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An Invitro comparison of removal efficiency of Calcium hydroxide delivered by different vehicles: A volumetric analysis using Cone Beam Computed Tomography

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Abstract

Introduction: This study evaluated and compared the removal efficiency of Calcium hydroxide ($Ca(OH)_2$) delivered by different vehicles using volumetric analysis.

Methods: The root canals of 42 human teeth with single canals were prepared up to size 25/0.06. Three groups were established according to the vehicles used to deliver $Ca(OH)_2$: Group-1, distilled water; Group-2, propylene glycol; Group-3, silicone oil. After seven days of storage at 37^{0}C and 100% humidity, samples were further divided into two sub-groups (n =7), based on the removal techniques employed: Manual irrigation and rotary instrumentation (Xp-Endo Finisher) with 5ml sodium hypochlorite (NaOCl) 5.25% as irrigant. Volumetric analysis was done utilizing cone beam-computed tomography (CBCT) twice, first after the placement of $Ca(OH)_2$ and then following its removal. Data was analyzed using Kruskal-Wallis test and Mann-Whitney test.

Results: Both removal techniques failed to completely remove $Ca(OH)_2$ from the root canals. Xp-Endo Finisher was significantly effective in removal of $Ca(OH)_2$ when compared to manual irrigation ($p<0.05$). Oil based $Ca(OH)_2$ was more difficult to remove than aqueous or viscous based $Ca(OH)_2$ ($p<0.05$).

Conclusion: Vehicle used to prepare intracanal medicament influences its retrieval. Combination of rotary instrumentation and irrigation results in lower amount of $Ca(OH)_2$ remnants irrespective of the type of vehicle present in the mix.

Keywords: Calcium hydroxide, CBCT, Intracanal medicament, Retrieval, Vehicles, Volumetric analysis.

Introduction

Oral cavity exhibits a complex microbial ecosystem which consists of over 700 bacterial species, classified into 11 divisions. Infected root canals share this complex microbial system and exhibits a unique niche for the development and multiplication of selective species of microorganisms playing a unique role in the development of apical periodontitis [1-3]. Since the introduction of $Ca(OH)_2$ by Hermann (1920), this intracanal medicament has been indicated to promote healing in many clinical situations, owing to its good antimicrobial properties and biocompatibility [4-6].

Although the overall mechanism of action of $Ca(OH)_2$ is not fully understood, many articles have been published highlighting its biological properties which are achieved by its dissociation into Ca^{2+} and OH^- ions. Its antibacterial efficacy is also influenced by the type of vehicle used for mixing, because it determines the velocity of ionic dissociation causing the paste to be solubilized and resorbed at various rates [7-8].

Before obturating the canal complete removal of $Ca(OH)_2$ is mandatory, since residual $Ca(OH)_2$ may cause failure of the root canal treatment [Rirruci et al., 1997 and Windley et al., 1997]. Clinical cases have shown that residual $Ca(OH)_2$ will affect the bond strength between the filling material, dentin and compromise the interfacial seal [9-11]. Finally, the solubility of $Ca(OH)_2$ in tissue fluids may, in the long term, leave voids in the filling/dentin interface that might favor bacterial proliferation [Ricucci & Langeland 1997, Schilder 2006].

The complete removal of $Ca(OH)_2$ is critical and can be accomplished via rotary, sonic & ultrasonic, canal brush etc. when aided by various irrigating agents including NaOCl, EDTA, their combination, maleic acid etc.[12-18]. Rotary instrumentation and ultrasonic were found to be better than other techniques [Kenee et al., 2006] [19].

The Xp-Endo Finisher (FKG Dentaire. La-Chaux-de-Fonds, Switzerland) is a size 25 non tapered nickel-titanium (Ni-Ti) instrument. It is made of proprietary thermo-mechanically treated Ni-Ti alloy named Max-Wire (Martensite-Austenite-electropolish-fileX). These are relatively straight in their M phase (martensitic phase) at room temperature; they change to a curved shape when exposed to intracanal temperature because of a phase transformation to A phase (austenitic phase). This phase transformation allows the instrument to expand to 6 mm in diameter when rotated [20-22].

The present study aimed to compare the removal efficiency of $Ca(OH)_2$ delivered by different vehicles. The volume of $Ca(OH)_2$ was analyzed using CBCT.

Materials And Methods

A total of 42 uniradicular teeth were used, after being selected and standardized by means of conventional radiographic analysis. Teeth that had more than one canal, incompletely formed apices or any pathological alterations were excluded from the study. After this stage of sample selection, the selected teeth were stored and surfaced - adhering to infection control protocol.

After preparation of the access cavity, the root canal was explored using ISO size 10 K-file (Dentsply, Mailiefer, Ballaigues, Switzerland), until the instrument reached the apical foramen; subsequently 1 mm was subtracted thus obtaining the working length with the aid of radiographs. Chemo-mechanical preparation was performed with

ProTaper files (Dentsply, Mailiefer, Ballaigues, Switzerland) up to size 25/0.06, with 2ml of 2.5% NaOCl followed by 2ml of 17% EDTA; final irrigation with 5ml of distilled water and then dried with absorbent paper points.

Three formulations of $Ca(OH)_2$ with different vehicles were selected. The samples were divided into three groups of 14 teeth each;

Group 1: Chemically pure $Ca(OH)_2$ (Deepti Pvt.Ltd, Maharashtra, India) + barium sulphate in the ratio of 1:4 (1-part barium sulphate and 4 parts $Ca(OH)_2$), + distilled water (aqueous vehicle) in a 1:1 ratio.

Group 2: Chemically pure $Ca(OH)_2$ + barium sulphate in the ratio of 1:4 (1-part barium sulphate and 4 parts $Ca(OH)_2$), + propylene glycol (viscous vehicle) in a 1:1 ratio.

Group 3: Metapex (Meta Biomed, Korea), a commercially available product, which is composed of $Ca(OH)_2$, silicone oil (oily vehicle) and iodoform.

Intracanal medicament was placed into the canal space until the excess material extruded through the apex, which was wiped off with moist cotton. Access cavities were temporarily sealed with a cotton pellet and Cavit-G (3M ESPE). Radiographs were taken to check the placement till the apex of the tooth, subsequently they were mounted in modelling wax for the purpose of CBCT. Teeth were then stored at 37℃ and 100% relative humidity for 7 days.

After CBCT imaging, the 3D object of filled material in each tooth was automatically created in the form of masks by growing a threshold region on the entire stack of scans using Mimics 15.0 and 3 - Matic 13.0 software (Materialise, Belgium) and the initial volumes (V_i) were estimated in mm^3 (1 mm^3 equals to 1e-9 m^3).

Experimental groups

The samples in each group were then randomly divided into two subgroups (n=7) on the basis of irrigation protocol used for removal.

Sub-group A: Manual irrigation using 5mL of 5.25% NaOCl with 27G closed-end single-side vented needle (Prime Dental Products Pvt. Ltd, Maharashtra, India).

Sub-group B: Rotary instrumentation with the Xp-Endo Finisher at a speed of 1000 rpm and a maximum torque of 1 Ncm (as recommended by manufacturer) using the X-Smart endodontic rotary motor (Dentsply, Mailiefer, Ballaigues, Switzerland), placed till the working length using 5mL of 5.25% NaOCl with 27G closed-end single-side vented needle.

A second CBCT was taken and the volume of residual material (V_r) in each tooth was estimated as before.

Mann-Whitney test was used to compare mean residual values between the three groups (Table 1) while Kruskal-Wallis test was used to compare the mean residual volumes between the subgroups (Table 2 and 3)

Results

In the statistical analysis, the initial volume (V_i) of the canals was shown to present no significant difference among the groups (Table 1) ($p>0.05$).

There was a significant difference ($p<0.05$) between the residual volumes when comparison was done between the subgroup A (manual irrigation) and B (Xp-Endo Finisher) of the three groups (Table 2 and 3).

According to the results obtained as seen in figure 1, oil based $Ca(OH)_2$ was more difficult to remove than powdered form of $Ca(OH)_2$ mixed with aqueous or viscous vehicles ($p<0.05$).

Xp-Endo Finisher was highly effective in removal of $Ca(OH)_2$ when compared to manual irrigation ($p<0.05$), it successfully removed complete $Ca(OH)_2$ from three samples in this study (2- aqueous medium; 1- viscous medium).

Discussion

Root canal dressing plays a fundamental role in obtaining antisepsis of root canals (Kakehashi et al., 1965; Siqueira & de Uzeda, 1996; Safavi et al., 1990; Saatchi et al., 2014; Sjögren et al., 1991; Gomes et al., 2002), however, its permanence on the root canal walls may compromise the adaptation of filling cement or its flow into the anatomically complex areas, and consequently, the quality of a hermetic seal (Vilela et al., 2011; Çalt & Serper, 1999; Nandini et al., 2006; Jorge et al., 2015). $Ca(OH)_2$ was chosen for this study as it's the most frequently used intracanal medicament. However, the vehicle's influence on the retrievability of $Ca(OH)_2$ is debatable. Therefore, three different types of vehicles were included in the study.

$Ca(OH)_2$ is a highly alkaline substance with a pH of 12.5 which is responsible for its bactericidal effects. It also has the ability to induce repair and stimulate hard tissue formation. Optimum duration of medication has been proposed to be 1-4 weeks according to the vehicle used (Siqueira & Lopes, 1999), prolonged period off which may lead to resorption and increased susceptibility of tooth fracture [23-27].

In general, three types of vehicles are used: aqueous, viscous or oily (Fava 1991, Holland 1994, Lopes et al., 1996). When calcium hydroxide is mixed with one of these vehicles, Ca^{2+} and OH^- are rapidly released. The diffusion of the paste within the tissues is directly proportional to the solubility of the vehicle [7,28,29]. Clinical situations that need rapid ionic, gradual and uniform ionic and very slow ionic dissociation require the use of aqueous, viscous and oily vehicles respectively. Since oily vehicles have least solubility whereas aqueous has the highest, it leads to multiple dressings when aqueous medium is used [7,30].

The effectiveness of calcium hydroxide as an intracanal medicament is enhanced owing to an alkaline pH and decreased surface tension. Since oily vehicles have the highest surface tension, it's the most difficult to retrieve from the canal [31,32]. Hence, a better clinical judgment based on scientific evidence, personal experience in dentistry, and statements from previous dentists, should be used to ensure that all possible risks are minimized.

Calcium hydroxide mixed with any vehicle lacks radiopacity, for which radiopaque materials are added to the paste like barium sulphate, bismuth oxide and compounds containing iodine and bromine (Alacam et al., 1990) in a proportion of 1:4 (Dumsha & Gutmann, 1985). Since this is an in vitro study, a proportion of 1:4 was followed. However, from a clinical standpoint, a proportion of 1:8 (1-part barium sulphate and 8 parts $Ca(OH)_2$) is suggested owing to the toxicity of bismuth and barium salts (Marais, 1996) [7,33].

This study used 5.25% NaOCl + 17% EDTA for the irrigation protocol with the goal of eliminating the smear layer, debris, soft tissue and disinfection of the canal. When the specimens were analyzed, the subgroups which received agitation with Xp-Endo Finisher in comparison with manual irrigation showed least residual volume. The possible explanation for the improved results would be that this method promotes a mechanical effect of agitation of the irrigant solution, causing it to splash up against the canal walls, favoring an improved removal of the root canal dressing.

Within the limitations of this study, it can be concluded that:

- Vehicle used to prepare $Ca(OH)_2$ influences its retrieval. Aqueous-based was found easier to be removed than viscous and oil-based $Ca(OH)_2$.

- Manual and rotary instrumentation techniques investigated in this study were unable to completely remove the calcium hydroxide from all the specimens.
- While Xp-Endo Finisher was more efficient in removing the $Ca(OH)_2$ from the apical thirds of few specimens, incidence of residual volumes was seen in most of the canals.
- Further studies have to be conducted to evaluate the removal of calcium hydroxide from root canals successfully.

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Legend Table and Figures

Groups			Mean	Standard Deviation	Mean diff	P value
Group 1	Vi	G1A	315.45	21.71	-30.48	0.56
		G1B	345.93	76.92		
	Vr	G1A	92.93	8.79	84.31	0.002*
		G1B	8.62	6.82		
Group 2	Vi	G1A	303.40	32.97	-4.03	0.84
		G1B	307.43	17.26		
	Vr	G1A	104.33	11.53	91.27	0.002*
		G1B	13.06	6.91		
Group 3	Vi	G1A	299.09	50.57	-23.74	0.40
		G1B	322.84	41.86		
	Vr	G1A	167.66	28.21	121.70	0.002*
		G1B	45.95	13.51		

Table 1: Comparison of the mean values using Mann-Whitney test (subgroup A and B)

Groups	Minimum	Maximum	Mean	Standard Deviation	Kruskal-Wallis	P value
Group 1A	75.84	103.50	92.93	8.79	14.92	0.001*
Group 2A	90.35	124.54	104.33	11.53		
Group 3A	127.48	211.01	167.66	28.21		

*significant

Table 2: Comparison of the mean residual volume (Vr) using Kruskal-Wallis test (subgroup A)

Groups	Minimum	Maximum	Mean	Standard Deviation	kruskal-wallis	P value
Group 1B	.00	17.20	8.62	6.82	14.07	0.001*
Group 2B	.00	20.97	13.06	6.91		
Group 3B	33.81	72.11	45.95	13.51		

Table 3: Comparison of the mean residual volume (Vr) using Kruskal-Wallis test (subgroup B)

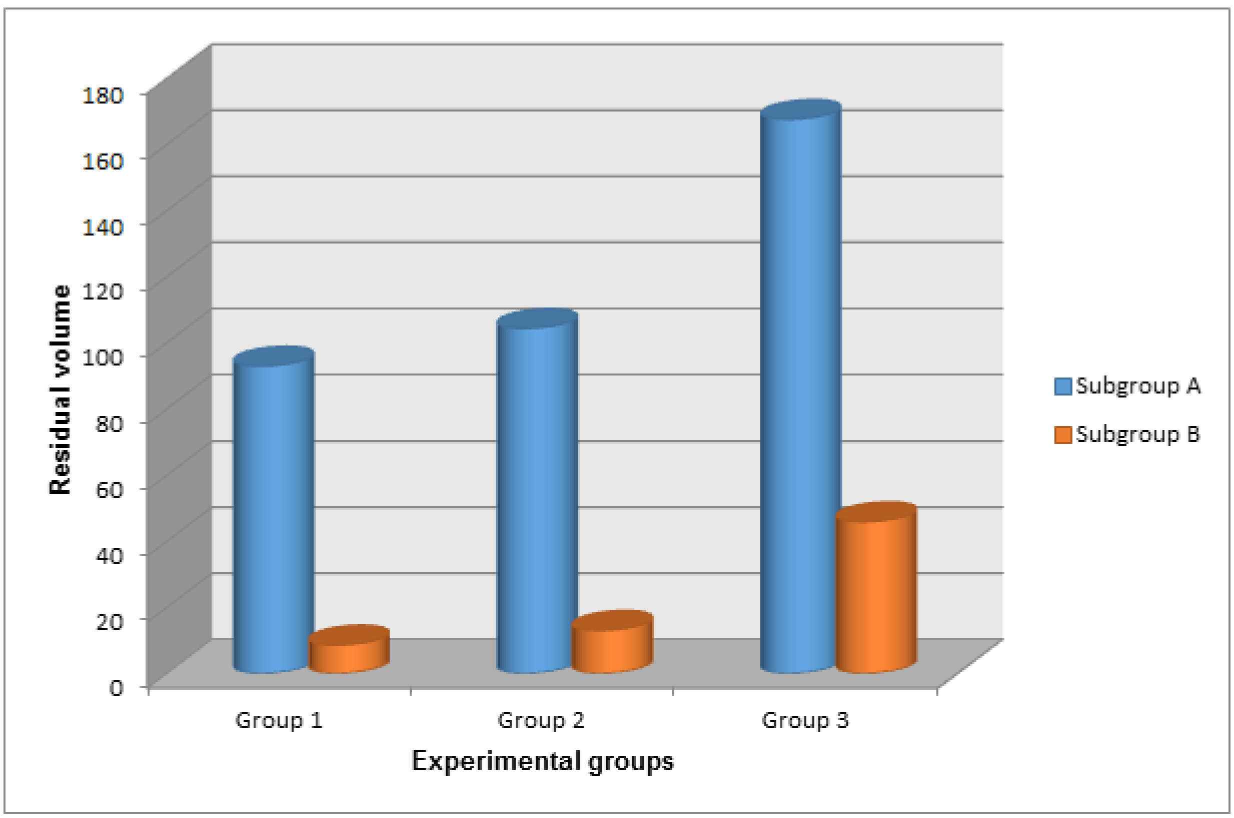

Figure 1: Graphical representation of comparison of residual volume between the groups (subgroup A and B)-Vr