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COMPARISON OF SONIC AND ULTRASONIC ACTIVATION FOR REMOVAL OF DIFFERENT TYPES OF CALCIUM HYDROXIDE FROM ROOT CANALS

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ABSTRACT

BACKGROUND: Calcium hydroxide a popular intracanal medicament used for persistent infections, and root perforations. However, it can impair sealer adaptation to dentin walls, increasing leakage risks. Therefore, complete removal before obturation is essential.

OBJECTIVES: To evaluate the residue of two types of Ca(OH)2 paste after using master apical file with syringe needle irrigation, sonic, and passive ultrasonic activation, assessed via stereomicroscope.

METHODS: Sixty extracted single-rooted mandibular premolars were instrumented using PROTAPER NEXT rotary files to file X3. The teeth were randomly divided into two groups: Group A, where 30 canals were filled with oil-based Ca(OH)2 (Metapex), and Group B, where 30 canals were filled with aqueous-based Ca(OH)2 paste (Metapaste). After one week, the bulk of Ca(OH)2 was removed using a #15k file to the working length with 3 ml of 2.5% NaOCl. Furtherly each group was subdivided into three subgroups for removal methods: A1, B1 (Master Apical File & Syringe Needle Irrigation), A2, B2 (PUI), A3, B3 (EDDY). Samples were sectioned longitudinally, scanned with a stereomicroscope, and images were analyzed using ImageJ software. The Kuga Scoring system evaluated remaining Ca(OH)2, and statistical analysis was performed using Three-way ANOVA with a significance level of P=0.05.

RESULTS: None of the techniques achieved complete Ca(OH)2 removal along the entire canal length. PUI and EDDY showed superior removal compared to MAF in both groups, with the coronal third having the most residual paste.

CONCLUSION: EDDY and PUI are more effective than MAF in removing calcium hydroxide.

KEYWORDS: Calcium hydroxide removal, Stereomicroscope, Sonic activation, EDDY, Ultrasonic activation.

RUNNING TITLE: Sonic vs. Ultrasonic: Calcium Hydroxide Removal

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INTRODUCTION

Microorganisms play a critical role in the etiology of periradicular diseases; intracanal medicaments are used to eliminate the remaining microorganisms during root canal preparation and to prevent the root canal system from getting infected again between appointments (1).

The most commonly used intracanal medicament is Calcium hydroxide, a potent medicament that helps to disinfect the root canal system and promote healing. Calcium hydroxide has been used for decades due to its antimicrobial properties and ability to promote healing (2). Research has shown that calcium hydroxide can effectively kill bacteria and neutralize toxins produced by bacteria within the root canal system; however, it must be effectively removed to allow for successful obturation (3). Studies indicate that calcium hydroxide presents specific drawbacks, such as weakens root structure and necessitating high levels of patient cooperation and motivation (4, 5).

The dissociation process of Ca(OH)2 paste, employed as a root canal medicament, involves various vehicles influencing ionic dissociation velocity, Ca(OH)2 dispersion, and duration of action. Water-soluble, viscous, and oil-based vehicles are the primary types. Viscous vehicles, particularly polyethylene glycol (PEG), release ions slowly, extending their presence in root canals, reducing necessary appointments. Oil-based vehicles face challenges in removal and leave residue, limiting their use. The choice of vehicle can impact Ca(OH)2's physical, chemical properties, and clinical applications, with PEG being a commonly utilized viscous vehicle due to low toxicity, high solubility, and substantial antibacterial activity (6).

Several techniques are available to facilitate the removal of calcium hydroxide from root canals. The most common method for the removal of calcium hydroxide from the root canal is the instrumentation of the root canal with the master apical file in combination with copious irrigation of NaOCL and EDTA (7).

Sonic activation is considered one of the methods for the removal of calcium hydroxide, particularly using EDDY™ (VDW, Munich, Germany). This technique is beneficial for removing pulpal remnants and causes cavitation and acoustic streaming. EDDY™ (VDW, Munich, Germany) tips are powered at a high frequency of up to 6,000 Hz by an airscaler with a vibration of 5,000 to 6,000 Hz that creates a three-dimensional movement (8).

Using ultrasonics in root canal therapy is highly effective, as the ultrasonically activated irrigants will aid in cleaning and disinfecting the root canals as well as in removing Ca(OH)2 remnants. Ultrasonic activation will lead to cavitation and acoustic streaming. The oscillatory movement of the ultrasonic agitates the irrigant, which increases the cleaning and disinfection of the root canals [(9)].

The research question was whether or not PUI, EDDY sonic activation can be more efficient than Master Apical file and syringe needle irrigation in removing oil based and aqueous based Ca(OH)2 from root canals.

The aim of this study was to evaluate the residue of two different types of calcium hydroxide paste after using master apical file with syringe needle irrigation, sonic and ultrasonic activation by the use of stereomicroscope.

The null hypothesis of this study was that there would be no significant difference between a master apical file with syringe needle irrigation, sonic and passive ultrasonic activation in the removal of different formulations of calcium hydroxide.

MATERIALS AND METHODS

This study was approved by the research ethics committee at the Faculty of Dentistry, Alexandria University (serial no. 0283-09/2021). It was conducted at the Faculty of Dentistry, Alexandria university, Egypt.

Sample Size Estimation:

The sample size was calculated using G*Power version 3.1.9.2. The minimal required sample to achieve a power of 80% to detect a standardized effect size in the amount of calcium hydroxide in the root canal (d=0.515) (medium-sized standardized effect size), and level of significance 95% (α=0.05), the minimum required sample size was found to be 10 teeth per group (number of groups=6) (Total sample size=60 teeth).

Preparation of the specimens

Sixty extracted single rooted mandibular premolar teeth were included in this study, the teeth were free from caries, cracks, calcifications and resorptions and with a curvature of < 25 degrees according to Schneider (10). Teeth with root fractures, previous root canal treatment, or curvatures were excluded from the study and were thoroughly cleaned and then preserved in saline solution up to the time of use. After access opening, root canals patency was checked with a #10 K-file, working length was determined by subtracting 1 mm from this measurement. A rubber stop was used to mark the file at its coronal reference point, the file was then removed and canal length was determined using an endodontic ruler. Glide path was established using a #15 k file to working length and root canal preparation was done using ProTaper next rotary files (Dentsply, Sirona, Tulsa, USA) according to manufacturer instruction (up to size X3 corresponding to file tip size 30). Irrigation was done between each file with 2 mL 2.5% NaOcl (PPH Cerkamed, Stalowa Wola, Poland) using a 30-gauge side vented needle (PPH Cerkamed, Stalowa Wola, Poland) that was placed 1 mm short to the working length. 5 mL of 17% EDTA (PPH Cerkamed, Stalowa Wola, Poland) was used after the root canal preparation for removal of the smear layer, then sterile paper points were used to dry the canals. Two types of calcium hydroxide paste (oil-based and aqueous -based then radiographs were done to confirm the filling of the root canal before (Meta Biomed CO.LTD, Korea) were inserted in the canal by using a syringe-type with disposable tips for easy delivery which was placed 1 mm short of the apex according to manufacturer's instructions, and all specimens were put on acrylic molds for standardization to allow precise cutting of the specimen by the Micracut (Metkon Metallography Bursa, Turkey), then radiographs were done to confirm the filling of the root canal before sealing the cavities with a sterile cotton pellet and temporary filling (Detax, Germany) were done, teeth were stored in an incubator at 37°C and 100% of humidity for seven days, resembling the oral environment.

Randomization

The samples were numbered and then randomly divided into two equal groups of 30 teeth by allocation concealment method each based on the methods of calcium hydroxide removal. Group A was filled with oil-based calcium hydroxide paste (Metapex), group B was filled with aqueous based calcium hydroxide (Metapaste). After one week the bulk of calcium hydroxide was removed by using #15k file to the working length with 3 ml of 2.5% NaOCL. Furtherly, each group was subdivided into three subgroups according to the method of removal of remaining calcium hydroxide as follows: A1, B1 (Master Apical File & Syringe Needle Irrigation), A2, B2 (PUI), A3, B3 (EDDY Sonic).

Calcium hydroxide Removal Techniques

Following a week of storage, the temporary filling was removed using a round diamond bur in a low speed handpiece. Every root canal was irrigated with 5 ml of 2.5% NaOCl using a 30 gauge

ProRinse side vented needle positioned 1 mm shorter than the working length.

Group A (Oil based calcium hydroxide)

Subgroup A1: Ca (OH)2 was removed using X3 Master Apical File with pecking motion 1-3 mm amplitude and Syringe Needle Irrigation to the working length, then 5mL of 2.5% NaOCL followed by 5mL of 17% EDTA were used. The canal received a final rinse using 5mL of 2.5% NaOCL, then root canals were dried and closed temporarily.

Subgroup A2: Ca(OH)2 was removed using Irrisafe file #20 (Acteon, France) mounted on Satelec P5 Neutron ultrasonic unit (Acteon, France) was used to perform PUI for removal of oil-based calcium hydroxide paste. The ultrasonic file was placed shorter than the working length by 1 mm. The file was centered in the canal and 2-3mm apical-coronal movements were done for 20 seconds and repeated for 3 cycles with frequency of 25-30 KHz with a total of 1 minute of PUI. This process was done with 5mL of 2.5% of NaOCL and once more with 17% EDTA. The root canals were rinsed using 5mL of 2.5% NaOCL dried and closed temporarily.

Subgroup A3: Ca(OH)2 was removed using Sonic irrigation with 6000 Hz air scaler with a vibration of 25-40 kHz. EDDY tip (VDW GmbH, Munich) was placed in the canal and activated at 2mm short from the working length according to the following protocol; 30 seconds with 5mL of 2.5% NaOCL irrigation followed by 30 seconds with 5mL of 17% EDTA. The root canals received a final rinse of 5mL of 2.5% NaOCL, dried and closed temporarily.

Group B (Aqueous-based calcium hydroxide)

Subgroup B1: Ca(OH)2was removed using similar technique as subgroup A1

Subgroup B2: Ca(OH)2was removed using similar technique as subgroup A2

Subgroup B3: Ca(OH)2was removed using similar technique as subgroup A3

The teeth were sectioned vertically by using the Micracut along the buccolingual plane into two halves. Examination of the specimen using the stereomicroscope (Olympus, Japan) at a magnification of #50x. Images were taken to measure the remaining calcium hydroxide along the whole area of the canal and then the whole surface area of the canals was measured by the use of ImageJ software. Kuga Scoring system was used to evaluate the remaining calcium hydroxide on the root canal walls (11).

Kuga Scoring system consist of four scores which are:

(score 0) Absence of residue.

(score 1) Small amount of residue (covering ≤20% of the surface).

(score 2) Moderate amount of residue (covering 20 60% of the surface).

(score 3) Large amount of residue (covering >60% of the surface).

Statistical analysis was performed by calculating the mean, standard deviation and the Three way Anova with a level of significance set at P value of 0.05. Both the stereomicroscopic evaluator and the statistician were blinded to the groups and subgroups.

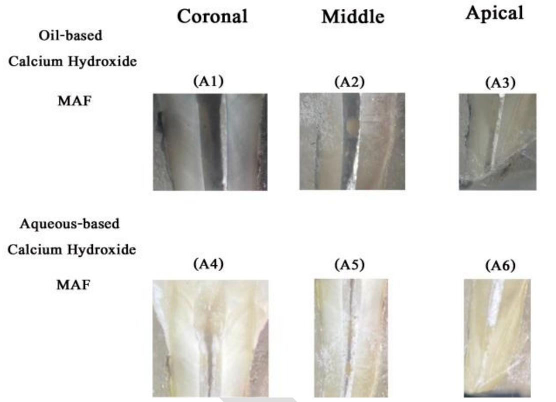

Figure (1): Stereomicroscope image of post-retrieval intracanal calcium hydroxide paste using master apical file with syringe needle irrigation showed all root canal thirds had a score of 2.

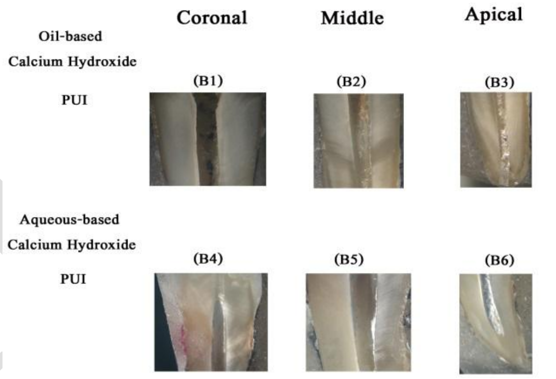

Figure (2): Stereomicroscope image of post-retrieval intracanal calcium hydroxide paste using PUI showed all root canal thirds had a score of 2.

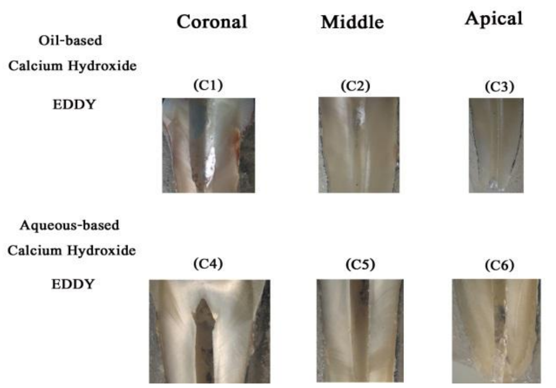

Figure (3): Stereomicroscope image of post-retrieval intracanal calcium hydroxide paste using EDDY showed all root canal thirds had a score of 2.

Figure (4): Radiographic image confirming placing of oil based calcium hydroxide paste in the root canal

Figure (5): Radiographic image confirming placing of aqueous based calcium hydroxide paste in the root canal

RESULTS

In all groups, the maximum percentage of residual calcium hydroxide was found in the coronal thirds in all subgroups and the minimum percentage was in the middle third in all subgroups. Along complete canal area, the best method of calcium hydroxide removal was EDDY sonic activation (subgroups A3, B3) where the mean = 35.62 + 4.59 in oil based calcium hydroxide and 33.9 + 4.02 in aqueous based calcium hydroxide (Table 1).

By using the Three Way ANOVA summary assessing the effect of independent variables on mean percent of residual calcium hydroxide. it was found that the method of calcium hydroxide removal and the root canal third had a significant impact on the percentage of residual calcium hydroxide ($P < 0.0001$), whereas the type of calcium hydroxide has no significant impact ($P = 0.114$) (Table2).

None of the tested techniques achieved complete removal of calcium hydroxide from the apical third of the canals. However, both PUI and EDDY groups resulted in better removal of calcium hydroxide from the coronal and middle thirds of the canals than ProTaper Next.

All root canal thirds had score 2 with no statistical significant difference between different methods of calcium hydroxide removal or root thirds.

Table (1): Mean and standard deviation values remaining calcium hydroxide percentage area among the study groups in relation to the root canal surface area.

Type of calcium hydroxide	Tooth levels	Group A1 (MAF) (n=10)	Group A2 (PUI) (n=10)	Group A3 (EDDY) (n=10)
		Mean (SD)		
Oil based calcium hydroxide	Apical	39.81 (4.12)	38.82 (3.10)	34.18 (2.39)
	Middle	34.80 (4.78)	32.24 (4.22)	28.70 (3.29)
	Coronal	54.45 (22.64)	47.24 (14.37)	43.98 (14.87)
	Total	43.02 (6.29)	39.43 (3.52)	35.62 (4.59)
		Group B1 (MAF) (n=10)	Group B2 (PUI) (n=10)	Group B3 (EDDY) (n=10)
		Mean (SD)		
Aqueous based calcium hydroxide	Apical	39.04 (2.73)	36.05 (1.03)	30.68 (1.37)
	Middle	33.78 (3.48)	30.27 (2.97)	25.17 (2.13)
	Coronal	49.14 (14.23)	47.88 (11.24)	43.43 (14.23)
	Total	40.65 (3.80)	38.07 (2.83)	33.09 (4.02)

Table (2): Three Way ANOVA summary assessing the effect of independent variables on mean percent of residual calcium hydroxide in relation to the root canal surface area.

Variable	Mean square	df	F test	P value	Partial Eta Squared
Type of calcium hydroxide	267.445	1	2.521	0.114	0.014
Subgroups (method)	964.493	2	9.092	<0.0001*	0.095
Root canal thirds	4725.703	2	44.547	<0.0001*	0.339

*Statistically significant differences≤0.05, Adjusted R Squared =0.973

Table (3): Comparison of calcium hydroxide residue on root canal walls using Kuga scoring system for Oil based calcium hydroxide and Aqueous based calcium hydroxide.

Type of calcium hydroxide	Tooth levels	Group A1 (MAF) (n=10)	Group A2 (PUI) (n=10)	Group A3 (EDDY) (n=10)	P value
		Median (IQR)			
Oil based calcium hydroxide	Apical	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)	1.00
	Middle	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)	1.00
	Coronal	2.0 (1.0)	2.0 (0.25)	2.0 (0.25)	0.517
	Total	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)	1.00
	P value	0.108	0.135	0.135	
Aqueous based calcium hydroxide	Apical	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)	1.00
	Middle	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)	1.00
	Coronal	2.0 (0.25)	2.0 (0.25)	2.0 (0.25)	1.00
	Total	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)	1.00
	P value	0.135	0.135	0.135	

DISCUSSION

The aim of this study was to evaluate the residue of two different types of calcium hydroxide paste after using master apical file with syringe needle irrigation, sonic and ultrasonic activation using stereomicroscope for evaluation.

None of the tested techniques were capable of complete removal Ca (OH)2 from root canals regardless the type of calcium hydroxide, so the null hypothesis was accepted.

There are different vehicles of Ca (OH)2 paste, which is used as a root canal medicament. The type of vehicle used can affect duration of action and the ease of removal of Ca (OH)2 from the root canals. There are three main types of vehicles: water-soluble, viscous, and oil-based (6), Both oil-based and aqueous-based calcium hydroxide are commonly found and utilized in the market. Nevertheless, the aqueous-based version contains barium sulfate, whereas the oil-based version contains Iodoform.

Aqueous-based calcium hydroxide has been recommended as a prolonged dressing in instances of non-vital teeth with large periapical lesions, as well as in apexification procedures (12). Oil-based calcium hydroxide that contains Iodoform is extensively employed because of its disinfectant and bone regenerative characteristics, leading to improved and expedited recovery of periapical lesions [(13)]. Accordingly, an aqueous based calcium hydroxide paste (MetaPaste) and oil based calcium hydroxide (MetaPex) were selected to fill the root canals in the present study.

In this study, single-canalled mandibular premolars were chosen aiming to assess the efficacy of the employed techniques in eliminating calcium hydroxide from oval-shaped canals, a common feature in mandibular premolars. In addition, length standardization was not utilized in the current study to simulate clinical condition.

The final apical diameter was chosen to be X3 (#30, 7% v taper) as the initial file (first apical binding file) was size # 15.

The effectiveness of endodontic irrigant to remove intracanal medicament is not only influenced by the irrigation technique used but also by the chemical composition of the irrigating agent. While sodium hypochlorite has long been considered the gold standard for endodontic irrigation, its ability to dissolve inorganic substances such as calcium is limited. This can result in inadequate removal of substances like Ca (OH)2. In light of this, numerous studies have emphasized the efficiency of chelating agents, particularly EDTA, in the removal of Ca (OH)2 (7, 8). Based on these findings in the present study

2.5% NaOCl followed by 17% EDTA was chosen as the preferred irrigants for CH removal.

In the current study, irrigation was done using a 30-gauge side vented ProRinse needle. This needle size enabled reaching the apical third of the canal without encountering any binding issues. Following the recommendations of Galić et al. (2018), the needle was positioned 1mm shorter than the working length. This adjustment ensures that the irrigant solution adequately reaches the entire length of the canal [(14)].

Various techniques have been employed to assess the presence of Ca (OH)2 residues within the root canal. These techniques include digital photographs, scanning electron microscopy (SEM), and light microscopy. In the present study Stereomicroscope was used to assess the remnants of Ca (OH)2 as the clear visualization provided by the stereomicroscope aids in accurately evaluating the extent of calcium hydroxide remnants (15). There are several scoring systems to evaluate Ca(OH)2 residues, however Kuga scoring system was used as it is a simple scoring system with 4-point scale only (16).

In the present study, regarding the effectiveness of different techniques employed to remove Ca(OH)2 from root canals, X3 MAF associated with syringe needle irrigation showed the highest mean percentage of residual Ca(OH)2 in both Ca(OH)2 types along complete canal length. These findings are in agreement with Khaleel et al (2013) (17), who demonstrated that ProTaper Next rotary file and needle irrigation were less effective in removal of Ca (OH)2 in all root canal thirds.

Ultrasonic and sonic activation induces cavitation and acoustic streaming, where the vibratory motion of the instrument agitates the irrigant, thereby enhancing the cleansing and disinfection of the root canals (18). However, EDDY sonic activation achieved the lowest mean percentage of residual Ca (OH)2 along complete length for both types of calcium hydroxide. This may be due to that EDDY sonic activation has soft polymer tips opposite to the rigid stainless steel ultrasonic tips which may result in better irrigant activation, acoustic streaming and cavitation leading to more removal of Ca (OH) (19). These results are in agreement with Donnermeyer et al who demonstrated that EDDY and PUI were significantly more effective in the removal of calcium hydroxide than the XPendo Finisher (20).

Regarding the mean percentage of residual Ca (OH)2 area among the study groups in different canal thirds, the highest mean percentage was found in the coronal third for all groups. This may be due to the oval cross section of mandibular premolar teeth at the coronal third of the root compared to more round cross section in both middle and apical thirds (21).

The result of the present study showed that the type of Ca(OH)2 has no effect on the mean percentage of the residual Ca(OH)2 area. This may be due to that this calculation was done in comparison to the root canal surface area.

One of the limitations of this study was the presence of root curvature which interfered with the straight forward cutting when using Micracut, leading to incomplete visualization of the root canal in both halves. Accordingly, the whole length of the canal couldn't be visualized when using the stereomicroscope. It's recommended to perform further study using the micro CT to get a three dimensional visualization of the whole curved canal.

CONCLUSION

Within the study limitations, the following can be concluded:

None of the tested techniques could achieve complete removal of aqueous and oil based Ca(OH)2 formulations from mandibular premolar root canals.

PUI and EDDY sonic activation demonstrates better ability to remove aqueous and oil based Ca(OH)2 formulations than MAF combined with syringe needle irrigation from mandibular premolar root canals.

Aqueous and oil based Ca(OH)2 formulations could be removed similarly from mandibular premolar root canals.

CONFLICT OF INTEREST

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

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