

REMOVAL OF CALCIUM HYDROXIDE INTRACANAL MEDICAMENT WITH FOUR DIFFERENT TECHNIQUES: A CONE BEAM COMPUTED TOMOGRAPHY IN VITRO STUDY

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ABSTRACT

BACKGROUND: Calcium hydroxide (Ca(OH)₂) is the most currently used intracanal medicament. Its remnants within the root canal have been found to negatively impact the final obturation. Accordingly, its complete removal is critical.

OBJECTIVES: This study aimed to compare the removal of Ca(OH)₂ paste from root canals using passive ultrasonic irrigation, EDDY sonic activation, Roeko canal brush and manual filing, using cone beam computed tomography (CBCT) for evaluation.

METHODS: Forty single canaled extracted human teeth were prepared using ProTaper Next files (X3) and filled with Ca(OH)₂ paste. The teeth were assigned randomly to four groups of 10, based on the method of Ca(OH)₂ removal: Group A: Passive ultrasonic irrigation (PUI), Group B: EDDY sonic activation, Group C: Roeko canal brush and Group D: manual filing (Control group). Samples were scanned with CBCT and the intracanal Ca(OH)₂ volume was measured pre and post retrieval. Statistical analysis was performed using Kruskal Wallis test followed by Bonferroni correction, with a level of significance set at P value of 0.05.

RESULTS: Complete removal of intracanal Ca(OH)₂ was not achieved by any of the tested techniques. However, PUI and EDDY removed a mean of (99.89% ± 0.19) and (99.86% ± 0.34) of the intracanal paste, respectively, with no statistically significant difference between them. The apical third demonstrated the largest volume of residual paste. There was a statistically significant difference when PUI and EDDY were compared to the control group (p < 0.0001).

CONCLUSION: PUI and EDDY are the most effective methods in removing intracanal calcium hydroxide.

KEYWORDS: CBCT, Calcium hydroxide removal, EDDY sonic activation, Passive ultrasonic irrigation, Roeko canal brush.

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INTRODUCTION

Microbial control has always been the main goal of endodontic therapy. Mechanical debridement and root canal disinfection are the means to achieve this goal (1). However, the anatomy of the root canal system makes achieving complete canal cleanliness a challenge. Consequently, came the role of intracanal medicaments. Their concept is to temporarily fill the root canal with a material that chemically as well as to physically would enhance eradication and prevent proliferation of microorganisms (2).

The most extensively used intracanal medicament is calcium hydroxide. The material's antimicrobial actions along with many other advantages, made it the best choice for inter-appointment dressing. Nevertheless, despite calcium hydroxide's benefits, its remnants on the canal walls have been found to negatively affect the final obturation. There have been reports of the material delaying the setting of Zinc Oxide Eugenol sealers, affecting the sealer's penetration into dentinal tubules as well as weakening their final bond to dentin (3). Interfering with the physical properties of the sealers has been proven to increase apical

leakage, and eventually compromise the outcome of endodontic treatment (4). Hence, the complete removal of calcium hydroxide paste prior to the final obturation is critical.

The most widely used method to remove calcium hydroxide intracanal medicament is through a manual file in combination with copious irrigation. However, this conventional method has been reported to remove only 60% of the intracanal paste (5).

Several irrigants such as sodium hypochlorite (NaOCl), Ethylenediaminetetraacetic acid (EDTA), their combination, as well as many chelators have been used to accomplish the complete and predictable removal of calcium hydroxide. However, manual irrigation alone, regardless of the agent used, was unable to completely remove intracanal paste (6).

Many methods are described to enhance the cleaning action of irrigants into the root canal. Activation through sonic and ultrasonic devices has been used to improve the action of irrigation. Ultrasonic irrigation without active instrumentation is described as passive ultrasonic irrigation (PUI). The function of PUI is derived from a small oscillating file or a smooth wire transmitting acoustic energy through ultrasonic waves, which causes streaming and cavitation of the irrigant within the root canal (7).

Sonically driven root canal irrigating system operate on much lower waves than ultrasonics. A newly introduced device is the EDDY system (VDW, Munich, Germany). It is a sonic irrigant activation device used in a frequency of 6000 Hz. The EDDY tip is made of a flexible polymer rod that is attached to a regular air scaler. According to the manufacturer, the high frequency sonication is transferred to the polymer tip causing a three dimensional motion at high amplitudes, due to the unique characteristics of the material. These movements cause cavitations and acoustic streaming of the irrigant; effects that were only caused by PUI (6).

Mechanically activating the irrigants within the canal to improve its action has been performed manually through a master apical file, or using rotary files. But a newer mechanical activation method is the Roeko endodontic canal brush (Coltene/Whaledent, Altstätten, Switzerland). This is a highly flexible microbrush. It is entirely molded from propylene and designed to be used manually or in a rotary motion with contra angle handpiece (8).

Numerous methods have been used to assess the amount of calcium hydroxide remnants within the root canal. Digital

photographs (4), stereomicroscope (9), scanning electron microscope (5), as well as micro computed tomography (10) are all examples of measuring methods. However, the recent availability of CBCT is considered as an accurate noninvasive imaging method, that has been employed to evaluate the quantity of residual intracanal calcium hydroxide. It provides a three dimensional volume measure without the need for sectioning the specimens (5).

To the authors best knowledge, no previous studies have compared the four techniques in question in regards to intracanal Ca(OH)₂ removal. Additionally, the literature investigating the use of CBCT in evaluating intracanal Ca(OH)₂ remnants is minimal.

The aim of this study was to compare the calcium hydroxide paste removal from the root canals with PUI, EDDY sonic activation, Roeko canal brush and manual filing, using cone beam computed tomography.

The null hypothesis of this study was that no difference would be found between the four techniques in calcium hydroxide paste removal from the root canals.

MATERIALS AND METHODS

This study was approved by the ethics committee of Faculty of Dentistry, Alexandria University (serial no. 0057-0812019). It was conducted at the Faculty of Dentistry, Alexandria university, Egypt.

Sample Size Estimation:

The sample size was calculated using SigmaStat software, version 3.5 (Systat Software Inc., Chicago, Illinois, USA). The minimal required sample to achieve a power of 80% (β error) and an (α error) of 5% ($p = 0.05$) in order to detect a significant difference was calculated to be 33 teeth.

Preparation of the specimens

Forty freshly extracted human teeth with single roots and single canals were included in this study. The selected teeth had completely formed apices in which the first fitted file was a size 15. The teeth were free from caries, cracks, calcifications and resorptions. Teeth with root fractures, previous root canal treatment, or curvatures $>5^\circ$ were excluded from the study. Teeth were thoroughly cleansed from debris, calculus and organic tissues and then preserved in saline solution up to the time of use to avoid dehydration. All teeth were examined with two digital radiographs in faciolingual and proximal views to check the existence of a single canal (Vertucci type I).

The crowns of the teeth were removed at the cervical line, and root canals were

initially accessed with a size 10 K file (Dentsply Maillefer, Ballaigues, Switzerland). The file was advanced through the canal until it was visualized at the apex, then the file was retracted to be flushed with the apex. The working length was calculated by deducting 1 mm from the measured length.

Manual K files were used to establish a glide path up to size 15, then canals were prepared with ProTaper Next files (Dentsply, Sirona, Tulsa, USA) up to size X3. The files were operated with the X-Smart plus rotary motor in continuous rotary motion at 300 rpm and a torque of 2 ncm. Irrigation was done using a 30 gauge ProRinse Endo irrigation tip (Dentsply, Sirona, Tulsa, USA) with 5 ml of 2.5% NaOCl (A.R.E Chemicals, Cairo, Egypt). The irrigation needle was positioned 1 mm shorter of the canal's working length. EDTA chelating gel (MD.ChelCream, MetaBiomed, Seoul, Korea) was used on the files as a lubricant throughout the preparation.

Canal patency was maintained throughout the preparation using a size 10 k file. A final rinse was performed with 5ml of EDTA solution (DHARMA Research, Miami, USA), followed by 5ml of normal saline. The canals were then dried with Protaper Next absorbent paper points size X3.

Calcium hydroxide filling

Calcium hydroxide paste (MetaPaste, MetaBiomed, Seoul, Korea) was applied into the canal, using a propylene tip placed 1 mm short of the apex. The tip was slowly retracted from the canal as the paste was being injected, until the paste was seen extruding from the canal's apex. A cotton pellet was used to remove the excess paste. Digital periapical radiographs were then taken to check the complete homogenous filling of the canals. Finally, a cotton pellet and Cavit temporary restoration (3M ESPE, Seefeld, USA) were used to seal the access cavity.

The samples were numbered and then randomly divided into four groups (n=10) based on the method of calcium hydroxide removal. Group A: PUI (PUI). Group B: EDDY sonic activation, Group C: Roeko canal brush, and Group (D): Manual K file (control group).

Pre-removal CBCT image

Roots were placed in blocks of softened modeling wax, in groups of five teeth per block, with one mm distance between each root. CBCT scans were taken for each block using J. Morita's Veraviewepocs 3D R100 scanner (J. Morita MFG Corp. Kyoto, Japan). The scans were taken with settings of 75 kVp tube voltage and 1 mA, with 9.4 seconds exposure time. Images were captured with a field of view (FOV) of 80 x 80mm and a

resolution of 0.125mm. Axial cut was positioned on the cervical line, while sagittal cut was at the midline.

OnDemand3D software (CyberMed Inc, Daejeon, Korea) was used to analyze the images. Volume rendering and 3D reconstruction of the calcium hydroxide paste inside each root were done, and the material's volume was measured and recorded in cubic millimeters (Figure 1).

Samples were stored in an incubator at a temperature of 37°C and 100% relative humidity for a week, resembling the oral environment.

Calcium hydroxide Removal Techniques

After one week of storage, the temporary restoration and cotton were removed using a round diamond bur in a low speed handpiece. All root canals were irrigated using 5 ml of 2.5% NaOCl with a 30 gauge ProRinse side vented needle (Dentsply, Sirona, Tulsa, USA). The needle was placed 1 mm short of the working length.

Group A: (PUI group) Passive ultrasonic irrigation was executed with a size 20, .00 taper IriSafe ultrasonic file, operated with the Satelec P5 Newtron ultrasonic system (Satelec Acteon, Merignac, France), set at an endo power of 10. The canals were rinsed with 1 ml of 2.5% NaOCl, then the file was introduced into the canal and placed one mm shorter than the working length. Activation was performed for 20 seconds, and the cycle was repeated 3 times. The remaining 2 ml of irrigant were then used to flush out the canal, bringing the total volume to 5 ml.

Group B: (EDDY group) The irrigant was activated with the EDDY polymer sonic tip (VDW, Munich, Germany). The tip was operated with an air scaler at a frequency of 6000Hz. The canal was flooded with 1 ml of irrigant, and the EDDY tip was advanced into the canal 1 mm shorter than the working length. Activation was performed for 20 seconds, then the irrigant was replenished. The cycle was repeated 3 times. The remaining 2 ml of irrigant were then used to flush out the canal, bringing the total volume to 5 ml.

Group C: (Roeko canal brush group) The canal was cleaned with a size medium Roeko canal brush (Coltene, Altstätten, Switzerland). The brush was operated with the X-Smart plus endodontic motor at 600rpm. The canal was rinsed with 1 ml of NaOCl, then the brush was advanced to the canal working length and used with a circumferential motion for 30 seconds. The cycle was repeated 1 more time, bringing the total time to 1 min. The canal received a final rinse with NaOCl until the 5 ml of irrigant was used. A fresh canal brush was used for each canal.

Group D: (Control Group) In this group calcium hydroxide was removed with a manual K file size 30 (Dentsply Maillefer, Ballaigues, Switzerland). A circumferential filing motion was performed to the canals full working length for 20 seconds, then the irrigant was replenished. This action was repeated 3 times. The remaining 2 ml of irrigant were then used to flush out the canal, bringing the total volume to 5 ml.

Finally, all the samples received a final rinse with 5 ml of 17% EDTA followed by 5ml of saline solution and dried with paper points.

Post removal CBCT image

After trials of calcium hydroxide removal were completed, the samples were once again scanned, repeating the same pre-removal scanning protocol. OnDemand3D software was used again to perform volume rendering and 3D reconstruction of the remaining calcium hydroxide material inside each canal. The density of dentine and calcium hydroxide were both measured, then the region of interest (ROI) tool was used to identify the calcium hydroxide remnants. Once all areas of the paste were marked, the total volume was computed (Figure 2). The volume of calcium hydroxide remnants within the canal were measured and the amount of paste removed was calculated as $[(a-b) \times 100/a]$. Where (a) represents the volume of the dressing prior to removal, and (b) is the volume of the dressing residues after removal procedures, as described by Raghu et al 2017 (2). Each canal's length was measured using the (Tapeline) tool in the software, the length was then equally divided into three sections. The volume of calcium hydroxide remnants in each third was then marked and computed in the same manner described previously.

Statistical analysis

Normality was checked using Shapiro Wilk test, box plots and descriptive Volume of the intracanal calcium hydroxide was presented using mean, median, standard deviation, inter quartile range (IQR), minimum and maximum. Kruskal Wallis test was used to compare the study groups, followed by pair wise comparisons with Bonferroni correction. Volume was compared between the coronal, middle and apical third within each group using Friedman test and followed by pair wise comparisons with Bonferroni correction. A p value of 0.05 was set as the level of significance. All tests were two tailed. Data were analyzed using IBM SPSS for windows version 23 (IBM, Armonk, New York, United States).

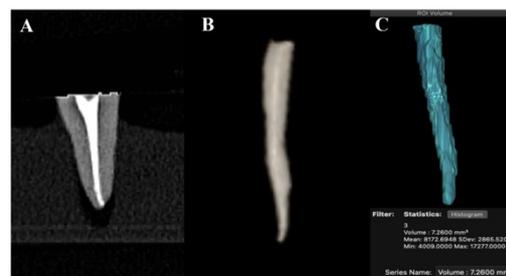


Figure 1: CBCT image coronal view (A) and 3D volume reconstruction (B,C) of pre-retrieval intracanal calcium hydroxide paste

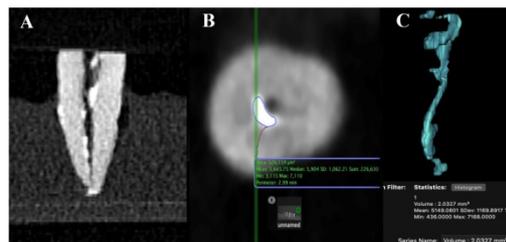


Figure 2: CBCT image of post-retrieval intracanal calcium hydroxide paste. Coronal view (A), axial view (B) and 3D volume reconstruction (C).

RESULTS

The volume of intracanal calcium hydroxide paste in all the tested groups were found to be significantly different ($p < 0.05$) when comparing pre and post removal scans (Table 1).

The highest mean percentages of removed volume of calcium hydroxide paste were demonstrated by PUI ($99.89\% \pm 0.19$) and EDDY ($99.86\% \pm 0.34$). Roeko canal brush removed a mean percentage of ($87.31\% \pm 14.95$), while the lowest mean percentage of removed volume was demonstrated by the control group (78.01 ± 10.03) (Figure 3).

When comparing PUI group to the control group, the statistical difference was found to be significant ($p < 0.0001$). On the other hand, when PUI was compared to EDDY ($p = 1$) and Roeko canal brush ($p = 0.053$) groups, no significant difference was detected. In addition, there was no significant difference when Roeko canal brush group was compared to the control group ($p = 0.829$).

EDDY group showed a statistically significant difference when compared to both Roeko canal brush ($p = 0.047$) and control (< 0.0001) groups (table 2).

None of the tested techniques could achieve complete removal of calcium hydroxide from the apical third of the canals. However, both PUI and EDDY groups resulted in complete removal from the coronal and middle thirds of the canals, leaving residual calcium hydroxide only in the apical third of the canals ($0.01 \pm 0.02 \text{ mm}^3$). Roeko canal

brush group and control group demonstrated residues in all thirds of the canals, with the highest volumes in the apical third (Figure 4). When PUI and EDDY groups were compared to the control group (Table 3), there was a statistically significant difference between coronal, middle and apical thirds ($p < 0.0001$). On the other hand, when compared to the Roeko canal brush there was a significant difference only in the coronal third ($p = 0.042$). The largest mean volume of calcium hydroxide paste remnants was seen in the apical third of the control group ($0.6 \pm 0.34 \text{ mm}^3$).

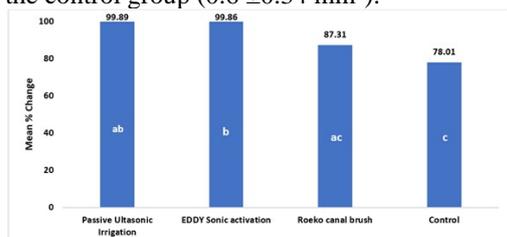


Figure 3: Bar chart demonstrating the mean percent of removed volume of intracanal calcium hydroxide paste. Different letters on the bars denote statistical significance between the groups

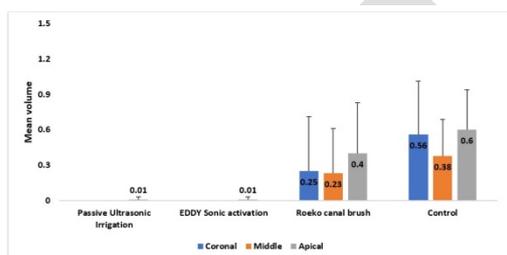


Figure 4: Bar chart demonstrating the mean volume of intracanal Calcium hydroxide remnants among the study groups at the coronal, middle and apical third.

Table 1: Comparison of the (Mean, Median and Min - Max) of the volume in mm^3 of intracanal Calcium hydroxide among the study groups pre and post-removal

		Passive Ultrasonic Irrigation (n=10)	EDDY Sonic activation (n=10)	Roeko canal brush (n=10)	Control (n=10)	Test (P value)
Before	Mean (SD)	8.08 (5.58)	11.67 (3.24)	7.27 (2.51)	8.32 (3.27)	6.960 (0.073)
	Median (IQR)	7.78 (9.52)	11.50 (2.51)	6.62 (1.30)	9.27 (5.74)	
	Min - Max	2.33 - 17.70	6.20 - 19.00	5.61 - 14.2	3.28 - 13.4	

		0	0	0	0	0
After	Mean (SD)	0.01 (0.02)	0.02 (0.04)	0.88 (1.07)	1.66 (0.59)	24.489 (<0.0001*)
	Median (IQR)	0.0 (0.02)	0.0 (0.01)	0.43 (1.76)	1.78 (1.10)	
	Min - Max	0.0 - 0.06	0.0 - 0.14	0.0 - 2.96	0.86 - 2.64	
Test (P value)		2.803 (0.005*)	2.803 (0.005*)	2.803 (0.005*)	2.803 (0.005*)	

*Statistically Significant at p value ≤ 0.05

Table 2: Pair wise comparisons regarding percent of removed volume of intracanal calcium hydroxide volume between the study groups

Groups	Compared to	P value
Passive Ultrasonic Irrigation	EDDY Sonic activation	1.00
	Roeko canal brush	0.053
	Control	<0.0001*
EDDY Sonic activation	Roeko canal brush	0.047*
	Control	<0.0001*
Roeko canal brush	Control	0.829

*Statistically Significant at p value ≤ 0.05

Table 3: Pair wise comparisons regarding volume of intracanal calcium hydroxide residues between the study groups

Groups	Compared to	P value		
		Coronal	Middle	Apical
Passive Ultrasonic Irrigation	EDDY Sonic activation	1.00	1.00	1.00
	Roeko canal brush	0.042*	0.301	0.084
	Control	<0.0001*	0.001*	<0.0001*
EDDY Sonic activation	Roeko canal brush	0.042*	0.301	0.084
	Control	<0.0001*	0.001*	<0.0001*
Roeko canal brush	Control	0.406	0.485	0.813

*Statistically Significant at p value ≤ 0.05

DISCUSSION

Intracanal medicaments are used to temporarily fill the root canal space, acting as antimicrobial agents. Calcium hydroxide is the most commonly used intracanal medicament because of its well established antimicrobial actions (11, 12). However, residues of calcium hydroxide paste on the root canal walls were reported to negatively influence the outcome of the final obturation (13-16). Therefore, completely removing intracanal calcium hydroxide is essential prior to the final obturation.

The aim of this study was to compare four removal methods of intracanal calcium hydroxide, namely PUI, EDDY sonic activation, Roeko canal brush, and manual K file using cone beam computed tomography. In the present study the pre and post removal volume of intracanal calcium hydroxide were compared, and the results showed that the removed volumes were statistically significant in all groups ($p < 0.005$). It was also revealed that both PUI and EDDY removed more volume of calcium hydroxide paste in comparison to the other two groups. Hence, the null hypothesis of the present study was rejected. These results are in agreement with Marques da Silva et al (17) and Keskin et al (9), who demonstrated that EDDY and PUI activation had considerably improved the removal of intracanal calcium hydroxide.

Passive ultrasonic irrigation achieved the highest percentage (99.89%) of removed volume of calcium hydroxide in the present study. This outcome was supported by the findings of Silva et al (10), Kucukkaya et al (18) and Lins et al (19). On the contrary, PUI was reported to have no significant difference on calcium hydroxide removal by Dias- Junior et al (20) and Harzivarthy et al (21). The outcome of these two studies could be attributed to the lack of a final rinse with EDTA, or any other chelating agent in their irrigation protocol.

The results of the present study demonstrated that the percent of removed volume of calcium hydroxide by EDDY (99.86%) was almost the same as the volume removed by PUI. This came in agreement with a study by Donnermeyer et al (6), reporting that EDDY and PUI both removed significantly more of calcium hydroxide paste. Results of the present study showed that Roeko canal brush removed less percentage of calcium hydroxide volume than PUI and EDDY sonic activation. The canal brush was operated for one minute inside the canal, implementing the manufacturer's recommendation, a period which may have

been insufficient for $\text{Ca}(\text{OH})_2$ removal. Similar results were reported by Zorzini et al (22) and Topcuoglu et al (23). Although Zorzini's study reported higher percentages of removal, which was explained by the use of higher volumes of irrigant solution. Turkyaydin et al (24) reported higher volumes of calcium hydroxide paste residues were left by PUI than with Roeko canal brush. A result that could be attributed to the use of oil based calcium hydroxide in that study.

In this study, distortion of the Roeko canal brush after use for 30 seconds was noticed by the examiner, a feature that could explain the lower volumes of removed calcium hydroxide. Another observation, was that the use of the canal brush led to packing of the intracanal paste apically and through the apex, a feature also reported by Gurdusys et al (25).

Regarding the location of the calcium hydroxide residues, PUI and EDDY achieved complete removal from the cervical and middle thirds of the canals, however complete removal from the apical thirds was not accomplished by any of the tested techniques. The efficiency of removal from the coronal and middle thirds could be attributed to the larger diameter in these areas, exposing dentin to a higher volume of irrigants and making $\text{Ca}(\text{OH})_2$ removal easier. This was in accordance with the findings of Shi et al (26). On the other hand, EDDY sonic activation was reported by Donnermeyer et al (6) to achieve the best results in the apical third. A finding that could be explained by the fact that the canals of that study were shaped up to size 40/04, creating an apical diameter that allows abundant irrigant exchange as well as a more freely moving instrument tip, unlike the limited apical diameter of a size 30 preparation used in the present study.

A limitation of this study, was performing a final rinse with 17% EDTA, a chelating agent known to enhance the removal of calcium hydroxide paste. This effect could have masked the actual difference between the tested removal techniques. Another limitation was using relatively straight canals with no prepared grooves or irregularities, hence, not allowing the assessment of the tested methods efficiency in calcium hydroxide removal from canal curves, isthmuses or grooves.

The fact that none of the tested techniques could achieve complete removal of the intracanal calcium hydroxide, means further investigations are needed to reach the optimal removal protocol.

CONCLUSION

Within the limitations of the present study, it was concluded that PUI and EDDY sonic activation were more efficient than Roeko

canal brush and manual filing in intracanal calcium hydroxide removal.

CONFLICT OF INTEREST

The authors deny any conflict of interests related to the current study.

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REFERENCES

1. Tahan E, Kilkis B, Tanriver M, Akdag M. A comparison of different irrigation/agitation methods for the removal of calcium hydroxide medicament from the root canal walls. *J Restor Dent.* 2015;3:44.
2. Raghu R, Pradeep G, Shetty A, Gautham PM, Puneetha PG, Reddy TV. Retrieval of calcium hydroxide intracanal medicament with three calcium chelators, ethylenediaminetetraacetic acid, citric acid, and chitosan from root canals: An in vitro cone beam computed tomography volumetric analysis. *J Conserv Dent.* 2017;20:25-9.
3. Khademi AA, Amini K, Ghodsian B, Zahed SM, Teymori F, Shadmehr E. Removal efficiency of calcium hydroxide intracanal medicament with RinsEndo system in comparison with passive ultrasonic irrigation, an in vitro study. *Dent Res J.* 2015;12:157-60.
4. Balvedi RP, Versiani MA, Manna FF, Biffi JC. A comparison of two techniques for the removal of calcium hydroxide from root canals. *Int Endod J.* 2010;43:763-8.
5. Urban K, Donnermeyer D, Schafer E, Burklein S. Canal cleanliness using different irrigation activation systems: a SEM evaluation. *Clin Oral Investig.* 2017;21:2681-7.
6. Donnermeyer D, Wyrsh H, Burklein S, Schafer E. Removal of calcium hydroxide from artificial grooves in straight root canals: Sonic activation using EDDY versus passive ultrasonic irrigation and XPendo finisher. *J Endod.* 2019;45:322-6.
7. Plotino G, Grande NM, Mercade M, Cortese T, Staffoli S, Gambarini G, et al. Efficacy of sonic and ultrasonic irrigation devices in the removal of debris from canal irregularities in artificial root canals. *J Appl Oral Sci.* 2019;27:e20180045.
8. Pabel AK, Hulsmann M. Comparison of different techniques for removal of calcium hydroxide from straight root canals: an in vitro study. *Odontology.* 2017;105:453-9.
9. Keskin C, Keleş A, Sarıyılmaz Ö. Efficacy of glycolic acid for the removal of calcium hydroxide from simulated internal Resorption cavities. *Clin Oral Investig.* 2021;25:4407-13.
10. Silva LJ, Pessoa OF, Teixeira MB, Gouveia CH, Braga RR. Micro-CT evaluation of calcium hydroxide removal through passive ultrasonic irrigation associated with or without an additional instrument. *Int Endod J.* 2015;48:768-73.
11. Siqueira JF Jr, Lopes HP. Mechanisms of antimicrobial activity of calcium hydroxide: a critical review. *Int Endod J.* 1999;32:361-9.
12. Athanassiadis B, Abbott PV, Walsh LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. *Aust Dent J* 2007;52:64-82.
13. Böttcher DE, Hirai VH, Da Silva Neto UX, Grecca FS. Effect of calcium hydroxide dressing on the long-term sealing ability of two different endodontic sealers: an in vitro study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;110:386-9.
14. Hosoya N, Kurayama H, Iino F, Arai T. Effects of calcium hydroxide on physical and sealing properties of canal sealers. *Int Endod J.* 2004;37:178-84.
15. Kim SK, Kim YO. Influence of calcium hydroxide intracanal medication on apical seal. *Int Endod J.* 2002;35:623-8.
16. Uzunoglu-Özyürek E, Erdoğan Ö, Aktemur Türker S. Effect of calcium hydroxide dressing on the dentinal tubule penetration of 2 different root canal sealers: A confocal laser scanning microscopic study. *J Endod.* 2018;44:1018-23.
17. Marques-da-Silva B, Alberton CS, Tomazinho FSF, Gabardo MCL, Duarte MAH, Vivan RR, et al. Effectiveness of five instruments when removing calcium hydroxide paste from simulated internal root resorption cavities in extracted maxillary central incisors. *Int Endod J.* 2020;53:366-75.
18. Küçükaya Eren S, Aksel H, Parashos P. A novel model for testing the efficiency of removal of calcium hydroxide from complex root canal anatomies. *Aust Endod J.* 2017;43:5-10.
19. Lins PD, Nogueira BC, Fagundes NC, Silva FR, Lima RR. Analysis of the effectiveness of calcium hydroxide removal with variation of technique and

- solvent vehicles. *Indian J Dent Res.* 2015;26:304-8.
20. Dias-Junior LCL, Castro RF, Fernandes AD, Guerreiro MYR, Silva E, Brandão J. Final Endodontic Irrigation with 70% Ethanol Enhanced Calcium Hydroxide Removal from the Apical Third. *J Endod.* 2021;47:105-11.
 21. Harzivarthy S, Hazar AB, Kartal N, Cimilli ZH. Evaluation of different irrigation solutions and activation methods on removing calcium hydroxide. *J Dent Sci.* 2021;16:700-5.
 22. Zorzin J, Wießner J, Wießner T, Lohbauer U, Petschelt A, Ebert J. Removal of radioactively marked calcium hydroxide from the root canal: Influence of volume of irrigation and activation. *J Endod.* 2016;42:637-40.
 23. Topçuoğlu HS, Düzgün S, Ceyhanlı KT, Aktı A, Pala K, Kesim B. Efficacy of different irrigation techniques in the removal of calcium hydroxide from a simulated internal root resorption cavity. *Int Endod J.* 2015;48:309-16.
 24. Turkyaydin D, Basturk FB, Goker S, Tarcin B, Berker YG, Ovecoglu HS. Efficacy of Endoactivator, CanalBrush, and passive ultrasonic irrigation in the removal of calcium hydroxide paste with iodoform and p-chlorophenol from root canals. *Niger J Clin Pract.* 2020;23:1237-42.
 25. Gorduysus M, Yilmaz Z, Gorduysus O, Atila B, Karapinar SO. Effectiveness of a new canal brushing technique in removing calcium hydroxide from the root canal system: A scanning electron microscope study. *J Conserv Dent.* 2012;15:367-71.
 26. Shi L, Wu S, Yang Y, Wan J. Efficacy of five irrigation techniques in removing calcium hydroxide from simulated S-shaped root canals. *J Dent Sci.* 2021.