Frontiers in Dentistry

Boosting Root-Canal Cleanliness: A Stereomicroscopic Study of Calcium Hydroxide Removal with a Gentlefile Finisher Brush and EDTA

Mohammad Ali Ketabi[1], Nafiseh Golshahi[2*], Babak Farzane[1], Ali Hassanzade Salmasi[1], Mohammad Mahdi Kiafar[1], Mohammad Naseri[1]

1.Department of Endodontics, Dental Faculty, AJA University of Medical Sciences, Tehran, Iran
2.Department of Endodontics, Dental Faculty, Kashan University of Medical Sciences, Kashan, Iran

Article Info

Article type:
Original Article

Article History:
Received: 02 Jul 2025
Accepted: 05 Jan 2026
Published: 06 Jul 2026

**** Corresponding author:***
Department of Endodontics, Dental Faculty, AJA University of Medical Sciences, Tehran, Iran

Email: nafise.gsh@gmail.com

A B S T R A C T

Objectives: Calcium hydroxide (CH) remnants in root canals can compromise root canal sealing, highlighting the need for effective removal techniques. This study assessed the efficacy of Gentlefile Finisher Brush (GB), in combination with ethylenediaminetetraacetic acid (EDTA), for CH removal by stereomicroscopic evaluation.

Materials and Methods: This in vitro study evaluated CH removal from 66 extracted single-rooted mandibular incisors. After canal preparation with ProTaper up to F2 and CH application, the specimens were incubated for 10 days and randomly divided into six groups on the basis of the irrigation method and instrument used: master apical file (MAF) or GB with saline or 17% EDTA (n=15 each) and positive and negative control groups (n=3 each). The CH was removed accordingly, and the teeth were longitudinally sectioned. The residual CH was quantified under a stereomicroscope at ×10 magnification using Digimizer software to compare the efficacy of different protocols. Data were analyzed using ANOVA and Tukey's test (alpha=0.05).

Results: The combination of GB with 17% EDTA resulted in the lowest residual CH (8.30%±6.29%) significantly outperforming all other protocols ($P<0.05$). MAF with saline resulted in the highest residue (52.27%±19.24%). The Tukey's post-hoc test confirmed that both the GB methods were significantly more effective than their MAF counterparts ($P<0.05$), while no significant difference was observed between the two MAF-based methods ($P>0.05$).

Conclusion: GB with 17% EDTA demonstrated superior efficacy in removing CH from root canals. These results highlight the importance of combining chelating irrigation with dynamic mechanical agitation to optimize intracanal cleanliness.

Keywords: Calcium Hydroxide; Dental Pulp Cavity; Root Canal Preparation; Root Canal Therapy

➢ **Cite this article as:** Ketabi MA, Golshahi N, Farzane B, Hassanzade Salmasi A, Kiafar MM, Naseri M. Boosting Root-Canal Cleanliness: A Stereomicroscopic Study of Calcium Hydroxide Removal with a Gentlefile Finisher Brush and EDTA. *Front Dent.* 2026:23:28. http://doi.org/10.18502/fid.v23i28.22718

INTRODUCTION

Root canal treatment is a complex dental procedure, and its success heavily relies on the thorough elimination of microorganisms from the root canal system (RCS) [1, 2]. Intracanal medicaments are commonly employed to disinfect the RCS and increase the likelihood of a successful outcome [3]. Calcium hydroxide (CH) is the most widely used intracanal medicament because of its bactericidal properties [4]. The antimicrobial effect of CH is attributed to the release of hydroxyl ions, which create a highly alkaline environment with a pH of 12.5, rendering it inhospitable for most bacteria [5]. Additionally, CH has been shown to reduce the levels of endotoxins, such as lipopolysaccharides, and significantly contribute to the healing of periapical lesions [6-8]. However, a systematic review by Saatchi et al. [5] revealed that combining CH with chlorhexidine did not improve its ex vivo antibacterial activity against Enterococcus faecalis. On the other hand, another systematic review indicated that single-visit treatments demonstrated better radiographic evidence of a normal periodontal ligament space than multi-session treatments using CH [9]. CH remains the most commonly used dressing in multi-session endodontic treatments despite these findings due to its proven benefits.

A critical challenge in using CH as an intracanal medicament is difficulty in its complete removal from the RCS before obturation. Despite efforts, achieving complete CH removal is often not feasible, and residual CH can negatively affect the quality of endodontic treatment [10, 11]. The remaining CH on the canal walls may influence the sealability of the root canal over time due to its dimensional instability and solubility. Additionally, residual CH can alter the physical properties of some sealers [12-14] and interfere with materials such as zinc oxide and eugenol sealers. It may also hinder sealer penetration into dentinal tubules and reduce the bond strength of AH Plus epoxy resin sealer [15].

Current root canal irrigation methods, such as those involving sodium hypochlorite or ethylenediaminetetraacetic acid (EDTA), are standard practices but are insufficient for completely removing CH from canal walls [1, 3]. There is no universally accepted protocol, and a combination of techniques, including recapitulation with master apical file (MAF), rotary instruments, or ultrasonic activation, is often employed to enhance cleaning. While these techniques have been extensively studied, none have proven to be entirely effective in removing residual CH before root canal obturation [16]. Even after extensive irrigation with saline, NaOCl, or EDTA, CH residues often remain on 20% to 45% of canal walls [17].

The Gentlefile Tornado Disinfection Kit (Gentlefile; MedicNRG, IL, USA) is a recent innovation that uses an ultra-flexible, braided stainless-steel brush system with an abrasive surface known as Gentlefile Finisher Brush (GB). The GB consists of three medical-grade stainless-steel wires, which rotate at a speed of 6,500rpm, generating a centrifugal force. This allows the brush to abrade the canal walls, facilitating three-dimensional cleaning and shaping. The system's GB, which is equipped with six flexible stainless-steel strands, opens outward under the influence of the rotating headpiece, allowing for effective scrubbing and smoothing of the canal walls. The manufacturer claims that this system is more effective than traditional methods for root canal cleaning. Considering the scarcity of information regarding its efficacy, this study aimed to evaluate the efficacy of the GB system combined with EDTA for CH removal from root canal dentinal walls using a stereomicroscope.

MATERIALS AND METHODS

This in vitro experimental study was conducted on 66 single-rooted mandibular incisors freshly extracted for periodontal reasons. The Ethics Committee of AJA University approved the study (IR. AJAUMS.REC.1398.250). The patients consented to the use of their extracted teeth for research purposes.

Eligibility criteria:

Teeth were included if they met the following criteria: presence of one single canal, no internal or external root resorption, no history of previous endodontic treatment, absence of fractures, cracks, or calcifications, and completely formed apical formation. Periapical radiographs were obtained from the mesiodistal and buccolingual directions to ensure that the teeth met these inclusion criteria. After extraction, soft and hard tissue residues were removed from the teeth, and the teeth were immersed in 5.25% sodium hypochlorite for 30 minutes. The teeth were then stored in 0.9% saline at room temperature to maintain hydration until further processing.

Sample preparation:

The teeth were decoronated at the cementoenamel junction using a diamond disc (Bego, Berman, Germany). The working length was determined by introducing a #15 K-file (Dentsply/Maillefer, Ballaigues, Switzerland) until the file tip was visible at the apex, subtracting 1 mm to establish the working length. A glide path was created using a hand file, followed by canal shaping with the ProTaper rotary system (Dentsply Maillefer, Ballaigues, Switzerland) up to F2 (0.25/0.08). During the cleaning and shaping process, the root canals were irrigated with 5 mL of 5.25% sodium hypochlorite (Cerkamed, Stalova Vola, Poland), and debris was removed.

To simulate the periodontium, the apical part of each root was coated with warm red dental wax (Cavex Modeling Wax, Holland BV, Haarlem, Netherlands). CH (Thomas, FFDM-Pneumat Co., France) was introduced into the canals via a Lentulo spiral (Dentsply Sirona, USA), except for three teeth in the negative control group. CH was condensed in multiple steps using a #80 paper point (Meta Biomed Co., Ltd., Cheongju, South Korea). The canals were radiographed from buccolingual and mesiodistal directions to confirm uniform filling. After confirming complete filling, the CH was removed from the coronal 3mm of the canal, and the coronal portion was sealed with temporary restorative material (Cavisol; ESPE Dental, Seefeld, Germany). All teeth were radiographed again, and defective fillings were corrected. The teeth were stored in 0.9% saline at 37°C for 10 days [1, 2, 4].

Sample grouping and irrigation protocols:

Following the 10-day storage period, the teeth were randomly assigned to four experimental groups and two control groups as follows:

-*Group 1 (MAF/saline; n=15):* Temporary restorations were removed using a round carbide bur (Mani Inc., Tochigi, Japan). A glide path was created by using the MAF to the working length, followed by irrigation with 2.5mL of saline using a 27-gauge syringe. The root canal walls were irrigated for 1 minute, followed by a final rinse with 2.5mL of saline.

-*Group 2 (GB/saline; n=15):* Similar to group 1, the temporary restoration was removed, and a glide path was created. However, GB (Fig. 1) was used to remove CH from the root canal walls in this group. After irrigation with 2.5mL saline, filing was performed for 1 minute with GB, and a final rinse with 2.5mL of saline was performed. A new brush was used for each tooth.

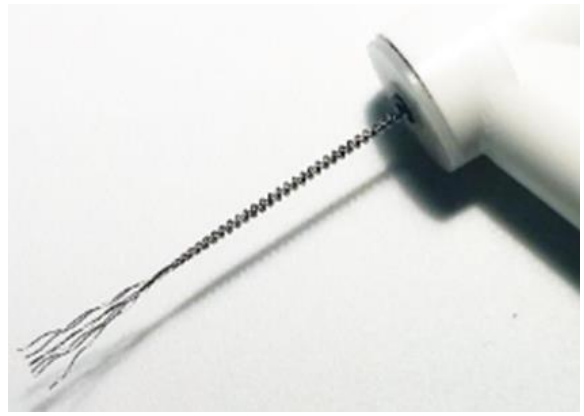

Fig 1. Gentlefile Finisher Brush.

-*Group 3 (MAF/EDTA; n=15):* The temporary restoration was removed, and a glide path was created as in group 1. However, 5mL of EDTA (Masterdent, Dentonics Inc., USA) was used for irrigation instead of saline. The CH removal process was similar to that in group 1, but EDTA was used as the irrigant.

-*Group 4 (GB/EDTA; n=15):* This group followed the same procedure as group 2 but with 5mL of EDTA instead of saline for irrigation. The GB was used for 1 minute, and the root canals were rinsed with 2.5mL of EDTA.

-*Group 5 (positive control; n=3):* CH was introduced into the canals but was not removed, serving as the positive control.

-*Group 6 (negative control; n=3):* No CH was introduced into the canals in this group.

Root sectioning and analysis:

After irrigation, the teeth were longitudinally sectioned using a 008 diamond fissure bur (D & Z, Germany). A groove was made around each tooth, and the teeth were split in half. Each half was inspected under a stereomicroscope (Nikon, Tokyo, Japan), and images were captured at x10 magnification (Fig. 2). The surface area of the regions coated with CH, identifiable by their white appearance, was measured using Digimizer version 5.4 software (MedCalc Software Ltd, Ostend, Belgium) (Fig. 3).

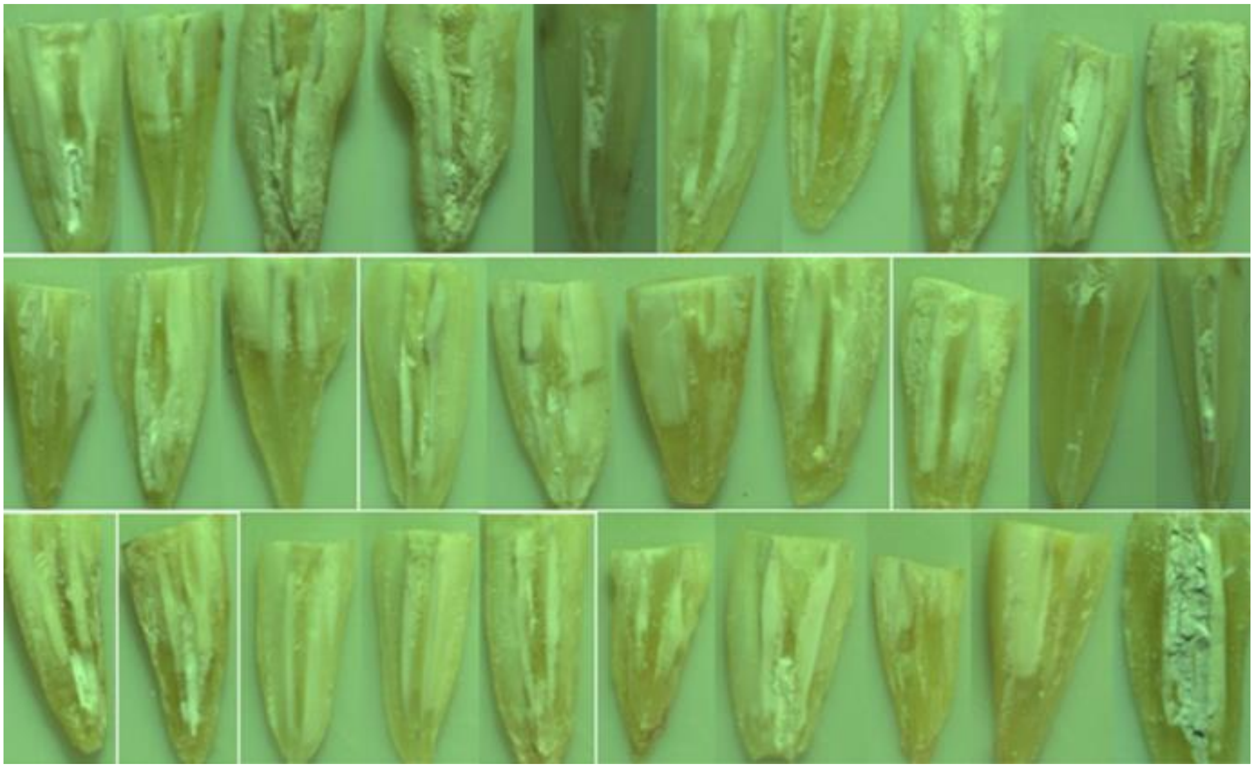

Fig 2. Longitudinally split teeth.

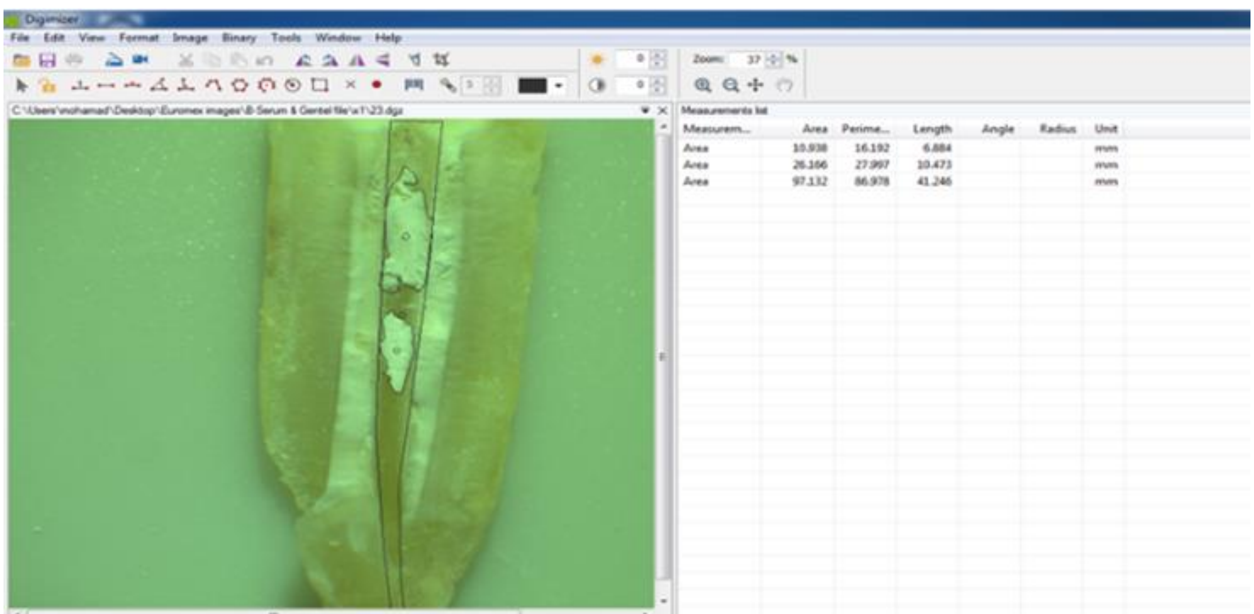

Fig 3. Digimizer software used for quantification of residual calcium hydroxide on root canal walls.

The surface area was reported in square millimeters (mm^2), and the percentage of the canal wall coated with CH was calculated relative to the total surface area. The mean values were recorded.

Statistical analysis:

Data analysis was performed using SPSS version 22 (SPSS Inc., IL, USA). The Kolmogorov–Smirnov test was applied to assess the normality of data distribution.

Accordingly, ANOVA was used for general comparison of the groups, and Tukey's test was applied for pairwise comparisons. $P<0.05$ was considered statistically significant.

RESULTS

The mean percentage of residual CH differed significantly among the four experimental protocols [one-way ANOVA, $F(3,56)=23.12$, $P<0.001$; Table 1]. The GB/EDTA combination produced the lowest percentage of residues (8.30%±6.29%; range: 0.32%–20.47%); whereas the MAF/saline group yielded the highest percentage (52.27%±19.24%; range: 20.00%–88.47%). One-way ANOVA confirmed the significant effect of the removal protocol on the percentage of residual CH [$F(3,56)=23.12$, $P<0.001$].

The Tukey's post-hoc test demonstrated that GB/EDTA outperformed all other groups ($P=0.000$ for all pairwise comparisons). GB/saline also removed significantly more CH than both MAF-based protocols ($P<0.001$). But, the difference between the MAF/saline and MAF/EDTA groups was not statistically significant (mean difference: 7.99%; $P=0.215$, Table 2).

DISCUSSION

This study demonstrated that activation with GB combined with 17% EDTA (GB/EDTA) removed significantly more CH than any alternative protocol tested. In contrast, conventional MAF irrigation with saline resulted in the most significant CH residues. These findings confirm that neither needle irrigation nor file agitation alone can effectively clean the complex anatomy of the RCS.

Residual CH compromises sealer penetration and increases the risk of microleakage [1]; therefore, its complete removal is critical yet notoriously difficult [18]. Although MAF instrumentation with NaOCl or EDTA is the technique most readily available to clinicians [19], its linear motion fails to scour anatomical irregularities such as fins, isthmuses, and lateral canals [13]. Supplementary agitation—passive ultrasonic irrigation (PUI), XP-endo Finisher (XPF), self-adjusting file, and Gentlefile—was introduced to address these limitations [3, 13].

Ultrasonic activation generates acoustic microstreaming and transient cavitation that drive solutions laterally [20], but optimal performance requires placing the tip to full working length, a maneuver that heightens the risk of irrigant extrusion in teeth with immature apices [21]. The GB mitigates this hazard: its seven stainless-steel strands flare centrifugally at 6,500rpm, scrub the dentinal walls, and agitate irrigants without deep insertion. This design likely explains the markedly superior cleansing achieved by GB/EDTA in the present study.

Our GB/EDTA results (mean residue: 8.30%) surpassed those of Balvedi et al. [2] who reported 44.6% residual CH after PUI and 52.3% after MAF. This disparity may stem from Balvedi's exclusive use of saline. A systematic review revealed that, compared with nonchelators, chelators significantly enhance CH removal when delivered through needle irrigation [22]. Similarly, Rodig et al. [23] reported that 20% EDTA outperformed 1% NaOCl, although manual instrumentation negated this advantage.

The absence of a significant difference between the MAF/EDTA and MAF/saline groups differs from previous evidence showing that calcium-chelating irrigants generally remove more CH than non-chelating solutions [24,25]. Suresh et al. [22] reported greater CH removal with calcium chelators across needle-irrigation,

Table 1. Measures of central dispersion for the percentage of residual calcium hydroxide in the study groups

Group	Mean	Std. deviation	Maximum	Minimum
MAF/saline	52.27	19.24	88.47	20.00
GB/saline	25.30	13.72	57.80	5.37
MAF/EDTA	44.28	20.29	82.27	5.19
GB/EDTA	8.30	6.29	20.47	0.32

Std. deviation: standard deviation; MAF: Master apical file; GB: Gentlefile Finisher Brush.

Table 2. Pairwise comparison of the percentage of residual calcium hydroxide between the groups using the Tukey's test

Group A	Group B	Mean difference	P value
MAF/saline	GB/saline	26.9687563	0.000
	MAF/EDTA	7.9887896	0.215
	GB/EDTA	43.9708361	0.000
GB/saline	MAF/EDTA	-18.9799667	0.000
	GB/EDTA	17.0020798	0.000
MAF/EDTA	GB/EDTA	35.9820465	0.000

MAF: Master apical file; GB: Gentlefile Finisher Brush.

agitation, and instrumentation protocols. Rodig et al. [23] also found that EDTA and citric acid produced better results than NaOCl and water. In the present study, EDTA produced the lowest residual CH only when it was combined with GB activation, suggesting that its effect depended on the mechanical agitation protocol.

Numerous studies have highlighted the promise of XPF. Some reported better CH removal than PUI [24], whereas others reported no advantage over standard EDTA/NaOCl protocols [25]. Direct comparisons revealed that XPF and the brush-finisher method removed similar amounts of CH, and both methods outperformed syringe irrigation [26]. However, none achieve total elimination, underscoring the continuing need for refinement.

Effective debridement depends on three factors: (1) delivery of an appropriate irrigant, (2) sufficient contact time, and (3) vigorous agitation that reaches the apical third. The present results endorse GB as an efficient adjunct, provided that EDTA is used for its calcium-chelating capacity. Clinicians should also consider placement techniques: Lentulo spirals operated at ≤5,000rpm, 2mm short of working length, limit extrusion while ensuring uniform medicament distribution [27-29].

The study's in vitro design and use of single-rooted incisors constrain clinical extrapolation. Multi-rooted teeth with more intricate canal systems may respond differently. Future research should evaluate GB performance in such anatomies, dissect the apical, middle, and coronal thirds separately, and incorporate high-resolution modalities—scanning electron microscopy or micro-computed tomography—for residue quantification. Additional work should examine brushes with NaOCl, chlorhexidine, or alternative intracanal medicaments such as Ledermix.

CONCLUSION

Within the limits of this in vitro study, activation with GB coupled with 17% EDTA was markedly more effective than conventional MAF irrigation, with either saline or EDTA, for removing CH from the RCS. The data underscore that complete chemomechanical debridement depends on the synergistic interplay of a chelating irrigant and vigorous, brush-type agitation that can scour canal intricacies without deep tip insertion or undue risk of irrigant extrusion.

CONFLICT OF INTEREST STATEMENT

None declared.

GENERATIVE AI IN SCIENTIFIC WRITING

None declared.

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