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Comparative Evaluation of Four Irrigating Solutions for the Removal of Calcium Hydroxide from Root Canal Walls: An In Vitro Study

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ABSTRACT

Introduction: Calcium hydroxide [$Ca(OH)_2$] is widely used as an intracanal medicament due to its antimicrobial properties, but its remnants may compromise root canal sealing. This study compared the effectiveness of four irrigating solutions—3% sodium hypochlorite (NaOCl), 17% ethylenediaminetetraacetic acid (EDTA), saline, and MTAD—for $Ca(OH)_2$ removal using passive ultrasonic irrigation (PUI).

Methods: Forty single-rooted human premolars were decoronated and prepared using the ProTaper Universal system. $Ca(OH)_2$ was placed for 7 days. Teeth were divided into four groups (n=10) based on final irrigant: NaOCl, EDTA, MTAD, and saline. Each irrigant was activated with PUI. Roots were split and examined under a stereomicroscope. Residual $Ca(OH)_2$ was scored (0–5) based on surface coverage. Data were analyzed using ANOVA and Tukey's post hoc tests ($p<0.05$).

Results: EDTA achieved the lowest mean score (1.08), indicating superior removal, followed by MTAD (2.71). NaOCl and saline were least effective (mean 4.00). Statistically significant differences were found among groups ($p<0.05$), especially in the apical third.

Conclusions: 17% EDTA was the most effective solution for $Ca(OH)_2$ removal when combined with PUI. MTAD showed moderate efficacy, while NaOCl and saline were significantly less effective

Keyword: Calcium hydroxide, passive ultrasonic irrigation, root canal therapy.

1. INTRODUCTION

Calcium hydroxide is widely used as an intracanal medicament in endodontics due to its antimicrobial properties and its ability to promote the healing of periapical tissues [1,2]. However, the residues left on canal walls can impede the penetration and sealing efficiency of root canal sealers, which may compromise the overall success of the treatment [3,4,5]. Thus, it is essential to thoroughly remove Ca $(OH)_2$ before the obturation process. Sodium hypochlorite (NaOCl) is a key agent in endodontic irrigation, valued for its tissue-dissolving and antimicrobial properties. However, it is not effective in removing calcium-based medicaments because it cannot chelate calcium ions [6,7]. EDTA is a well-established chelating agent that effectively removes inorganic debris and has shown promising results in eliminating Ca $(OH)_2$ residues [8,9]. MTAD, a combination of doxycycline, citric acid, and a detergent, not only provides chelation and smear layer removal but also offers additional antimicrobial benefits [10,11]. Saline is often used as a control in studies since it does not possess any active chemical cleaning properties [12]. In recent years, passive ultrasonic irrigation (PUI) has been introduced to enhance the efficacy of irrigants, particularly in challenging areas like the apical third of the canal, by improving the flow of irrigants and the effects of cavitation [13,14]. This study aims to evaluate the effectiveness of four different irrigants—NaOCl, EDTA, MTAD, and saline—in the removal of Ca $(OH)_2$ when activated with PUI.

2. MATERIALS AND METHODS

Sample Preparation

Forty extracted human premolars with single, straight canals were selected. Teeth with cracks, resorptive defects, or previous endodontic treatment were excluded. All samples were decoronated to standardize root length. The process of decoronation was executed utilizing a diamond disk, culminating in an overall length of 14 mm [Figure 1A].

The working length of the root canals was established to be 1 mm shorter than the apex, which was achieved using a #10 K-file for accurate measurement. Following this, the root canals were shaped with the ProTaper Universal rotary system, progressing to a maximum size of F3. The Crown Down Technique is employed to prepare root canals utilizing the Protaper Universal System to achieve optimal irrigation [Figure 1B]. Throughout the instrumentation process, the canals were continuously irrigated with a 3% sodium hypochlorite (NaOCl) solution to ensure effective cleaning and disinfection.

Calcium Hydroxide Placement

Following the initial preparation phase, the canals underwent a drying process before being filled with a paste composed of calcium hydroxide (Ca $(OH)_2$) mixed with saline solution [Figure 1C]. Once the filling was completed, the access cavities were securely sealed using Intermediate Restorative Material (IRM). The specimens were then stored for a period of seven days to allow for proper setting and stabilization. To ensure that there was no leakage during this time, the external surfaces of the roots were carefully coated with nail varnish, providing an additional layer of protection.

Grouping and Irrigation Protocol

Samples were randomly allocated into four groups (n=10) [Figure 1D] according to the final irrigant used:

Group 1: 3% NaOCl

Group 2: 17% EDTA

Group 3: MTAD

Group 4: Saline

Each group was administered 6 ml of the designated irrigant, which was activated through passive ultrasonic irrigation (PUI) for 1 minute [Figure 1E].

Evaluation of Ca $(OH)_2$ Removal

Roots were split longitudinally. Each half was observed under a stereomicroscope at 30X magnification [Figure 2F], and the presence of residual Ca $(OH)_2$ was scored:

0 = No residue

1 = 0–10%

2 = 11–25%

3 = 26–50%

4 = 51–75%

5 = 76–100%

Statistical Analysis

The data were analyzed using SPSS version 27, a statistical software package widely used for data management and analysis. To compare the different groups within the dataset, a one-way ANOVA was conducted, which is a statistical method used to determine if there are any statistically significant differences between the means of three or more independent groups. Following the ANOVA, Tukey's post hoc test was applied to identify which specific groups differed from each other. A p-value of less than 0.05 was considered to indicate statistical significance, meaning that there is less than a 5% probability that the observed differences occurred by chance.

Results

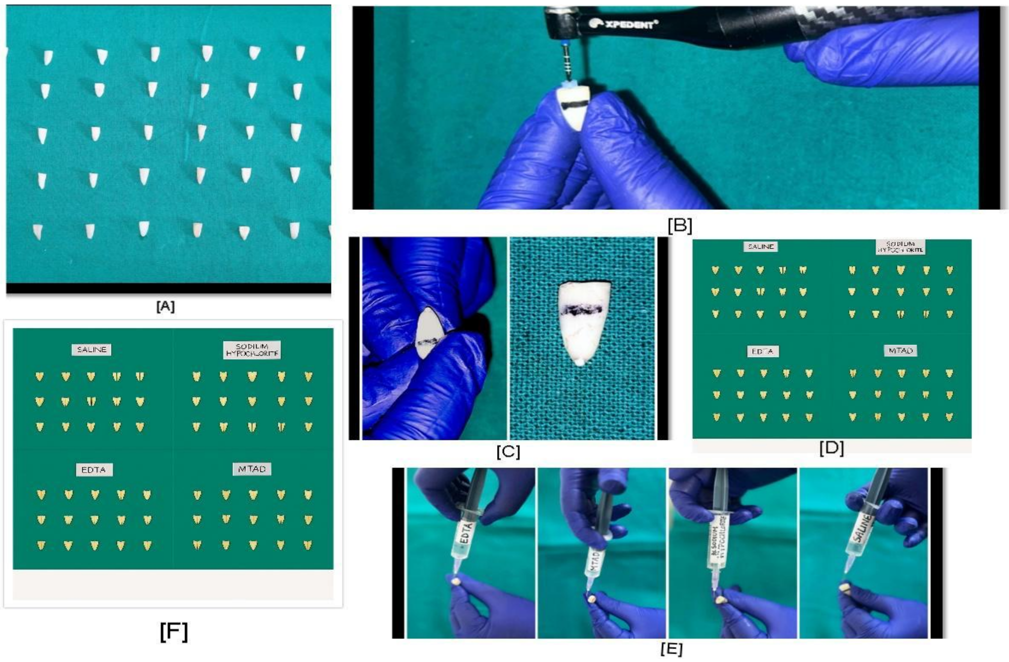
EDTA demonstrated the highest level of effectiveness in removing Ca $(OH)_2$, particularly in the coronal and middle thirds of the tooth structure [Figure 2 I]. In comparison, MTAD showed a moderate level of efficacy in this regard [Figure 2J]. On the other hand, both NaOCl and saline were found to be the least effective agents for this purpose [Figure 2G & 2H]. Furthermore, statistical analysis revealed significant differences in effectiveness among the various treatment groups, with a p-value of less than 0.05 indicating that the results were not due to chance. The subsequent analysis of the four groups, including their mean scores and residual calcium hydroxide levels, indicates that EDTA maintains the lowest residual, followed by MTAD, NaOCl, and saline [Table 1]. The apical third shows the highest residue (31–50%) with NaOCl/EDTA, the coronal third is best cleaned (≤20%) using EDTA/MTAD, and the middle third has intermediate residue (21–40%) with most irrigants [Table 2].

Table 1. Comprehensive evaluation of the Irrigant, including the average score and remaining $Ca(OH)_2$ (%)

Irrigant	Mean Score	Residual Ca $(OH)_2$ (%)
EDTA	1.08	3–10%
MTAD	2.71	29–50%
NaOCl	4.00	68–99%
Saline	4.00	89–99%

Table 2: Overall assessment of the sample size regarding the Residual coverage percentage, along with its interpretation

Canal Region	Residual Coverage (%)	Key Irrigants	Interpretation
Apical Third	31–50	NaOCl/EDTA	Highest residue
Coronal Third	≤20	EDTA/MTAD	Best cleaned
Middle Third	21–40	Most Irrigants	Intermediate residue



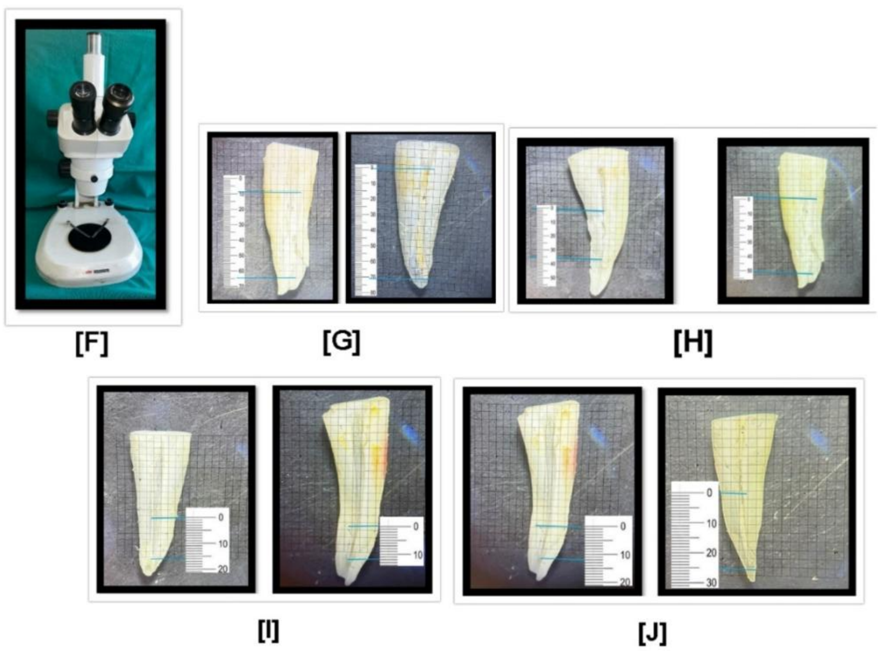
A: 40 Premolars decoronated and arranged

B: Biomechanical preparation done using densply protaper rotary file system.

C: Apical extrusion of calcium hydroxide

D: Premolars split longitudinally after placement of calcium   hydroxide before irrigation with irrigants

E: Premolars with EDTA, MTAD, Sodium hypochlorite and saline



F: Stereomicroscope

G:Resiual calcium hydroxide on the walls after irrigation with saline

H:Residual calcium hydroxide on the walls after irrigation with sodium hypochlorite

I:Residual calcium hydroxide on the walls after irrigation with MTAD.

J:Residual calcium hydroxide on the walls after irrigation with liquid EDTA.

3. DISCUSSION

The findings indicate that EDTA is considerably more efficient in eliminating Ca $(OH)_2$ from canal walls, probably because of its potent chelating properties and its demineralizing impact on dentin [8,9]. MTAD showed moderate effectiveness, aligning with its citric acid content and its detergent properties that improve penetration and the removal of the smear layer [10,11].

Sodium hypochlorite (NaOCl) is widely recognized for its antimicrobial properties and its ability to dissolve tissue. However, it has demonstrated a limited capacity to effectively eliminate inorganic calcium hydroxide (Ca $(OH)_2$) residues. This limitation arises from NaOCl inability to chelate, which is the process of binding metal ions. In the study, saline was employed as a control substance, and as anticipated, it exhibited the least effectiveness in removing these residues.

The apical third posed the most significant challenge for all groups, highlighting anatomical complexities that restrict irrigant flow and mechanical cleaning [14,16]. The application of PUI enhanced the effectiveness of the irrigant, probably because of improved acoustic streaming and cavitation, which is especially advantageous in constricted apical areas [13,17].

4. CONCLUSION

The present in vitro study provides a comprehensive comparison of four commonly used irrigating solutions—17% EDTA, MTAD, 3% sodium hypochlorite, and saline—for their effectiveness in removing calcium hydroxide from the root canal walls. The findings clearly indicate that 17% EDTA, when used in combination with passive ultrasonic activation, is significantly more effective than the other tested solutions in eliminating calcium hydroxide residues, particularly from the coronal and middle thirds of the canal, which is consistent with previous studies [6,7,8,15,17]. Although MTAD demonstrated moderate efficacy, neither sodium hypochlorite nor saline was able to achieve satisfactory removal, especially in the apical third where complete debridement is often most challenging [9,10,11].

These results underscore the importance of selecting appropriate irrigating agents and activation techniques to ensure thorough removal of intracanal medicaments prior to obturation. The superior performance of 17% EDTA highlights its value in clinical endodontic protocols, as residual calcium hydroxide may impair the sealing ability of root canal filling materials and compromise treatment outcomes [12,16,24]. Therefore, the adoption of sequential irrigation protocols that incorporate chelating agents like EDTA, along with activation methods such as passive ultrasonic irrigation, is strongly recommended for achieving optimal canal cleanliness [13,14,15,16].

In summary, this study supports the routine use of 17% EDTA as the irrigant of choice for the effective removal of calcium hydroxide from root canal walls. Implementing these findings into clinical practice can contribute to improved endodontic success rates by ensuring cleaner canals and better adaptation of obturating materials [6,7,8,19,20].

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