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Research Article

COMPARISON OF EFFECTIVENESS OF THREE DIFFERENT IRRIGATION SYSTEMS IN REMOVAL OF INTRACANAL CALCIUM HYDROXIDE BY CLEARING TEETH TECHNIQUE; AN INVITRO STUDY

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A B S T R A C T

Introduction: Calcium hydroxide [Ca(OH)2] paste is generally used as intra canal medicament for several weeks. It must be completely removed prior to final obturation, if not Ca(OH)2 residues can affect the quality of root canal obturation by reducing the sealing ability of endodontic sealers, increases apical leakage, results in resorption etc. Various irrigation protocols are employed for effective removal of Ca(OH)2. **Materials and methods:** 30 freshly extracted single rooted human maxillary anterior teeth were selected. The root canals were then instrumented with ProTaper rotary files up to a size of F3 ProTaper. Between each rotary file, canals were irrigated with 3ml of 3% NaOCl and then rinsed with 17% EDTA for 60 seconds. After instrumentation, aqueous radiopaque Ca(OH)2 paste (CAL-EXCEL) was mixed with a drop of India ink and introduced into all the root canals using lentulo spiral and stored for 1 week. Later Ca(OH)2 paste was removed using conventional irrigation (Needle), ultrasonic irrigation (Piezoelectric) and sonic irrigation (Endoactivator) techniques. After irrigation access cavities were filled with glass ionomer cement and then subjected to clearing technique making them transparent to visualize the internal anatomy of the root canals. The cleared teeth were then observed under stereomicroscope for remnants of India ink stained calcium hydroxide

Results: All the analysis were done using SPSS version 18. Comparison of amount of calcium hydroxide remaining among the study groups was done using Mann-Whitney U test and Kruskal-Wallis tests. Statistically significant differences were found between conventional versus ultrasonic ($P<0.01$) and conventional versus sonic irrigation ($P<0.05$). There was no statistical significant difference between ultrasonic and sonic irrigation.

Conclusion: Ultrasonic irrigation technique was better able to remove Ca(OH)2 from the root canal as compared to sonic irrigation and conventional needle irrigation technique. Conventional needle irrigation had least ability to remove Ca (OH)2 from the root canal.

INTRODUCTION

The primary aim of endodontic treatment is to remove as much microbiota as possible from the root canal system and then to create an environment in which any remaining organisms cannot survive.[1] The effectiveness of endodontic files, rotary instrumentation, irrigating solutions, and chelating agents to clean, shape, and disinfect root canals underpins the success, longevity, and reliability of modern endodontic treatments.[2] Reducing the bacterial count in infected canals is accomplished by a combination of mechanical instrumentation, various irrigation solutions, and antibacterial medicaments placed into the canal.[3]

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Among the various intracanal medicaments, calcium hydroxide [$Ca(OH)_2$] is the most commonly used.Ca(OH)2 has been used in dentistry since the 1920s. It was introduced by Hermann as an endodontic antimicrobial agent. It has profound antimicrobial activity, tissue dissolution, degradation of lipopolysaccharide and inhibition of osteoclastic activity.

Since Ca(OH)2 kills bacteria through the effects of hydroxyl ions, its efficacy depends largely on the availability of these ions in the solution, which in turn is dependent on the vehicle in which Ca(OH)2 is carried. The medicament vehicle plays a very important role in the overall disinfection process because it determines the velocity of ionic dissociation causing the paste to be solubilized and resorbed at various rates by the periapical tissues and within the root canal. Ca(OH)2 is usually placed as an intracanal medicament for periods of 1–4 weeks. Before the root canal is filled, the medicament within the root canal must be removed.[4]

However, after placement, its removal from the root canal system has been a concern. Calcium hydroxide residues on the canal walls interfere negatively in endodontic treatment prognosis, influence dentine bond strength, affects the adhesion of the endodontic filling material to the root canal walls and the penetration of sealers into dentinal tubules, react chemically with the sealer, interfering with its physical properties.[5]

To date, various products and techniques have been recommended for removing the Ca(OH)2 from root canals. The most commonly described technique is removal of medicament using a master apical file and copious irrigation at working length. Several studies have examined different intracanal irrigants such as saline, sodium hypochlorite (NaOCl), ethylene diaminetetraacetic acid (EDTA), and citric acid, along with combinations for removing Ca(OH)2. However, none of them removed the Ca(OH)2 from the dentin walls completely. These results showed that it is difficult to completely remove the Ca (OH)2 using the irrigants alone.

Therefore, various irrigation agitation techniques, including mechanical instrumentation with rotary and patency files or sonic or ultrasonic devices, and laser irradiation have been improved. However, there is still no general consensus on the most effective technique.[3]

Ultrasonic and EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK) irrigation systems have been developed as adjunct procedures to enhance the removal of Ca(OH)2 remnants after needle irrigation. Because of its activation of irrigants and its clinical availability, ultrasonic irrigation is now commonly used. However, the effectiveness of ultrasonic irrigation in removing Ca(OH)2 varies greatly depending upon the irrigating solution and vehicle used.[6]

Various methods have been utilized to evaluate the amount of calcium hydroxide removed from the root canal systems like radiographic methods, Scanning Electron Microscopic method (SEM), Cone Beam Computed Tomography method and high resolution micro-Computed Tomography (micro-CT). Radiographic methods provide only two dimentional view of the root canal system, SEM requires sectioning of the teeth to be done and the recent radiographic methods are known to be technique sensitive and very expensive.

Over the last 100 years, the tooth-clearing technique was utilised in human dental pulp morphology studies, as it provides a 3-D view of the pulp cavity in relation to the exterior of the teeth, allows a thorough examination of the pulp chambers and root canals, while maintaining the original anatomy of the root canal. It is inexpensive and is very simple to perform.[7]

Thus in this study, clearing teeth technique has been utilized to evaluate the amount of India ink stained calcium hydroxide removed using three different irrigation techniques.

Aim: The aim of this study was to compare the effectiveness of ultrasonic, sonic and needle irrigation in removing the remnants of India ink stained calcium hydroxide, evaluated using clearing teeth technique.

MATERIALS AND METHODS

This study was conducted in the department of Conservative Dentistry & Endodontics, C.K.S. Theja Institute of Dental Sciences. Thirty freshly extracted human single rooted, maxillary anterior teeth were selected (Fig 1). Samples with immature apical foramina, endodontic treatment, non-carious cervical lesions, or root fracture were excluded. All samples were rinsed with tap water and stored in neutral-buffered formalin solution until further use. Soft tissues and dental calculus were removed by hand with a periodontal scaler.

Fig 1: 30 Extracted Human Maxillary Anterior Teeth

A conventional access cavity was prepared and a size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the canal until the file tip reached apical foramen (Fig2), to establish apical patency. The working length was registered as 0.5mm shorter than the foramen. The canals were instrumented with size 15 and size 20 hand K files and were further instrumented with ProTaper rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) according to manufacturer's instructions; the final instrument was F3 file(Fig3). Pulp chamber and root canals were filled with irrigating solution during canal instrumentation. The canals were flushed with 3ml of 3% sodium hypochlorite solution between instruments. After instrumentation, 5ml of 3% sodium hypochlorite and 5ml of 17% ethylenediaminetetraacetic acid (EDTA) solution was used to irrigate the canal for 3 min as the final rinse. The irrigation solution in the pulp chamber was aspirated and the canals were dried with paper points.

Fig 2 Working length determination with 15k file.

Fig 3 Biomechanical preparation done upto Protaper F3

Sterile Ca(OH)2 is a radiopaque, water-soluble root canal medicament. India ink(Fig4a) was mixed with this calcium hydroxide paste (Fig4b) to give a contrast color to the paste which helps in evaluation during clearing teeth technique; calcium hydroxide paste mixed with India ink was filled into root canal. until paste was extruded from the apical foramen. Lentulo spirals (Dentsply Maillefer) were used to pack the slurry into the canals (Fig 4c). A cotton pellet was placed over Ca(OH)2 paste and the coronal access cavities were sealed with temporary restoration. Nail varnish was applied to the root tips of all the samples and they were randomly divided into three groups (Fig5).

Fig 4a India ink

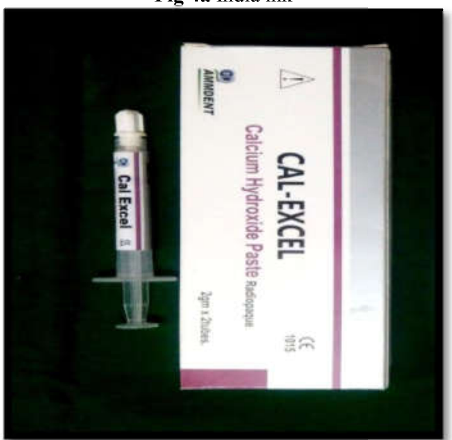


Fig 4b Calcium hydroxide paste (CAL-EXCEL)

Fig 4c Calcium hydroxide mixed with India ink filled in the root canal with lentulospiral

Fig 5 Nail varnish applied and divided into 3 groups

Group 1: Conventional needle irrigation

Group 2: Ultrasonic irrigation

Group 3: Sonic irrigation with Endoactivator

Later all the samples were stored at 37ºC and 100% humidity for 1 week.

After one week, the temporary restorations were removed in all the samples and were then subjected to three types of irrigation protocol for calcium hydroxide removal.

Group 1: Conventional needle irrigation (Fig6)

Each root canal was irrigated with 6ml of 3% NaOCl solution for 60 sec using a 30-gauge blunt-tip needle (Ultradent, South Jordan, UT) situated 1mm short of the working length. Irrigating solution was delivered at a flow rate of 6 ml/min.

Fig 6 Conventional needle irrigation

Group 2: Ultrasonic irrigation (Fig7)

Each root canal was irrigated with a stainless steel, noncutting, and ultrasonic Irri Safe size 20 file mounted on a Suprasson Newtron XS ultrasonic unit. The root canal was filled with 2mL of 3% NaOCl solution then the file was inserted passively 2 mm short of the working length and was activated for a period of 20 seconds using a power setting of five. The procedure was repeated three times.

Fig 7 Ultrasonic Irrigation

Group 3: Sonic Irrigation with Endoactivator (Fig8)

Each root canal was irrigated with EndoActivator for 60 sec (setting: headpieces 10,000 cycles per min). A sonic tip (size 25, taper 0.04) was inserted into the canal and agitated 2mm short of the working length without touching the walls. The root canal was filled with 2ml of 3% NaOCl, and then activated by EndoActivator for 20 sec. The procedure was repeated three times.

Fig 8 Sonic Irrigation With Endoactivator

After the process of irrigation, the root canals were dried, cotton pellet placed and the access cavities were filled with Glass Ionomer Cement. All the samples were now subjected to the process of clearing (Fig9).

Fig 9 Materials for Clearing the Teeth

Fig 10 Samples cleared and stored in methyl salicylate

Teeth were immersed in 5% nitric acid for 36 hours, for decalcification, with the solution being replenished every 8 hours. After completion of decalcification, the teeth were cleaned under tap water for 3 minutes, to remove any traces of acid, if present. Samples were then dehydrated by subjecting to 80% isopropyl alcohol for 12 hours followed by 90% for 1 hour and 99.9% for 3hours with solution being changed every 1hour. Finally they were cleared and stored in 99.9% methyl salicylate until analysis (Fig 10).

All the cleared specimens (Fig11) were observed under stereomicroscope at 30X magnification with eye piece lens 10X and objective lens 3X. Samples were scored based on amount of calcium hydroxide remaining in the root canal. All samples were scored by two trained evaluators who were blinded for group assignment pertaining to each sample.

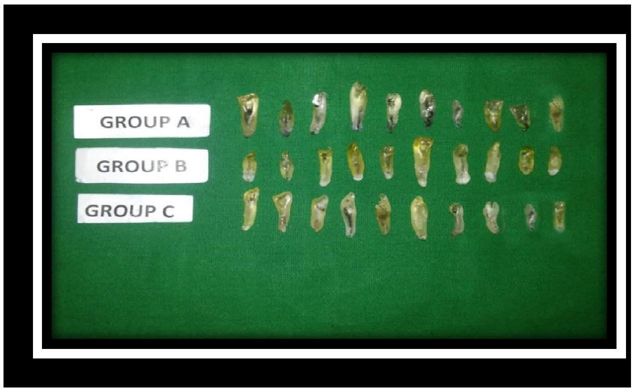


Fig 11 Samples after clearing the teeth

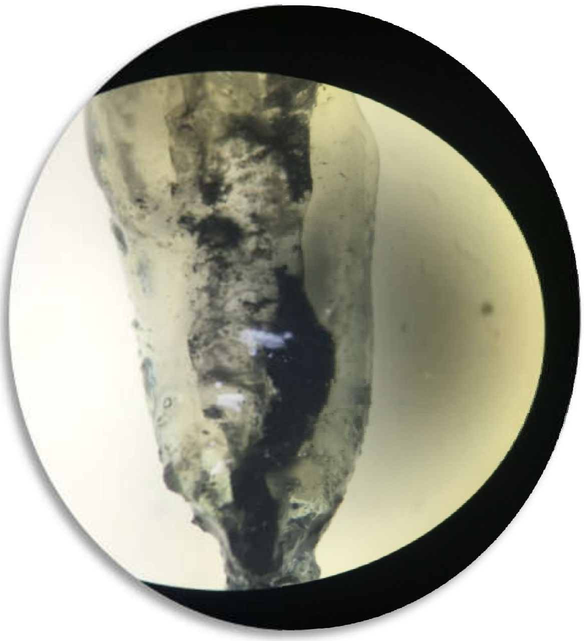


Fig 12 Stereomicroscopic image after Conventional Needle irrigation

The scoring criteria were as follows

0- Complete Ca[OH]2 removed from the entire canal
1- Ca[OH]2 remaining in one part of the root canal
2- Ca[OH]2 remaining in two parts of the root canal
3-Ca[OH]2 remaining in three or more parts of the root canal.

Fig 13 Stereomicroscopic image after Ultrasonic Irrigation

Fig 14 Stereomicroscopic image after Sonic Irrigation

Statistical analysis

All the analysis was done using SPSS version 18. A p-value of <0.05 was considered statistically significant. Comparison of amount of calcium hydroxide remaining among the study groups was done using Mann-Whitney U test and Kruskal-Wallis tests.

RESULTS

Results have shown that none of the groups were able to completely remove the $Ca(OH)_2$ dressing from the root canal. However a statistically significant difference (p<.001) was seen among the groups using Kruskal – Wallis test.

The Ultrasonic irrigation group (group 2) (Fig 13) was better in removing Ca(OH)2 from the root canal compared to conventional needle irrigation (group 1) (Fig 12) and sonic irrigation with Endoactivator (group 3) (Fig 14). Sonic irrigation with Endoactivator group (group 3) was also significantly better in removing $Ca(OH)_2$ from the root canal compared to conventional needle irrigation(p=0.013). However, there was no significant difference in the amount of $Ca(OH)_2$ removed from the root canal between Ultrasonic irrigation and sonic irrigation with Endoactivator (p=0.33).

Table 1 Comparison of Amount of $Ca(OH)_2$ Remaining In Group 1 and Group 2

Group	N	Mean Rank	Sum Of Ranks	Mann-Whitney U Test	Wilcoxon W	Z	P-Value
Group 1	10	14	140				
Group 2	10	7	70				
Total	20			15	70	-2.737	0.006

Inference of Table 1

Mann-Whitney U test was done to compare the amount of calcium hydroxide removed from the root canals between group 1(Needle irrigation) and group 2(Ultrasonic irrigation). There was significant difference among the groups, with group 2 being better able to remove the $Ca(OH)_2$ than needle irrigation(p=0.006; statistically significant).

Table 2 Comparison of the Amount of Calcium Hydroxide Remaining In Group 1 and Group 3

Group	N	Mean Rank	Sum Of Ranks	Mann-Whitney U Test	Wilcoxon W	Z	P-Value
Group 1	10	13.7	137				
Group 3	10	7.3	73	18	73	-2.471	0.013
Total	20						

Inference of Table 2

In this table, group 1(Needle irrigation) was compared with group 3(Sonic irrigation). Group 3 was better able to remove the calcium hydroxide from the root canals than needle irrigation with statiatically significant difference(p=0.013; statistically significant).

Table 3 Comparison of the Amount of Calcium Hydroxide Remaining In Group 2 and Group 3

Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U Test	Wilcoxon W	Z	P-Value
Group 2	10	9.25	92.5				
Group 3	10	11.75	117.5	37.5	92.5	-0.973	0.33
Total	20						

Inference of Table 3

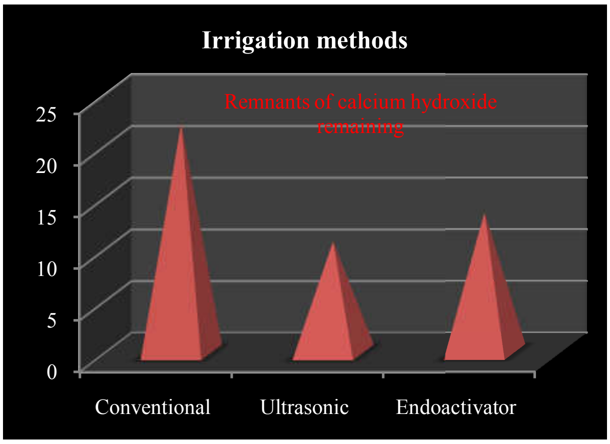
In this table, group 2 (Ultrasonic group) was compared with group 3(Sonic irrigation). Group 2 was better able to remove calcium hydroxide from the root canals than the sonic irrigation but there was no significant difference between the two groups(p=0.33;not significant).

Table 4 Comparison of The Amount of Calcium Hydroxide Remaining In Group 1, Group 2 and Group 3

Group	N	Mean Rank	Chi-square test	df	P-Value
Group 1	10	22.2			
Group 2	10	10.75	9.527	2	0.009
Group 3	10	13.55			

Inference of Table 4 and Graph 4

Kruskal-Wallis test was done to compare the amount of calcium hydroxide remaining in all the groups. There was least amount of calcium hydroxide remained in ultrasonic group, followed by sonic irrigation group and highest amount of calcium hydroxide remaining was observed in needle irrigation group.



Graph 1 Comparison of Amount of Calcium Hydroxide Remaining In Group1, Group 2 And Group 3.

DISCUSSION

One of the goals of root canal treatment is elimination of bacteria and their by-products from the root canal system. $Ca(OH)_2$ has been established as the most frequently used intracanal medicament because of its antimicrobial efficacy against most bacterial species identified in endodontic infections (Byström *et al.* 1985, Kawashima *et al.* 2009). Intracanal medicaments should be removed completely from root canals to avoid negative effects on sealer penetration. However, it is difficult to remove completely Ca(OH)2 from the root canal using conventional methods. Therefore, in the present study sonic and ultrasonic activation was used to remove $Ca(OH)_2$ from the straight root canals along with conventional needle irrigation.

The main finding of this study was that ultrasonic irrigation was statistically superior to sonic and conventional needle irrigation techniques in removing the $Ca(OH)_2$. Therefore, the null hypothesis which states that there is no difference between various techniques is rejected. In the present study, the techniques were compared in straight root canals and further studies should be conducted to evaluate the effectiveness of the techniques in curved root canals.

Ultrasonics usage to activate irrigant in the canal has shown to be a clinically proven and efficient adjunct to cleaning and shaping instrument sequences and is used by many endodontic specialists. Ultrasonic activation of irrigants produces 2 helpful effects: 1. Cavitation, defined as the formation of thousands of tiny bubbles which rapidly implode, producing a "shock wave" removing biofilm. 2. Acoustic streaming which produces shear forces that will help extricate debris from instrumented canals. Irrisafe file resembles a K-type file and has thin parallel tip with non-cutting, rounded flutes. These flutes affect acoustic streaming, but does not engage the dentin or transport the canal.[8]

Activation of the irrigant in the ultrasonic system has been shown to be more effective than syringe irrigation in removing $Ca(OH)_2$ from the root canal walls (Maalouf *et al.* 2013, Yucel *et al.* 2013). As mentioned above, in the present study, ultrasonic irrigation was superior to needle irrigation.

Studies have shown that the amount of debris was significantly less in Passive Ultrasonic Irrigation(PUI) irrigated root canals than in hand irrigated root canals. For PUI irrigated canals the amount of debris was 95% less than in untreated canals and for hand irrigated canals the amount of debris was 67% less than in untreated canals.[8] Lee *et al* (2004a) reported that ultrasonic irrigation removed debris more effectively from the grooves, whereas less debris remained in the depressions after syringe irrigation.[9] These studies were in accordance to our present study where ultrasonic irrigation (group 2) left significantly less amount of $Ca(OH)_2$ than the conventional needle irrigation(group1).

In group 3 the sonic activation of the irrigant with Endoactivator has been used. The results show that sonic activation is superior to needle irrigation but inferior to ultrasonic activation. These results were in accordance with reports of other studies by Castelo-Baz *et al.*, Spoorthy *et al.*, de Gregorio. Jiang *et al.* (2010) reported that no cavitation seemed to take place either on the sonic tip itself or on the wall of the glass model of the root canal. They explained this by the velocity of the sonic tip which was below the threshold needed for cavitation. Recently, Macedo *et al.* (2013) confirmed this result. The ineffectiveness of sonic irrigation could result from its inability to create cavitation.

Dongxia Li *et al* in 2015 reported that Needle, EndoActivaton and Ultrasonic irrigation all effectively removed Ca(OH)2 from the coronal and middle thirds of the root canal. However, in the apical third, the Ultrasonic groups had significantly higher $Ca(OH)_2$-removal percentages than did the EndoActivator and needle groups. The higher efficacy of ultrasonic irrigation likely resulted from transmission of ultrasonic energy to the irrigant, producing high shear stress in the root canal system.[10]

In contrast, needle irrigation and EndoActivator did not clean the apical third or the isthmus areas effectively, even when their tips were placed close to the root apex. It has been reported that trapped air in the apical area does not create a vapor lock and block, which prevents fluid movement and exchange.[11] Unlike Ultrasonic irrigation, needle or EndoActivator irrigation can produce adequate fluid movement to suck air from the apical region or destroy the dead block. Furthermore, the needle delivers irrigants no further than 1mm beyond the needle tip, and therefore the apical third is inaccessible for flushing.[12,13] EndoActivator, delivering insufficient volume of irrigants to the apical area and lacking cavitation, resulted in low efficiency of Ca(OH)2 removal. Therefore, in our present study, ultrasonic irrigation was better able to remove the Ca(OH)2 than the sonic irrigation and conventional needle irrigation.[14,15]

Thus, the results of our present study indicate that ultrasonic irrigation was better able to remove the $Ca(OH)_2$ from the root canal as compared to sonic irrigation and needle irrigation but there was no statistically significant difference between ultrasonic and sonic irrigation. However, complete removal of $Ca(OH)_2$ from the root canal walls could not be achieved regardless of the removal technique; further studies should be undertaken with other techniques of root canal irrigation to evaluate the complete removal of intracanal dressing from the root canal walls.

CONCLUSION

- Ultrasonic irrigation could significantly remove better Ca[OH]2 from the root canal compared to standard needle irrigation and sonic irrigation
- Ultrasonic irrigation and sonic irrigation were significantly better in removing $Ca(OH)_2$ from the root canal compared to needle irrigation.
- There was no significant difference between ultrasonic and sonic irrigation when they both were compared.

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