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RESEARCH ARTICLE

Efficacy of different devices in removing calcium hydroxide from the root canal

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ABSTRACT

Objectives: The aim of this *in vitro* study was to compare the removal efficiency of calcium hydroxide (CH) medicament from the root canal walls with various devices.

Materials and Methods: The root canals of 85 extracted human maxillary incisors were prepared with ProTaper NiTi rotary files and randomly divided into five experimental groups (n = 15), whilst the remaining teeth (n = 10) served as positive and negative controls. In each experimental group, CH was placed into the canals by using a lentulo spiral. The negative control did not receive CH placement, and the positive control received the CH, but no subsequent removal. After 7 days, the CH was removed using five different techniques: Group (G) I, Master apical file (MAF) + manual needle irrigation (MNI); GII, CanalBrush (CB) +MNI; GIII, RinsEndo (RE); GIV, Self-adjusting file (SAF) + Vatea; GV, CB+MNI, followed by SAF+Vatea. Irrigants, total irrigant volumes and total irrigation time were kept constant throughout the study for all the experimental groups. The roots were grooved longitudinally and split into halves. Images of each half of the canal were acquired by a digital camera. 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. Randomly selected three specimens from each group also evaluated with SEM. The 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 CH were found in all experimental teeth regardless of the device used. When examining the root canal as a whole, there was no significant difference between the groups. When examining the efficacy of CH removal from the apical, middle and cervical third of the canal separately between groups there was a statistically significant difference between the middle (p=0.003) and cervical (p=0.006) thirds.

Conclusion: None of the techniques removed the CH medicament completely; the use of the RE and SAF facilitated removal of CH especially from the cervical third.

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INTRODUCTION

The primary goal of root canal therapy is to reduce or eliminate bacteria and their by-products from an infected root canal system.[1] To this end, intracanal medication to disinfect the root canal system has been advocated to enhance therapeutic success.[2] Calcium hydroxide (CH) is an effective intracanal medicament during endodontic therapy, but reportedly, failing to completely remove CH from the root canal walls following therapy influences dentin bond strength[3] and sealer penetration into the dentinal tubules,[4] as well as markedly compromises the quality of the seal provided by the root filling.[5] Residual CH may also chemically react with the sealer, reducing its flow and working time.[6] Therefore, removal of the CH medicament prior to root filling is mandatory.

The most frequently described removal technique is root canal instrumentation with a master apical file (MAF) and copious irrigation.[7] Previous studies[8,9] showed that irrigation with sodium hypochlorite (NaOCl) alone does not efficiently remove CH medication. Alternatively, ethylenediaminetetraacedic acid (EDTA) irrigation and repeating the MAF instrumentation has been recommended, as well as rotary instruments with ultrasonically activated tips, such as the RinsEndo (RE), CanalBrush (CB), and Self-adjusting file (SAF).[8-15] Yet, none of these techniques have successfully removed the CH medicament completely.[8-16]

In light of these observations, the present study evaluated the efficacy of MAF combined with manual needle irrigation (MNI), SAF, RE, CB, and CB combined with SAF (CBS) for removing CH from root canals.

MATERIALS AND METHODS

A total 85 extracted human maxillary incisor teeth with a <10° curvature were reduced to a standardized 14 mm root length from the coronal aspect using a slow-speed water-cooled precision saw. None of the teeth had visible root caries, fractures, or cracks on microscopic examination at ×12 magnifications. Patency was confirmed with a #10 K-file (Mani, Utsunomiya Tochigi, Japan), and the root canals were enlarged using ProTaper rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) until an F4 file reached the working length (1 mm from the apical foramen). The root canals were irrigated with 2 mL of 5.25% NaOCl (Sultan, WA, USA) between each file size. After preparation, the root canals were irrigated with 17% EDTA (Vista Dental Products, Racine, WI, USA) for 1 min followed by 10 mL of distilled water to remove all chemicals and dried with paper points.

Five teeth were randomly selected as negative control and remained unfilled. CH powder (Merck, Darmstadt, Germany) and distilled water at a powder to liquid ratio of 1:1.5 were mixed and the root canals of 80 teeth were filled with CH paste using a lentulo spiral (Mani), in a low-speed handpiece until the material extruded through the foramen. Mesio-distal and bucco-lingual radiographs were obtained to confirm complete canal filling. The access cavities were temporarily sealed with a cotton pellet and a temporary filling material (Cavit Espe, Seefeld, Germany), and the specimens were stored at 37 °C. The positive control group (n = 5) did not undergo subsequent CH removal. The remaining teeth were randomly distributed into five experimental groups according to the CH removal techniques as following:

Master Apical File (MAF): Root canals filed manually with a size #40 Hedström file in a circumferential filing action for 60 s and received a final flush 10 mL of 2.5% NaOCl, 5 mL 17% EDTA for 1 minute and 5mL distilled water delivered via MNI.

CanalBrush (CB): A size #40 Hedström file used just for reaching working length and a medium-sized CanalBrush (Roeko Canal Brush™, Coltène/Whaledent, Langenau, Germany) was placed in a slow-speed handpiece (600 rpm) and advanced to the working length. A circumferential motion was made with the CanalBrush for 60 s. Then canal received a final flush 10 mL of 2.5% NaOCl, 5 mL 17% EDTA for 1 minute and 5mL distilled water delivered via MNI.

RinsEndo (RE): A size #40 Hedström file used just for reaching working length and irrigation with RE (Dürr Dental, Bietigheim-Bissingen, Germany) was carried out using the needle provided by the manufacturer (needle size 45 with a 7-mm-long exit aperture). 10 mL of 2.5% NaOCl was the irrigant used during 60 s. 5 mL 17% EDTA for 1 minute and 5mL-distilled water were delivered via MNI.

Self-adjusting file (SAF): A size #40 Hedström file used just for reaching working length and afterwards SAF (Redent-Nova, Ra'anana, Israel) with 2.0 mm diameter and 25 mm length was operated in the canal using an RDT3 NX handpiece head. The SAF was used with Vatea for 60 s with 2.5% NaOCl at a flow rate of 10 mL/min. 5 mL 17% EDTA for 1 minute and 5mL distilled water were delivered via MNI.

CB followed by SAF (CBS): A size #40 Hedström file used just for reaching working length, a medium-sized CB was placed in a slow-speed handpiece (600 rpm) and advanced to the working length. A circumferential motion was made with the CB for 30 s. Canal received a flush 5 mL of 2.5% NaOCl delivered with MNI, then SAF was used with Vatea for 30 s with 2.5% NaOCl at a flow rate of 10 mL/min. Finally 5 mL 17% EDTA for 1 minute and 5mL distilled water delivered via MNI.

Thereafter, grooves were prepared with a water-cooled diamond bur on the buccal and lingual surfaces, and the teeth were split along the long axis buccolingually using a surgical chisel.[7] Each root half was digitally photographed (Canon EOS 600D, Canon Inc., Ōita Japan) with an operation microscope (Carl Zeiss OPMI PROergo, Oberkochen, Germany) mounted camera at ×16 magnification.

Digital images were scored by two calibrated endodontists in a blind manner as described by Lambrianidis et al.:[7] score 1, no visible remnants; score 2, scattered remnants; score 3, distinct masses; and score 4, densely packed remnants.

Tooth specimens were evaluated at the apical, middle, and cervical thirds, and the highest score was recorded. Following calibration with select specimens, all involved investigators evaluated the specimens, and in cases of disagreement, sections were re-evaluated jointly by the observers. Data were analyzed using the Kruskal-Wallis and Mann-Whitney U tests, with Bonferroni correction, at a 95% confidence level ($P < 0.05$). IBM SPSS Version 21.0 (SPSS Inc, Chicago, IL, USA) was used as the statistical tool. In addition, three randomly selected specimens in each group were prepared for scanning electron microscope (SEM; JEOL JSM-6400, Tokyo, Japan) analysis to measure the residual CH. The selected specimens were dehydrated by a series of graded ethanol solutions, coated with a gold layer, and then evaluated using SEM at ×300 and ×1000 magnifications. Figure 1 was representative SEM images of middle third of experimental and control groups.

RESULTS

Residual CH was found in all experimental teeth regardless of the removal technique. Statistical comparisons between each third (apical/middle/cervical) within the

five groups and between each group are shown in Table 1 and Table 2, respectively. The positive control teeth showed densely packed remnants in all thirds (Fig. 1a), which is not observed in the negative control. Notably, there was a statistically significant difference in CH removal between the middle (p=0.003) and cervical (p=0.006) thirds. There was no significant difference between the apical thirds associated with the greatest remaining CH in all of the groups.

The pair-wise comparison of cervical thirds showed that RE was significantly different between the CB, MAF, and CBS groups (p=0.002, p=0.001, and p=0.004, respectively). RE and SAF resulted in the best (lowest) scores with no significant difference between the cervical thirds. Pair-wise comparison of the middle thirds revealed that MAF was significantly different from the SAF and CBS groups (p=0.004). When the groups were individually evaluated, MAF had statistically different CH removal between the apical (highest score), middle, and cervical (lowest score) thirds; in the CB group, the middle third (lowest score) was significantly different from apical and cervical thirds (p < 0.016). In the RE group, the apical third (highest score) was significantly different from middle and cervical thirds, while in the SAF and CBS groups, significant difference was only found between the apical and

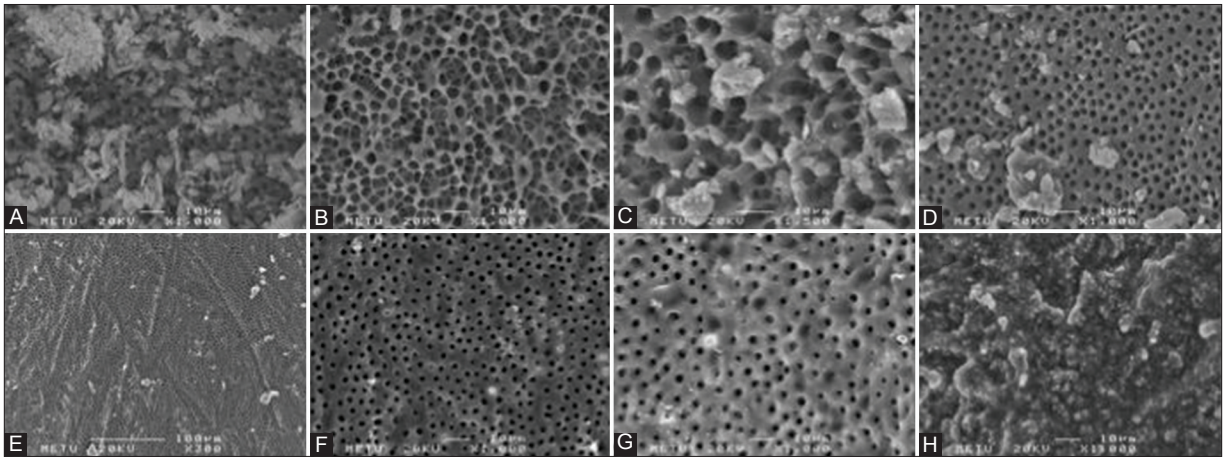

Figure 1. Representative SEM images of middle thirds of all groups: (A) MAF, (B) CB, (C) RE, (D) SAF, (E) and (F) CBS, (G) Negative Control; and (H) Positive control

Table 1. Statistical analyses of the differences between each third (apical/middle/cervical) within the five groups

	MAF	CB	RE	SAF	CBS
Apical/middle/cervical[a]	**0.000**	**0.000**	**0.000**	**0.000**	**0.014**
Apical/middle[b]	**0.000**[cd]	**0.000**[cd]	**0.000**[cd]	0.047	0.017
Apical/cervical[b]	**0.000**[cd]	0.073	**0.000**[cd]	**0.000**[cd]	**0.007**[cd]
Middle/cervical[b]	**0.006**[ce]	**0.013**[ce]	0.081	0.064	0.773

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]Apical third showed more remnants. [e]Cervical third showed more remnants

cervical thirds ($p < 0.016$). Overall, when examining the root canal as a whole, there was no significant difference between the groups.

SEM evaluation revealed residual CH and dentinal tubule erosion in the RE and CB groups after CH removal (Fig. 1B and 1C). Representative operation microscope images of groups were shown in Figure 2.

DISCUSSION

Adhesion between root canal sealers and radicular dentin helps maintain the sealer-dentin interface integrity without being disrupted long term.[17] CH residue negatively affects sealer penetration into the dentinal tubules and may reduce the sealing ability.[18] Although complete CH removal from the root canal system is recommended, there is a lack of consensus on an ideal calcium

Table 2. Statistical analyses of the differences between each group

	Apical	Middle	Cervical	Total
MAF/CB/RE/SAF/CBS[a]	0.738	**0.003**	**0.006**	0.109
MAF/CB[b]	-	0.822	0.640	-
MAF/RE[b]	-	0.152	**0.001**[cd]	-
MAF/SAF[b]	-	**0.004**[ce]	0.175	-
MAF/CBS[b]	-	**0.004**[ce]	0.620	-
CB/RE[b]	-	0.233	**0.002**[cd]	-
CB/SAF[b]	-	0.006	0.120	-
CB/CBS[b]	-	0.008	0.905	-
RE/SAF[b]	-	0.113	0.049	-
RE/CBS[b]	-	0.140	0.004[cd]	-
SAF/CBS[b]	-	0.875	0.131	-

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]$p<0.005$ (Bonferroni's correction). [d]RE group showing less remnants. [e]MAF group showing less remnants

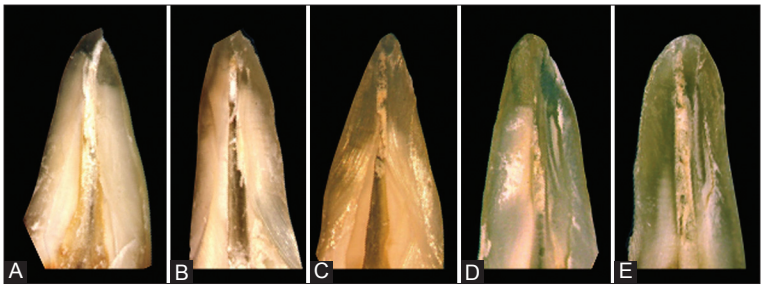

Figure 2. Representative operation microscope images of all groups: (A) MAF, (B) CB, (C) RE, (D) SAF, (E) CBS

hydroxide removal method from the root canal system. Reportedly, a combination of 15% EDTA and 2.5% NaOCl solution with hand instrumentation improves the efficiency of CH removal from the root canal.[19] Therefore, in the current study, a combined 17% EDTA and 2.5 % NaOCl along with circumferential filing with MAF were used to compare the effectiveness of other removal techniques.

Various methods have been used to investigate the amount of residues on the canal walls, including digital photography, stereomicroscopy, scanning electron microscopy, micro-computed tomography (micro-CT), and spiral CT.[7,9,10] In the present study, a scoring system after longitudinal cleavage facilitated comparison between the groups, rather than calculating the percentage ratio of medicament coated surface area to the total canal surface area as previously reported.[9] A scoring system was considered reliable because of the difficulty in automatically selecting the residue-covered areas with appropriate software, which is caused by the color similarity between the CH paste and certain dentin areas.

The present study results obtained under the experimental conditions indicate that none of the techniques completely removed CH from the root canals. This is consistent with previous studies, which show CH debris on the root canal walls, regardless of the removal technique.[7-16] In several studies, CB was found ineffective in removing CH due to it's packing effect,[9,10,20] these findings are consistent with the present study's results. CB did not remove CH from any of the root canal thirds, and erosive defects were detected on SEM of selected specimens (Fig. 1B). Manufacturers recommend applying CB for 30 seconds in the root canal, but this time was inadequate for completely removing the residual CH,[9] 60 seconds also proved inadequate for CH removal, but a longer duration may impact the erosive defects.

There is limited comparable data investigating the use of RE for CH removal.[12,21] Rödig et al.[12] showed that neither ultrasonic irrigation nor RE effectively removed CH from the apical third of the root canal. Based on the present study results, RE was unable to remove CH from the apical third, but it was statistically superior in removing CH from cervical third compared to the other techniques. Hauser et al.[22] reported that RE enhanced the penetration depth of a dye marked rinsing solution into root canal wall dentin. This can contribute to erosion induced by irrigation solutions; however, no data assessing this issue is available. Notably, SEM photographs reveal erosive defects in specimens exposed to irrigants delivered with RE (Fig. 1C).

A newly developed SAF utilizes an irrigation device (Vatea; ReDent-Nova) that provides continuous irrigation during use. Recent studies have shown that the device can contact all canal walls evenly, generating more complete root canal shapes than achievable with rotary instrumentation.[23] SAF did not completely remove residual CH in any previous studies.[10,11,24] Paranjpe et al.[25] reported that the SAF system provided uncontrollable apical instrumentation and inadequate apical irrigation. They also report that the SAF is not a penetrating instrument and is too flexible to remove the bulk of root filling material and CH residue.[11,26] Visible streaks on the dentin surfaces formed in acoronal-apical direction; this is consistent with a previous study (Fig. 1E and 1F), indicating that the SAF did clean and debride the root canal system to remove CH but could not achieve complete CH removal.[11,24] Potentially, using the SAF for a longer time may remove more CH by increasing the contact time with the canal walls and the irrigant activation duration. CB has a packing effect and therefore, was combined with SAF in the final group; however, this

combination was still unsatisfactory for complete CH removal.

When the three canal locations were compared, the apical third typically fared worse than the other two locations, indicating the difficulty of cleaning this region. Furthermore, no statistical difference was found between the experimental groups at the apical third, presumably because thorough cleaning of this area is difficult regardless of the device. In all of the experimental groups, there was a statistical difference in cleanliness between the coronal and apical third, except in the SAF group, which showed no statistical difference between the apical and coronal thirds. In the cervical third, there were significantly better results in the RE group compared to the other groups.

The irrigation volume and duration were kept constant throughout the study in all of the experimental groups. It was previously shown that 30 seconds was inadequate for complete CH removal;[9,24] therefore, in the present study, 60 s was allotted for CH removal from the root canals. Achieving thoroughly clean root canals depends on effective irrigant delivery, solution agitation, and its direct contact with the entire canal wall, particularly in the apical third.[27] One reason for incomplete CH removal may be inadequate irrigation solution or its inability to reach the target region. In the present study, the contact time of the irrigation solution in the root canals was limited to 60 seconds. This may also have caused the lessened CH removal in the apical third.

CONCLUSION

Within the present study limitations, CH residue remained in the root canal regardless of the device used, especially in the apical third. Because only a limited number of specimens were imaged under SEM, further studies are needed to confirm the contribution of these devices to dentinal tubule erosion.

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