal. *International Endodontic Journal*, **39**, 55–61, 2006.

Aim To compare the efficiency of removing calcium hydroxide [$Ca(OH)_2$]/chlorhexidine (CHX) (gel), $Ca(OH)_2$/CHX (solution) and $Ca(OH)_2$/saline pastes with the use of instrumentation and irrigation with sodium hypochlorite and ethylene diamine tetraacetic acid (EDTA) solutions. Moreover the role of the patency file in the cleanliness of the apical third of the root canal was evaluated.

Methodology Sixty-four human single-rooted teeth with straight canals were used. Root canal preparation was performed with a stepback technique using Hedström (H) files. Teeth were randomly assigned to three groups and subsequently filled with one of the pastes: $Ca(OH)_2$/CHX (gel), $Ca(OH)_2$/CHX (solution) and $Ca(OH)_2$/saline paste. The medicaments were removed 10 days later using instrumentation and irrigation with 1% sodium hypochlorite and 17% EDTA, with or without obtaining patency of the apical foramen with a size 10 H-file. The crowns were removed at the cemento-enamel junction and the roots were grooved longitudinally and split into halves. Images of all halves were acquired with the use of a flatbed scanner. A scoring system of 1 to 4 was used to assess the amount of residue on the cervical, middle and apical third of the canal. Data were subjected to statistical analysis using Kruskal–Wallis and Mann–Whitney tests, with Bonferroni correction, at 95% confidence level ($P < 0.05$).

Results Remnants of medicament were found in all experimental teeth regardless of the experimental material used and the use of the patency file. When examining the root canal as a whole, $Ca(OH)_2$/CHX (gel) paste was associated with significantly larger amount of residue, whereas the $Ca(OH)_2$/CHX (solution) paste was associated with less amount ($P < 0.05$) than the other two medicaments with or without the use of a patency file.

Conclusions None of the techniques used in this study removed the inter-appointment root canal medicaments effectively; the use of the patency file facilitated removal of more of the medicament in the apical third of those straight canals.

Keywords: calcium hydroxide, chlorhexidine, intracanal medicament, patency file.

Received 6 December 2004; accepted 12 September 2005

Introduction

Thorough instrumentation supported by irrigation reduces the number of microorganisms in the infected root canal (Byström & Sundqvist 1981). However eradication of microorganisms from canal irregularities is enhanced by intracanal medicaments that prevent proliferation of residual strains as well as recontamination (Chong & Pitt Ford 1992).

Calcium hydroxide ($Ca(OH)_2$) is used widely as an intracanal medicament between treatment sessions because of its well-documented antibacterial activity against most of the strains identified in root canal infections (Law & Messer 2004). $Ca(OH)_2$ powder is mixed routinely with water or saline and the paste is left in the root canal for several days or weeks.

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However, specific microorganisms have proved to be resistant to $Ca(OH)_2$ (Haapasalo & Ørstavik 1987, Nair *et al.* 1990, Waltimo *et al.* 1999) and moreover the paste's long-term antimicrobial efficiency has been questioned (Peters *et al.* 2002). Alternative medicaments or additional agents have been investigated in order to facilitate microbial eradication. Chlorhexidine digluconate (CHX) has been introduced as a root canal irrigant at various concentrations (Stevens & Grossman 1983, Byström *et al.* 1985, Jeansonne & White 1994). Although its tissue dissolving action is questionable (Zehnder *et al.* 1993, Naenni *et al.* 2004, Okino *et al.* 2004) it has an antibacterial effect comparable to and more prolonged than that of sodium hypochlorite (NaOCl) (Stevens & Grossman 1983, Ohara *et al.* 1993, White *et al.* 1997, Lindskog *et al.* 1998, Estrela *et al.* 2003), up to 12 weeks following obturation of the root canal (Rosenthal *et al.* 2004). These properties are combined with a much lower toxicity (Yesilsoy *et al.* 1995) and a better-tolerated odour than those of NaOCl.

Recently the use of CHX as an intracanal medicament has been suggested either in the form of 2% gel (Almyroudi *et al.* 2002, Basrani *et al.* 2002, Gomes *et al.* 2003) or solution placed in a sustained release device (Cervone *et al.* 1990, Heling *et al.* 1992a,b) such as Periochip® (Procter & Gamble, Cincinnati, OH, USA) (Almyroudi *et al.* 2002, Basrani *et al.* 2002, Gomes *et al.* 2003) or active points (Lin *et al.* 2003, Podbielski *et al.* 2003). Studies showed that CHX is particularly effective against *Enterococcus faecalis* and *Candida* strains, which have been implicated in endodontic treatment failures and are resistant to treatment with $Ca(OH)_2$ (Waltimo *et al.* 1997, Evans *et al.* 2003, Gomes *et al.* 2003).

To obtain a wide spectrum of antimicrobial activity, pastes consisting of $Ca(OH)_2$ mixed with 2% CHX solution (Evans *et al.* 2003) or gel (Almyroudi *et al.* 2002, Basrani *et al.* 2002, Gomes *et al.* 2003, Basrani *et al.* 2004) have been investigated. Because of the variety of the study models, biological indicators, observation periods and microorganisms used, the results are inconsistent. Without the components adversely effecting the solubility and activity of one another, their combination exhibits an additive or synergistic effect on some endodontal pathogens such as *Peptostreptococcus micros* and *Streptococcus intermedius* (Podbielski *et al.* 2003) or *E. faecalis* (Evans *et al.* 2003). CHX in different concentrations and in combination with $Ca(OH)_2$ has satisfactory physicochemical properties (pH, radio-opacity and working time) that would allow it to be used as an intracanal medicament (Basrani *et al.* 2004). On the contrary, some investigators concluded that mixing $Ca(OH)_2$ with solutions including CHX did not provide any increased antimicrobial effect compared with the conventional use of $Ca(OH)_2$ (Haeni *et al.* 2003). Even though 2% CHX gel was more effective than $Ca(OH)_2$ against *E. faecalis* up to observation day 15, a combination of the two was effective for the first 2 days, but its antimicrobial activity decreased significantly after the seventh day (Gomes *et al.* 2003).

Intracanal $Ca(OH)_2$ is usually removed from the root canal by the use of copious irrigation with either NaOCl or saline, combined with instrumentation and a final rinse with 17% ethylene diamine tetraacetic acid (EDTA). However, none of the above techniques is efficient in removing all the material from the canal walls, leaving up to 45% of the root canal surface covered with remnants (Lambrianidis *et al.* 1999). Moreover, the residual $Ca(OH)_2$ may interact with the root canal sealer and interfere with its sealing ability (Margelos *et al.* 1997). Gels containing CHX can be difficult to remove from the canal space (Evans *et al.* 2003) and the effectiveness of the removal procedures of $Ca(OH)_2$/CHX mixture, when used as an intracanal medicament, have not been studied.

The aim of this study was to evaluate the removal efficiency of a $Ca(OH)_2$/CHX (gel) paste, a $Ca(OH)_2$/CHX (solution) paste and a $Ca(OH)_2$/saline paste using instrumentation with or without a patency file and irrigation with NaOCl and EDTA solutions.

Materials and methods

Sixty-four freshly extracted human single-rooted teeth were used in this study. Following extraction the teeth were stored for two days at room temperature in 3% NaOCl to remove organic debris. Subsequently they were scaled with ultrasonics, washed with distilled water for the removal of any calculus or soft tissue debris and then immersed in 10% formalin solution until use.

Criteria for tooth selection included: a single root canal, no visible root caries, fractures or cracks on examination with a ×4-magnifying glass, no signs of internal or external resorption or calcification and a completely formed apex. Roots with not >5° of curvature according to Schneider (1971) were considered straight and were included in this study. Preoperative mesiodistal and buccolingual radiographs were exposed for each root to confirm the canal anatomy. Only root

canals in which the first file that snug at the apex was size 20 were included in this study.

A single operator instrumented all teeth, which were held in the hand. After access cavities were prepared, a size 10 H-file (Antaeos; Vereinigte Dentalwerke GmbH & Co., Munich, Germany) was introduced into the canal until it was visible at the apical foramen. The working length was determined by subtracting 1 mm from this measurement. This same file was used during preparation and it was introduced into the canal until it was visible at the apical foramen to ascertain patency at all times. Root canal preparation was performed using H-files with a stepback technique. Instrumentation was standardized with a size 45 reaching full working length to a size 70 H-file 4 mm coronally and a final coronal flaring with size 2 and 3 Gates-Glidden drills (Antaeos; Vereinigte Dentalwerke GmbH & Co.). A 17% EDTA gel (Nordent, Thessaloniki, Greece) was used as a chelating agent and was introduced in the canal on the tip of each successive instrument. The canals were irrigated between instruments with 5 mL of 1% NaOCl. Irrigation was performed using 5 mL disposable plastic syringes with 27-gauge needle tips (Endo EZ; Ultradent Products Inc., South Jordan, UT, USA) placed passively into the canal, up to 3 mm from the apical foramen without binding.

Teeth were divided randomly into experimental Groups A, B and C of 21 teeth each, the remaining tooth remained untouched and served as a negative control. The root canals were dried with paper points and then filled with the experimental material. Teeth of group A were filled with chemically pure $Ca(OH)_2$ (Henry Schein Company, Melville, NY, USA) mixed with saline (1 : 1.5, w/v), teeth of group B with a mixture of chemically pure $Ca(OH)_2$ with 0.2% w/v CHX gel (Periogard; Colgate-Palmolive, New York, NY, USA) (1 : 1.5, w/v) and teeth of group C with a mixture of chemically pure $Ca(OH)_2$ and 0.2% CHX solution (Chlorohex; Periogard, Colgate-Palmolive) (1 : 1.5, w/v). All medicaments used were mixed to a creamy consistency on a glass slab using $Ca(OH)_2$ powder and the respective solution or gel. Pastes were placed with a size 35 lentulo paste carrier (Antaeos; Vereinigte Dentalwerke & Co.) on a contra-angle 1 : 1 handpiece (W&H; Bürmoos, Austria), until the medicament was visible at the apical foramen. The access cavities were temporarily sealed with a cotton pellet and a filling (Cavit; Espe, Seefeld, Germany) to a depth of 3 mm.

Teeth were stored at 37 ± 1 °C and 100% relative humidity for 10 days. A tooth from each group served as a positive control and the remaining 20 were randomly divided into two subgroups Ap, Ao, Bp, Bo, Cp and Co, containing 10 teeth each. The temporary filling was removed with an excavator.

In subgroups Ap, Bp and Cp the medicament was removed with instrumentation using the master apical file in a circumferential filing action, irrigation with 5 mL of 1% NaOCl, followed by irrigation with 5 mL of 17% EDTA (Henry Schein Company) and a final rinse with 5 mL of 1% NaOCl. Irrigation was performed under the same conditions as in the instrumentation phase. Patency of the apical foramen was obtained by introducing a size 10 H-file until it was visible at the apical foramen several times during the procedure. The root canals were dried with paper points.

In subgroups Ao, Bo and Co teeth were treated in the same way but no patency file was used. The crowns were removed at the cemento-enamel junction with a diamond disk. The roots were grooved longitudinally from buccal and lingual directions at the maximum buccolingual diameter without entering the root canal, and were split into halves with a pair of pliers. Sections were cleaned from any remaining dust with a short blast of air. Sections were scanned (Scanjet 5470c; Hewlett Packard Co., Palo Alto, CA, USA), at 600 ppi and 32-bit resolution (True Color images), and 600% magnification. Adobe Photoshop 7.0 (Adobe Corporation, San Jose, CA, USA) was used to process all images. During the scanning of the specimens, brightness and contrast were standardized. Images were viewed in a 17″ monitor (Samsung 757NF; Samsung Electronics Co., Seoul, Korea), calibrated according to the manufacturer's instructions to minimize gamma-distortion of the displayed images.

A scoring system was defined to assess the quantity of the residue on the canal walls. Evaluation scales used were: score 1 – no visible remnants, score 2 – scattered remnants, score 3 – distinct masses, score 4 – densely packed remnants. Remnants were evaluated in each third of all sections (apical, middle, cervical) and the highest score observed was recorded. Following calibration with selected specimens (Fig. 1) evaluation was performed by all investigators involved in the study and in cases of disagreement sections were re-evaluated jointly by the observers. Data were subjected to statistical interpretation using Kruskal–Wallis and Mann–Whitney tests, with Bonferroni correction, at 95% confidence level ($P < 0.05$).

Results

Remnants of medicament were found in all experimental teeth regardless of the material used and the

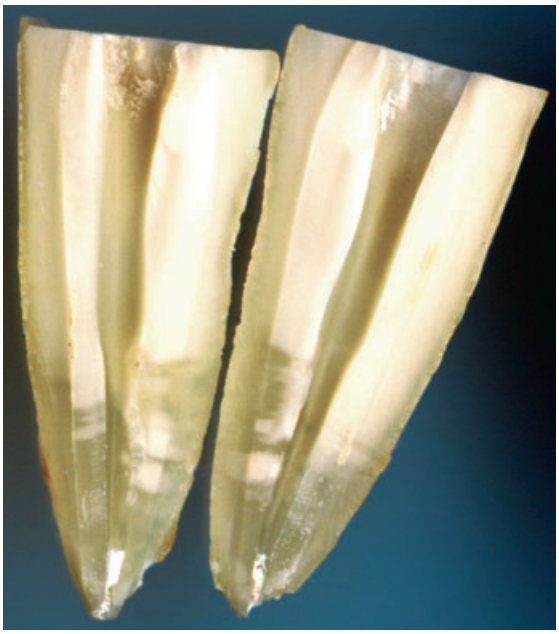

Figure 1 Root canal after the removal of calcium hydroxide/chlorhexidine gel paste. No patency file was used. Note characteristic patterns of residual debris corresponding to score 2 (middle third), score 3 (cervical third) and score 4 (apical third). This specimen was used for the observer calibration.

introduction of the patency file. Positive control teeth in all groups showed densely packed remnants in all thirds as opposed to the negative control.

When examining the efficacy of medicament removal from the apical, middle and cervical third of the canal separately (Table 1) between groups where no patency was used, there was a statistically significant difference ($P < 0.05$ with Bonferroni correction when necessary) between the apical and both middle and cervical thirds, with the apical third associated with the largest amount of debris. In groups where patency was used no significant difference ($P > 0.05$ with Bonferroni correction when necessary) was found between the thirds of the canal.

Regarding the cleanliness of each third of the root canal wall for all three medicaments with or without the use of the patency file (Table 2) a statistically significant difference ($P < 0.05$ with Bonferroni correction when necessary) was found only in the apical third, showing that the use of the patency file resulted in less medicament remaining in this part of the root canal (Fig. 2).

When comparing all groups at all root canal levels (Table 3) in the apical third $Ca(OH)_2$/CHX (gel) paste was associated with significantly larger amounts of medicament when no patency file was used ($P < 0.05$ with Bonferroni correction when necessary), whereas when a patency file was used the $Ca(OH)_2$/CHX (solution) paste was associated with more residue on the root canal walls ($P < 0.05$ with Bonferroni correction when necessary). In the middle and cervical thirds in groups where no patency was used the $Ca(OH)_2$/CHX (gel) paste was associated with more residue ($P < 0.05$ with Bonferroni correction when necessary), but there was no difference ($P > 0.05$ with Bonferroni correction when necessary) among groups when patency was used. Overall, when examining the root canal as a whole, $Ca(OH)_2$/CHX (gel) paste was associated with significantly larger amount of residue, whereas the $Ca(OH)_2$/CHX (solution) paste was associated with less amount ($P < 0.05$ with Bonferroni correction when necessary) than the other two medicaments with or without the use of a patency file.

Table 1 Statistical analysis of the differences between each third (apical/middle/cervical), within the six groups

	Ao	Bo	Co	Ap	Bp	Cp
Apical/middle/cervical[a]	**0.001**	**0.000**	**0.006**	0.328	0.089	0.228
Apical/middle[b]	**0.001**[c,e]	**0.000**[c,e]	**0.005**[c,e]	–	–	–
Apical/cervical[b]	**0.002**[d,f]	**0.000**[d,f]	**0.010**[d,f]	–	–	–
Middle/cervical[b]	0.438	0.766	0.616	–	–	–

Significant differences are marked with bold font ($P < 0.05$).
[a]Kruskal–Wallis test.
[b]Mann–Whitney test, results interpreted according to Bonferroni's correction when necessary.
[c]$P < 0.016$ (Bonferroni's correction).
[d]$P < 0.025$ (Bonferroni's correction).
[e]Middle third showing less remnants.
[f]Cervical third showing less remnants.

Table 2 Statistical analysis of the differences between groups where no patency file was used and groups where patency was used

Groups	Apical	Middle	Cervical
Ao/Ap	**0.003**[b]	0.698	0.965
Bo/Bp	**0.000**[c]	0.541	0.904
Co/Cp	**0.002**[d]	0.685	0.551
No patency/patency[a]	**0.000**[e]	0.436	0.742

Significant differences are marked with bold font (Mann–Whitney test, $P < 0.05$).
[a]Comparison of all groups without patency (Ao, Bo, Co) to all groups with patency (Ap, Bp, Cp).
[b]Ap group showing less remnants.
[c]Bp group showing less remnants.
[d]Cp group showing less remnants.
[e]Combined patency groups showing less remnants.

Figure 2 Root canal after the removal of calcium hydroxide/chlorhexidine (solution) paste. Patency file was used. Note the cleanliness of the apical part compared with the one in Fig. 1.

Table 3 Statistical analysis of the differences between each group

	Apical	Middle	Cervical	Total
Ao/Bo/Co[a]	**0.001**	**0.045**	**0.028**	**0.000**
Ao/Bo[b]	**0.011**[d,e]	0.176	0.333	**0.021**[d,e]
Ao/Co[b]	0.148	0.240	**0.007**[c,f]	**0.030**[f]
Bo/Co[b]	**0.000**[c,f]	**0.014**[c,f]	0.110	**0.000**[c,f]
Ap/Bp/Cp[a]	**0.000**	0.063	0.115	**0.000**
Ap/Bp[b]	0.069	–	–	**0.020**[g]
Ap/Cp[b]	**0.016**[d,h]	–	–	**0.006**[d,h]
Bp/Cp[b]	**0.000**[c]	–	–	**0.000**[c,h]

Significant differences are marked with bold font ($P < 0.05$).
[a]Kruskal–Wallis test.
[b]Mann–Whitney test, results interpreted according to Bonferroni's correction when necessary.
[c]$P < 0.016$ (Bonferroni's correction).
[d]$P < 0.025$ (Bonferroni's correction).
[e]Ao group showing less remnants.
[f]Co group showing less remnants.
[g]Ap group showing less remnants.
[h]Cp group showing less remnants.

Discussion

None of the medicaments was removed entirely from the root canal walls, leaving remnants mostly in the apical third. The procedure used in this study for the removal of the intracanal medicament is the standard protocol employed widely in clinical practice (Baumgartner *et al.* 2002).

Depending on the filling material used and the type of sealer selected for obturation the remnants could interfere with its adaptation on the canal walls and jeopardize the outcome of the root canal treatment (Margelos *et al.* 1997). CHX has been shown to adsorb onto the hydroxyapatite of dental hard tissues with subsequent release, preventing microbial colonization on that surface for some time (Rölla *et al.* 1970, Basrani *et al.* 2002, Evans *et al.* 2003). Whilst this property enhances the subsequent bonding of adhesive post-core systems probably by absorbing dentine bonding agents inside the dentinal tubules (Erdemir *et al.* 2004), its effect on bond strengths of various types of obturation materials and the outcome of post-treatment procedures has not been investigated.

Residual $Ca(OH)_2$ influences the setting mechanism of various types of root canal sealers (Margelos *et al.* 1997, Hosoya *et al.* 2004). The short-term clinical implications are a rapid setting reaction of the sealer that may prevent the placement of gutta-percha (Margelos *et al.* 1997). Moreover contact with $Ca(OH)_2$ remaining on the canal wall can cause considerable changes to the physical properties and the sealing ability of various sealers (Hosoya *et al.* 2004). The long-term significance of these findings is not known.

Regardless of the medicament used in the present study, remnants were found in the apical region. Although an apical plug with $Ca(OH)_2$ has been advocated for its prolonged antimicrobial activity after filling of the canal space (Holland 1984), it is preferable to remove it as it might enhance apical leakage, as it is believed to be diluted in contact with tissue fluids. Patency filing left no densely packed remnants (score 3) but only scattered remnants and distinct masses (scores 1 and 2). This finding together with the observation from a previous study (Lambrianidis *et al.* 2001), that the use of patency file has no effect on the amount of extruded material during root canal preparation, is evidence that it may be useful during canal preparation.

In the present study, a scoring system was used to facilitate comparison among groups instead of calculating the percentage ratio of medicament coated surface area to the total canal surface area as previously reported (Lambrianidis *et al.* 1999). Using a scoring system was considered a reliable method because of the difficulties in automatically selecting the areas covered with remnants with appropriate software, because of the colour similarities between the CHX containing materials and some areas of dentine.

A flatbed scanner was used to scan the specimens. The image resolution that was used in the present work was similar to a previous study (Betti & Bramante 2001), whereas the magnification used (600%) was six times greater, resulting in images with overall resolution of 1200 ppi when viewed in the 300% magnification necessary for the evaluation of the canal wall cleanliness. This resolution was more than sufficient, considering the fact that the monitor used could display images with a maximum resolution of 96 ppi. Images acquired by a digital or SLR camera mounted on a stereoscopic microscope might have been of higher resolution. Nevertheless, data from a pilot study that preceded the evaluation of the specimens concluded that both methods of image acquisition did not alter the results. Therefore, the use of the more convenient scanner-method was preferred.

Conclusions

None of the techniques used in this study removed the inter-appointment root canal medicaments effectively. Overall, $Ca(OH)_2$/CHX (gel) paste was associated with significantly larger amount of residue, whereas $Ca(OH)_2$/CHX (solution) paste was associated with less residue than the other two medicaments with or without the use of a patency file. The use of the patency file facilitated removal of the medicaments in the apical third of the straight canals used in this study.

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