An examination of the effectiveness of removing Ca(OH)$_2$ residues from the apical third of root canal walls using three different techniques

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Abstract. Ca(OH)$_2$ residues on the root canal walls affect the quality of obturation. The aim of this study was to compare the effectiveness of three different methods in removing these residues. The root canals of 30 premolars were prepared using the ProTaper system. The Ca(OH)$_2$ paste was applied to the canal walls and left for 7 days. The samples were then divided into three groups, based on the method of removal of Ca(OH)$_2$, as follows: Group I (NaOCl-EDTA for irrigation), Group II (irrigation + Canal Brush), and Group III (irrigation + NiTi file). The samples were then bisected buccolingually, and the surface area of the residue was measured using a stereomicroscopy (12× magnification) and AxioCam. Results. The most effective method was found to be irrigation + Canal Brush, followed by groups III and I. However, these differences were not statistically significant (p < 0.05). Conclusion. In the Canal Brush in an effective way of removing (OH)$_2$ residues, although its efficacy was not significantly different from the other methods.

1. Introduction

Root canal treatments involve removal of all infected pulp tissues from the root canal, followed by restoration so as to prevent bacteria from re-entering [1]. The medicaments typically used for this type of treatment aim to prevent or inhibit the growth of micro-organisms between appointments, and therefore, must ideally meet the requirements of germicides and fungicides. Such agents must: a) be non-irritable to the periapical tissue, b) remain stable in a solution, c) exhibit antimicrobial effects, d) remain active even in the presence of blood, serum, or derivatives of tissue proteins, e) have low surface tension, f) do not interfere with periapical tissue repair, g) do not stain the tooth structure, h) remain inactive when placed in the culture medium, and i) do not induce an immune response between cells [2,3]. Calcium hydroxide is one such medicament that is widely used in root canal treatment as it exhibits antimicrobial activity, high alkalinity, and inhibition of tooth resorption [4-6].

Prior to restoration, the calcium hydroxide residues must be cleaned from the root canal walls as previous studies have reported that they may affect the success of the treatment by forming a cement adaptation barrier in the dentinal tubules and inducing a chemical reaction between the silica and calcium hydroxide [7,8]. Margelos et al. (1997) reported several problems associated with the interaction between calcium hydroxide and zinc oxide-eugenol syrup, whereas Kim et al. (2002) suggested that teeth treated using calcium hydroxide exhibited significantly greater apical leakage [8].
The calcium hydroxide may be removed from the root canals with the help of hand endodontic needles, sonic activation, irrigation materials, ultrasonic passives, root canal brushes, and nickel-titanium endodontic needles [9-12]. A combination of NaOCl and EDTA is commonly recommended as an irrigation material for cleaning the root canals as the former has antibacterial properties and can remove organic debris, whereas the latter is effective in removing inorganic debris. However, NaOCl is ineffective in removing the dentine powder coating produced during root canal instrumentation, whereas EDTA is incapable of removing organic debris [13,14].

The application of irrigation solution generally using syringe needle size 27G can only effectively release the irrigation fluid as far as 1 mm from the tip of the needle. This may cause problems as the needle tip only enters the coronal third of the root canal and fails to reach the middle third. Irrigation using EDTA and NaOCl solutions, applied using a size 27G Monoject syringe, produces effective solvent debridement in the coronal and middle thirds of the root canal but is less effective in the apical third [15,16].

Ruddle first introduced rotary brushes to facilitate removal of debris and the smear layer from prepared root canals. These devices usually comprise of a tapered arm and a brush and may also be used to clean residual calcium hydroxide medicaments [17]. Although hand endodontic needles with or without irrigation fluid can be used to remove calcium hydroxide from the root canal walls, their efficacy is considerably lower than that of the NiTi swivel instruments which provide better cleaning [18] A previous study reported that NiTi F1 ProTaper needles were more efficient at removing calcium hydroxide residues from the root canal whereas another study comparing three types of NiTi endodontic needles reported no significant differences between the needles with regard to efficacy cleaning the canals [16,19].

The aim of this study was to compare the efficacy of 2.5% NaOCl + 17% EDTA, root canal brushes, and NiTi endodontic needles in removing calcium hydroxide residues from the apical third of the root canal. Research in this area will allow identification of the best procedure for removing calcium hydroxide residues from the root canal walls, which, in turn, would lead to successful obturation of the canals, particularly in the apical third.

2. Methods

Random grouping was done to group teeth into three equals group. The root canals were prepared using the crown-down technique, which facilitated optimum irrigation that effectively removed the dentine powder produced during canal preparation [22]. The root canals of all teeth included in this study were first prepared using the ProTaper system (up to size F3), and then randomly allocated into one of three groups such that all groups were equal in size. Irrigation of the root canal was carried out using 5 ml of 17% EDTA and 5 ml of 2.5% NaOCl. Additionally, 2 ml of 2.5% NaOCl was applied using a 30-gauge needle between each round of irrigation. Thereafter, the root canals were dried, and calcium hydroxide was applied on the walls up to the apical orifice, which was temporarily covered. All samples were stored at room temperature for 7 days under damp conditions.

- **Group 1 (n = 10):** After 7 days, the calcium hydroxide medicaments were removed using 5 ml of 2.5% NaOCl + 5 ml of 17% EDTA, and the canals were rinsed using 5 ml of 2.5% NaOCl. The samples were temporarily closed prior to cleavage.
- **Group 2 (n = 10):** After 7 days, the calcium hydroxide medicaments were cleaned using 5 ml of 2.5% NaOCl + 5 ml of 17% EDTA, and then brushed using a Canal Brush at 600 rpm with circumferential movement for 30 s. The canals were then rinsed using 5 ml of 2.5% NaOCl, dried, and closed temporarily.
- **Group 3 (n = 10):** After 7 days, the calcium hydroxide medicaments were cleaned using 5 ml of 2.5% NaOCl + 5 ml of 17% EDTA, and then washed with NiTi Pro Taper F2 at 250 rpm with circumferential movement for 30 s. The canals were then rinsed using 5 ml of 2.5% NaOCl, dried, and closed temporarily.

The teeth were then vertically divided into 2 parts along the buccolingual plane, and one of the parts was randomly selected and examined using a stereomicroscope. The Ca(OH)₂ residue on the
walls of the root canal was quantified by measuring its surface area (in mm$^2$) at a point 4 mm coronal to the apex using the AXIOCAM program integrated in a stereomicroscope system (Figure 1).

![Figure 1](image-url)

**Figure 1.** (A) Surface residue of Ca(OH)$_2$ after cleaning with a CanalBrush. (B) Calculation of the surface area of residue in mm$^2$ using the AXIOCAM program.

### 3. Results

This study used the Shapiro–Wilk test to examine the data distribution as the sample size was <50. In case of normal distribution, the ANOVA test was used to compare the data on efficacy of calcium hydroxide removal between the three groups, while the Kruskal–Wallis test would be used for analysis if the data were not normally distributed. However, in this study, the Shapiro–Wilk test showed that the data were normally distributed ($p > 0.05$, Table 1), and the one-way ANOVA test was used to compare the three groups.

| Group | N  | Mean ± SD       | P*       |
|-------|----|-----------------|----------|
| P1    | 10 | 0.78 ± 0.365    | 0.535    |
| P2    | 10 | 0.68 ± 0.35     | 0.522    |
| P3    | 10 | 0.775 ± 0.489   | 0.062    |

Description: * Shapiro–Wilk normality test; $p > 0.05$

P1: Irrigation with 2.5% NaOCl + 17% EDTA
P2: Irrigation with 2.5% NaOCl + 17% EDTA + Root Brush
P3: Irrigation with 2.5% NaOCl + 17% EDTA + NiTi Endodontic Needles

| Group  | N  | Mean difference | 95% Confidence Interval | p*    |
|--------|----|-----------------|-------------------------|-------|
| P1 x P2| 10 | 0.1             | -0.2936 - 0.4936        | 0.805 |
| P1 x P3| 10 | 0.987           | -0.3886 - 0.3886        | 0.999 |
| P2 x P3| 10 | 0.887           | -0.2986 - 0.4886        | 0.822 |

Direction: *ANOVA; $p < 0.05$

Comparison of Group 1 (NaOCl 2.5% + EDTA 17%) and Group 2 (NaOCl 2.5% + EDTA 17% + root canal brush) showed a mean difference of 0.1 (minimum range: 0.2587–0.4936, $p = 0.805$) in the surface area of calcium hydroxide residue, whereas comparison of Group 1 (NaOCl 2.5% + EDTA 17%) and Group 3 (NaOCl 2.5% + EDTA 17% + NiTi ProTaper F2) showed no significant difference (mean difference: 0.987, range: -0.3886–0.3886, $p = 0.999$). Comparison of Group 2 (NaOCl 2.5% +
EDTA 17% + root canal brush) and Group 3 (NaOCl 2.5% + EDTA 17% + NiTi endodontic needle) showed a mean difference of 0.887 (minimum range: 0.2986–0.4886, p-value = 0.822) in the surface area of calcium hydroxide residue (Table 2).

4. Discussion

This study included lower mandibular premolars with single roots, which were confirmed using photo X-rays. The total sample size was 30, with each group containing 10 teeth. The tooth samples were stored in a saline solution so as to retain the dental moisture and maintain conditions that were similar to the oral cavity. The lengths of all teeth were measured visually up to the apical foramen using a K-file ISO 10, and a working length of 0.5 mm was then subtracted from this [20,21].

ProTapers are frequently used to clean and form the root canals as their progressive taper and cross-sectional convex, triangular, modified guiding tip allow easy adaptation to the crown-down technique [23,24] These rotary instruments produce uniform root canal preparation and require a minimum of two finishing files for the apical third of the root canal [25].

This study used 2.5% NaOCl + 17% EDTA for irrigation, and the goals of this step were to eliminate all debris and soft tissues from the root canals, lubricate and sterilize them, and eliminate the smear layer [26,27]. Sodium hypochlorite is one of irrigation material with reduction oxidation characteristics in the form of clear solution and contains about 5% chlorine [28]. EDTA serves as a chelating agent and attracts the metal ions chemically bound to calcium, thus improving chemomechanical cleansing during root canal treatments. It is particularly useful in case of calcified or narrow root canals and dentine degradation [29,30].

The non-setting calcium hydroxide (UltraCal XS) injection technique, which contained 35% calcium hydroxide in aquades and barium sulfate as a radio-opaque material, was used to apply Ca(OH)₂ to the root canals. Gibson et al. (2008) reported that the injection technique resulted in fillings with 74% density, and this was considerably better than the spiral filler technique which only produced 36% density [16,31]. The calcium hydroxide was left in the root canals for 7 days at 37°C and humidity levels similar to that of the oral cavity. This time day period was chosen as previous studies have suggested that this was the minimum amount of time necessary for calcium hydroxide to reach a pH of 9.3–10 [32].

Rirruci et al. (1997) and Windley et al. (1997) suggested that the presence of calcium hydroxide on the root canal walls may affect the success of the root canal treatment, [33,34] whereas Calt (1997) suggested that residual calcium hydroxide interacted with ZOE sealers resulting in calcium eugonolate that was soluble in certain conditions [7]. Barbizam et al. (2008) reported that the residual calcium hydroxide affected the adhesion of the sealer to the root canal wall, thus affecting the hermetic quality of the obturation [35].

Aside from being a root canal irrigation at the time of preparation of NaOCl and EDTA reused as a medicament cleaner of calcium hydroxide gave better results than using only NaOCl.[36,7] Prajogi (2007) reported that although using the 17% EDTA irrigation + NaOCl 2.5%, NaOCl 17% + As. The citrate 10% still shows residue left behind on the root canal wall. [20] This was similar to the current study where the use of 2.5% NaOCl + 17% EDTA alone did not produce significantly different results from those produced by Groups 2 or 3 (5% NaOCl + 17% EDTA with root canal brushes or NiTi endodontic needles). Tasdemir et al. (2011) also reported residual calcium hydroxide in all study samples, despite instrumentation using passive ultrasonic irrigation and CanalBrush [37].

However, the evidence on the use of CanalBrush as a calcium hydroxide medicament cleanser is still limited. This instrument was developed to be small and flexible, with the aim of assisting removal of debris from root canals following instrumentation in conjunction with irrigation fluids [16]. Kozak et al. (2009) reported that the CanalBrush appeared to exhibit slightly higher efficiency in cleansing calcium hydroxide residues compared with other techniques in artificial root canals. Moreover, it was also effective in cleaning narrow root canals through direct contact with the walls [38].

The results of this study showed that irrigation along with endodontic needles was more effective in cleaning the root canal walls compared with irrigation alone. Kuga et al. (2010) performed a medicinal
cleansing of calcium hydroxide carried out two different endodontic NiTi needles with preparation teeth until F2 ProTaper cleared using ProTaper F1 gave better results than K3 with the same tapering size as F2 [16]. Another study, also conducted by Kuga et al. (2012) reported no significant differences in the efficacy of removing calcium hydroxide residues between three different rotary endodontic needles [19]. In accordance with previous evidence, the current study also used the F2 ProTaper as a purge instrument, with the aim of aiding cleaning without affecting the final preparation form created by the F3 ProTaper [16].

This study showed that the root canal brushes were effective in cleaning the root canal tip as the calcium hydroxide residue had the least surface area compared with that produced by the NiTi ProTaper and 2.5% NaOCl irrigation + EDTA 17%, although this difference was not statistically significant. Root canal brushes used in this study used medium size with the same D₀ size with D₀ F3 ProTaper at the end of each sample. While the endodontic needle of NiTi used is smaller than D₀ final preparation is F2 with D₀ = 25.

5. Conclusion
In conclusion, stereomicroscopic examination of root canal wall cleaning using different techniques showed that irrigation using 2.5% NaOCl + 17% EDTA only left the largest surface area of calcium hydroxide residue, whereas irrigation along with instrumentation using brushes resulted in the smallest surface area of calcium hydroxide residue. However, this difference was not statistically significant.

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