Tikrit Journal for Dental Sciences 14(1) (2026) 56-65
https://doi.org/10.25130/tjds.14.1.6

Tikrit Journal
for
Dental Sciences
https://tjds.tu.edu.iq
Print ISSN:2073-1213
Online ISSN:3105-9384

Efficacy of Ultrasonic Activation of 17% EDTA in the Removal of Bioceramic Root Canal Sealer During Retreatment: A Scanning Electron Microscopy Study

Mustafa Imad Saleh [1] *
Emad Farhan Alkhalidi [2]

[1,2] Department of Conservative Dentistry, College of Dentistry, University of Mosul, Mosul, Iraq

Keywords:
bioceramic sealear,EDTA, ultrasonic activation
Article Info.:

Article History:
Received: 25/8/2025
Received in revised form: 20/10/2025.
Accepted: 28/10/2025
Final Proofreading: 28/10/2025
Available Online: 1/6/2026

Citation: Saleh MI, Alkhalidi EF. Efficacy of Ultrasonic Activation of 17% EDTA in the Removal of Bioceramic Root Canal Sealer During Retreatment: A Scanning Electron Microscopy Study. Tikrit Journal for Dental Sciences 2026; 14(1): 56-65
https://doi.org/10.25130/tjds.14.1.6.

***Corresponding Author:**
Email:
mustafa.23dep3@student.uomosul.edu.iq
B.D.S. Dept. of Conservative Dentistry, College of Dentistry, Univ. of Mosul, Mosul, Iraq

Abstract

Background: Complete root canal filling material removal throughout the retreatment is essential for effective disinfection and long-term treatment success. Bioceramic-based sealers, while offering excellent sealing and biocompatibility, are difficult to remove due to their chemical bonding and deep dentinal tubule penetration. Chelating agents such as 17% EDTA can dissolve the inorganic smear layer, and ultrasonic activation has been proposed to enhance its cleaning performance.

Aim: To evaluate the effectiveness of ultrasonic activation of 17% EDTA in removing bioceramic sealer remnants compared to EDTA without activation and file-only retreatment.

Materials and Methods: A total of 30 extracted human mandibular premolars have been prepared, obturated with a bioceramic sealer, and incubated for four weeks. The specimens have been allocated randomly to three groups (n = 10 each): Group1 – 17% EDTA with no ultrasonic activation; Group2 – 17% EDTA with ultra-sonic activation; Group3 – control (files only). Retreatment has been performed with the use of ProTaper Universal Retreatment files. In Groups 1 and 2, EDTA has been delivered with a 30-gauge side-vented needle; in Group2, ultrasonic activation was applied for 20 seconds initially and 30 seconds during final irrigation. Samples were sectioned, imaged under SEM at coronal, middle, and apical thirds, and analyzed using ImageJ to quantify the percentage of uncleaned surface area. Data had been evaluated with the use of Shapiro–Wilk and one-way ANOVA tests ($p < 0.050$).

Results: Mean residual debris was 39.8% ± 2.5 (EDTA + ultrasonic), 47.3% ± 2.8 (EDTA alone), and 65.2% ± 3.1 (control), showing significant differences ($p < 0.001$).

Conclusion:
Ultrasonic activation markedly enhanced sealer removal, especially in the apical third, improving overall canal cleanliness.

Introduction:

The crucial objective of the endodontic treatment is preserving apical and periapical tissue health, in addition to the prevention of root filled canal recontamination(1). The endodontic treatment success is highly influenced by root canal obturation quality and the used materials, which include the endodontic sealers (2). The endodontic sealer plays a very important role in treatment of the root canals. It fills spaces, irregularities of the root canal and minor discrepancies between core filling material and the walls of the canal so that they form some coherent mass (3). Root canal sealers have an essential function in biological reactions with the tissues that surround it, since they encourage attachment between gutta-percha and dentinal walls, in addition to enabling the sealing of lateral, accessory canals, and multiple foramina, which promote healing when they come in contact with periapical tissues (4). Root canal filling materials need to be biocompatible as they can come into contact with periapical tissues directly (in extrusion cases) or indirectly through products that are released throughout the setting reaction (5). The sealers are classified according to their primary chemical composition into the following classes: zinc oxide–eugenol, glass ionomer, calcium hydroxide, resin, silicone, and bioceramic-based sealers , Lately, calcium silicate-based sealers (CSBS, bioceramic) have become quite popular(6). Many CSBS varieties were developed as pre-mixed and powder–liquid compositions. Throughout setting, bioceramic-based sealers release hydroxyl and calcium ions, leading to a pH increase (>12). As a result, they show long-term antibacterial characteristics (7). In addition to that, bioceramic sealers bond chemically to dentinal tubules through hydroxyapatite production. During root canal treatment, sealers may project through accessory canals or apical foramen and interact with periapical tissues (8). Even though it is easy to remove gutta-percha, which has been utilized as the main core filling material, throughout retreatment , a significant drawback related to bioceramic materials is the challenge encountered in their removal from the root canal during re-treatment (9). Conventional retreatment methods are ineffective in the removal of bioceramic sealer(7). Bioceramic-based root canal sealers are hard to remove from the root canal system as a result of their highly rigid structure once set and their interaction with dental tissues after failed treatment (10). Efforts have been made towards developing supplemental protocols to facilitate the removal of set bioceramic sealers. These protocols include using alternative solvents, mechanical removal, and irrigation activation (11). Several approaches, including hand files, reciprocating, or rotary equipment, have been utilized for root canal filling removal. Nonetheless, studies have indicated that none of these approaches can fully eliminate root filling materials, especially in complex anatomical configurations such as oval-shaped, curved canals, and isthmuses(12). Modern irrigation activation techniques, including sonic and ultrasonic, were developed to enhance cleaning. Additional activation of irrigation during re-treatment was found to increase root canal filling material removal by 1.50–2.10 times (13). EDTA is a chelating solution broadly used for removing the smear layer. Its principal activity is removal of the inorganic part of smear layer. It is available in paste and liquid forms with concentrations of 15% and 17%. During endodontic treatment, washing with EDTA and NaOCl is recommended to eliminate both inorganic and organic parts of the smear layer(2). So the objective of this study is to evaluate the effectiveness of ultrasonic activation in enhancing the performance of 17% EDTA solution during endodontic retreatment procedures, specifically for bioceramic-based root canal sealer removal, by improving irrigant penetration, facilitating disruption of the sealer–dentin interface, and promoting efficient debris elimination from complex root canal anatomies.

Material and Method

The study was approved by the Research Ethics Committee of the College of Dentistry at Mosul University in Iraq since it used human teeth that had been extracted for orthodontic reasons. It was given a clearance number (REC reference no. UoM.Dent. 25/1017). The experimental work was conducted in the Department of Conservative Dentistry, College of Dentistry, University of Mosul, from January 2024 to June 2025.

Samples Preparation:

Thirty extracted human lower premolars were collected from patients aged between 18 and 28 years who had undergone extraction for orthodontic treatment purposes. All selected teeth exhibited straight canals, fully formed apices, and no signs of internal or external resorption(14). After extraction, the teeth were rinsed with running water, disinfected, and stored in 1% thymol solution in a closed container to prevent microbial growth (15). Diagnostic periapical radiographs were taken (Vatec, Korea); A digital Vernier caliper was used to measure tooth length; extremely short specimens were excluded. The final 30 teeth were standardized to a length of 17 mm from the apex by sectioning the crowns with a diamond disc bur mounted on a straight handpiece fixed to a surveyor under continuous water coolant (16). Access cavities were prepared using a diamond round bur, and the entire roof of the pulp chamber was removed. Canal patency was confirmed with a size 10K-file (Dentsply Maillefer, Switzerland), followed by a size 15K-file. The working length was established at 16.5 mm, calculated by subtracting 0.5 mm from the length at which the file tip was visible at the apical foramen (17). Instrumentation was performed using the crown-down approach with ProTaper Next rotary nickel–titanium files (Dentsply Maillefer, Switzerland), starting with SX and progressing through S1, S2, F1, F2, F3, F4, and F5 (18). Speed and torque followed preset device settings. SX enlarged the coronal two-thirds, followed by S1 and S2 to WL, then F1–F5 to complete shaping (19). The irrigation protocol included 2 ml of 5% NaOCl (Cerkamed, Poland) as irrigant and 17% EDTA gel (Miveovem, Turkey) as lubricant throughout instrumentation. Samples were then rinsed sequentially with 5 ml of 5% NaOCl for 1 min, 5 ml of distilled water for 1 min, 5 ml of 17% EDTA for 1 min, and 5 ml of distilled water for 1 min (19). Sealer was inserted into canals, followed by placement of F5 gutta-percha cones with the single-cone technique(18) . Excess material was removed with heated instruments. Teeth were wrapped in moist cotton, sealed coronally with GIC, placed individually in test tubes, and incubated at 37 °C and 95% humidity for 4 weeks to allow complete setting (20).

Grouping of Samples:

All samples had been randomly divided to 3 groups with 10 samples for each as follow:

Group1 – EDTA 17% Without Ultrasonic Activation

Following obturation with a bioceramic sealer and incubation, retreatment has been initiated with the utilization of Pro-Taper Universal Retreatment files (D1, D2, D3) to mechanically remove the root canal filling bulk. The chelating solution (17% EDTA) was delivered manually with the use of a 30-gauge side-vented needle inserted 2mm short of working length (WL). The protocol for EDTA exposure remained consistent across all canal thirds:

- **Coronal third**: D1 file was used, followed by EDTA application for 1 minute during instrumentation and an additional 2 minutes afterward.
- **Middle third**: D2 file was used, with the same EDTA application times as above.
- **Apical third**: D3 file was used, again followed by the same EDTA exposure timing.

Instrumentation went on until there were no more obvious signs of obturation in the files, which meant they had been thoroughly cleaned. The goal of using EDTA was to chelate the smear layer and loosen the leftover sealer, although this group did not apply ultrasonic or laser activation.

Group 2 – EDTA 17% With Ultrasonic Activation

Retreatment has been performed with utilizing ProTaper Universal Retreatment files (D1, D2, D3) to remove the bulk of obturation material. A 17% EDTA solution has been delivered with a 30-gauge side-vented needle inserted 2mm short of WL, followed by ultrasonic activation. An ultrasonic tip (size 20, taper 0.01) was placed 1mm short of WL and activated at a medium power setting for 20 seconds during initial irrigation and 30 seconds during final irrigation. Gentle up-and-down motions were used to improve irrigant penetration and disrupt sealer remnants, especially in the apical third.

Group 3 – Control Group (Files Only)

This group underwent retreatment using ProTaper Universal Retreatment files (D1 for coronal third, D2 for middle third, D3 for apical third) without the use of any chemical irrigants or activation. No EDTA, ultrasonic, or laser activation was applied. This group served as the baseline to evaluate the cleaning efficacy of mechanical instrumentation alone.

Evaluation of the residual bioceramic sealer

After retreatment, all samples were sectioned longitudinally using a diamond disc bur mounted on a straight slow-speed handpiece under continuous water coolant. Firstly, these specimens were examned with a digital stereomicroscope connected to a computer. Images were produced at 5× magnification to detect the entire root surface and image at 10× magnification to examine the coronal, middle, and apical thirds separately(4). The images facilitated documentation of each location and were then used for quantitative analysis. We chose random samples from each group for more surface characterization and studied them with a scanning electron microscope (SEM)(12). 9 images were gotten for each sample (three from each root third) focusing on the center of each region. Images were produced with 100× magnification for general examination, 250× for smear layer assessment, and 1000× for detailed examination of sealer residues and dentinal tubule exposure.(21). All SEM pictures were processed using ImageJ software (v. 1.53, National Institutes of Health, Bethesda, MD, US) to quantify the residual sealant. The software has been calibrated using the embedded scale bar in each image. The canal wall area was manually outlined using the polygon tool, and the remaining bioceramic sealer was isolated using the Color Threshold function. The sealer-covered regions were measured in square millimeters using the Analyze > Measure tool, and the percentage of uncleaned area was calculated relative to the total canal surface. Each image was analyzed three times to ensure consistency, and the mean value has been used for the statistical comparisons as son in figure (1,2,3)(22).

All analyses were performed using SPSS statistical software version 26.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 90 root canal thirds area (30 sample each sample with 3 area;coronal, middle, apical) were analyzed and evenly distributed across three groups (n = 30 per group). The primary measured outcome was the percentage of uncleaned canal surface area after retreatment using different EDTA irrigation protocols.

Overall Comparative Analysis

Table 1 shows the mean percentage of uncleaned root canal surfaces across all three groups. The control group exhibited the highest residual debris percentage (**65.2% ± 3.1**), followed by EDTA without activation (**47.3% ± 2.8**). The lowest value was recorded in the EDTA with ultrasonic activation group (**39.8% ± 2.5**). The Shapiro–Wilk test confirmed that results were normally distributed across all experimental groups, as none of the p-values were below the 0.05 significance level. Following this, a one-way ANOVA revealed a statistically significant difference among the groups ($p < 0.001$), indicating that the irrigation protocol had a significant effect on the residual of residual debris inside the canals.

Comparative Evaluation by Canal Thirds

Coronal Third

The control group had the highest debris (**65.0% ± 2.9**), while EDTA + Ultrasonic activation showed the lowest (**40.1% ± 1.8**) as seen in figure 4.

Middle Third

The control group showed the highest debris (**65.4% ± 3.3**), while EDTA + Ultrasonic activation again had the lowest (**39.5% ± 1.5**) as seen in figure 4.

ApicalThird

The apical third showed similar trends, with the control group highest (**65.2% ± 3.1**) and EDTA + Ultrasonic activation lowest (**39.8% ± 1.6**) as seen in figure 4.

Discussion

This study evaluated effects of 17% EDTA irrigation with and with no ultra-sonic activation when compared to file-only mechanical retreatment in the removal of bio-ceramic sealer remnants from the walls of root canal. Across all canal thirds, ultrasonic activation of EDTA achieved the lowest residual debris values (overall mean: 39.8% ± 2.5), followed by EDTA without activation (47.3% ± 2.8), while the control group (files only) exhibited the highest values (65.2% ± 3.1). The results demonstrate that the chelating properties of EDTA, along with its ultrasonic activation, markedly improve sealer removal during retreatment.

Effect of EDTA Without Activation

The application of EDTA alone markedly diminished residual debris in all canal thirds compared to the control group, validating its capacity to chelate inorganic constituents of the smear layer and partially dissolve hydroxyapatite deposits generated by bioceramic sealers. The results correspond with previous research by Cruz-Filho and Prado, who demonstrated that EDTA effectively removes the smear layer and exposes dentinal tubules, this led to improving mechanical cleaning. However, without activation, it is limited in it is ability to penetrate deeper abnormalities and complex anatomical area.(23).

Activation of EDTA by ultrasonic increases cleaning performance, producing significant decreases in residual sealer compared to non-activated EDTA. The improvement was most apparent in the apical third area, where canal constriction and anatomical complexity typically decrease irrigant flow. This correspond with research by Plotino and van der Sluis, which shown that acoustic streaming and cavitation produced by ultrasonics improve irrigant penetration and rupture the adherence of biofilm and debris(12). Capar et al. (2014) and Kato et al. (2020) also showed that ultrasonic agitation aided the clearance of filler materials during endodontic retreatment, especially in the apical area (22),(24). All of the groups, the apical third area had a greater amount of debris than the coronal and middle thirds, confirming the understood difficulty of cleaning this area. Ultrasonic activation regularly decrease apical debris compared to EDTA alone and the control, indicating its efficacy in decrease irrigate stagnation in the apical area (25). Our results corrspond with those of Gergi and Sabbagh, as well as Rödig, who showed that ultrasonic activation aided in the removal of filling materials and smear layer in comparison to syringe irrigation. Ballal showed that ultrasonic activation of chelators aided in the removal of debris and dentinal plugs, that lead to improving the exposure of dentinal tubules for subsequent disinfection. In the context of bioceramic sealer retreatment, Kharouf showed the challenges related with the removal of these sealers, attributed to their strong adhesion to dentin and deep penetration into tubules. The results we obtained showed that ultrasonic activation of EDTA effectively reduces this problem to limited degree (26).

Conclusion

Activation of 17% EDTA by ultrasonic method showed a greater ability in eliminating bioceramic sealer remnants than non-activated EDTA irrigation and file-only retreatment. This effect of cleaning was occurred in all canal thirds area, with the most significant improvement was seen in the apical third, where anatomical complexity generally prevents irrigant penetration. The results we obtained show the efficacy of both chelation with ultrasonic activation to enhance debris disruption, smear layer removal, and irrigant distribution in endodontic retreatment. The integration of ultrasonic activation into retreatment protocols may aided in the probability of attaining a cleaner canal system, which is necessary for effective disinfection and long-term treatment success.

Funding: self-funding

Conflicts of Interest

No conflicts of interest related with this study. The research was done independently, without any commercial or financial relationships.

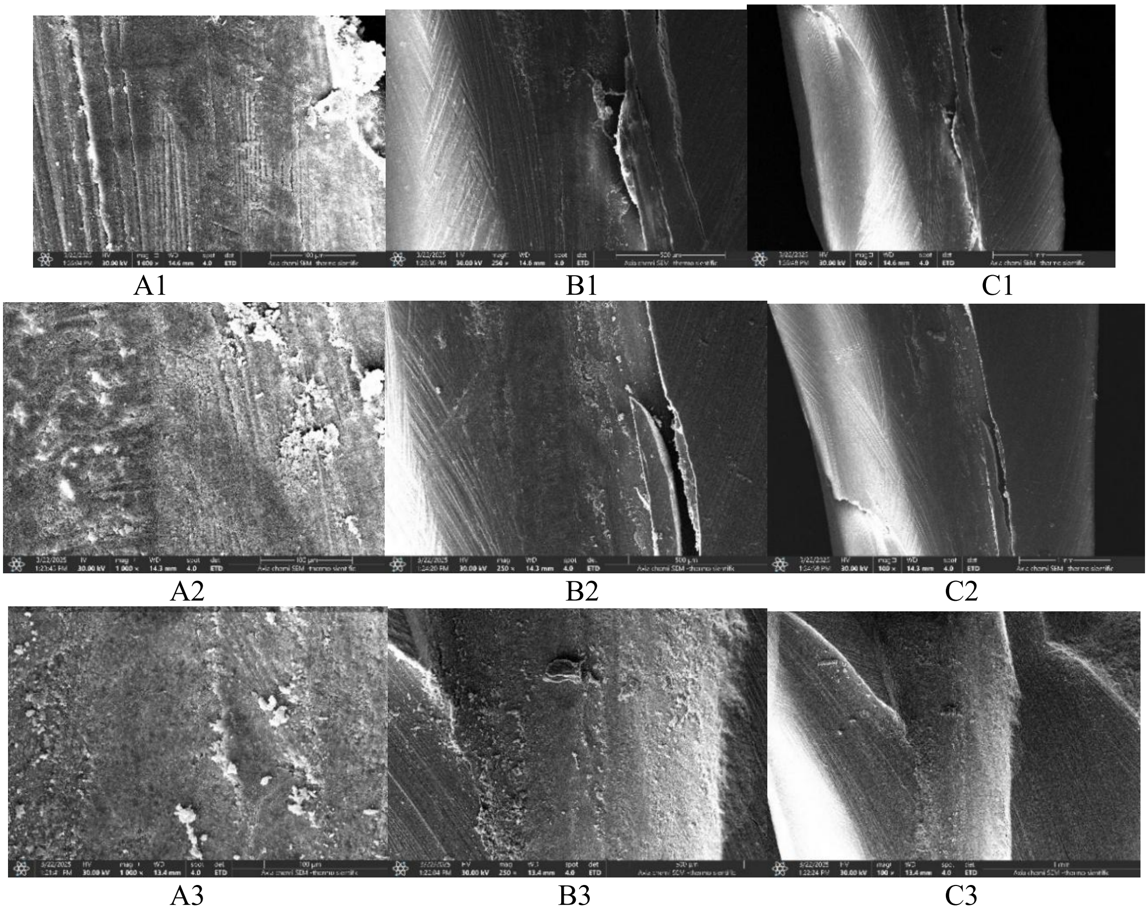

Figure 1. images of SEM of EDTA group (17% EDTA without activation), with three area apical, middle and coronal at 100×, 250×, and 1000× magnifications. Apical third (A1–C1), middle third (A2–C2), coronal third (A3–C3).

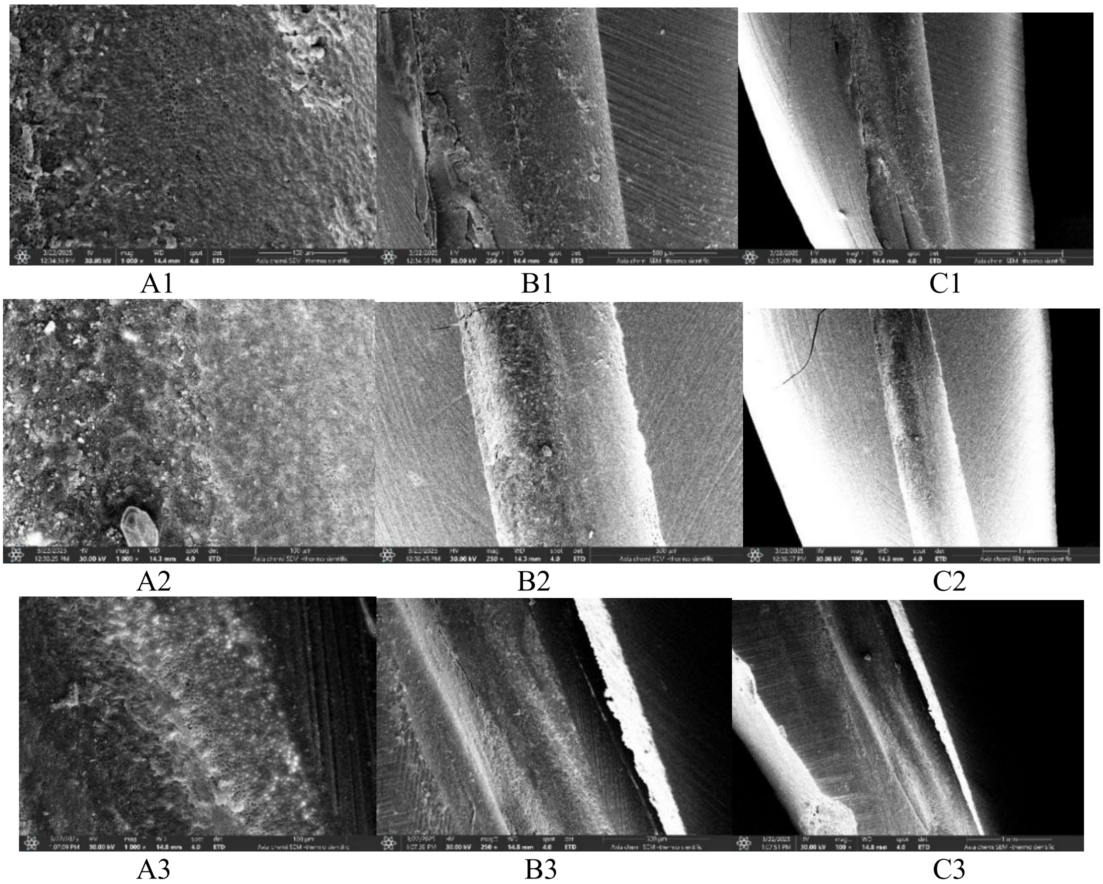

Figure 2 image of SEM for EDTA + Activation group, with three area apical, middle and coronal at 100×, 250×, and 1000× magnifications. Apical third (A1–C1), middle third (A2–C2), coronal third (A3–C3).

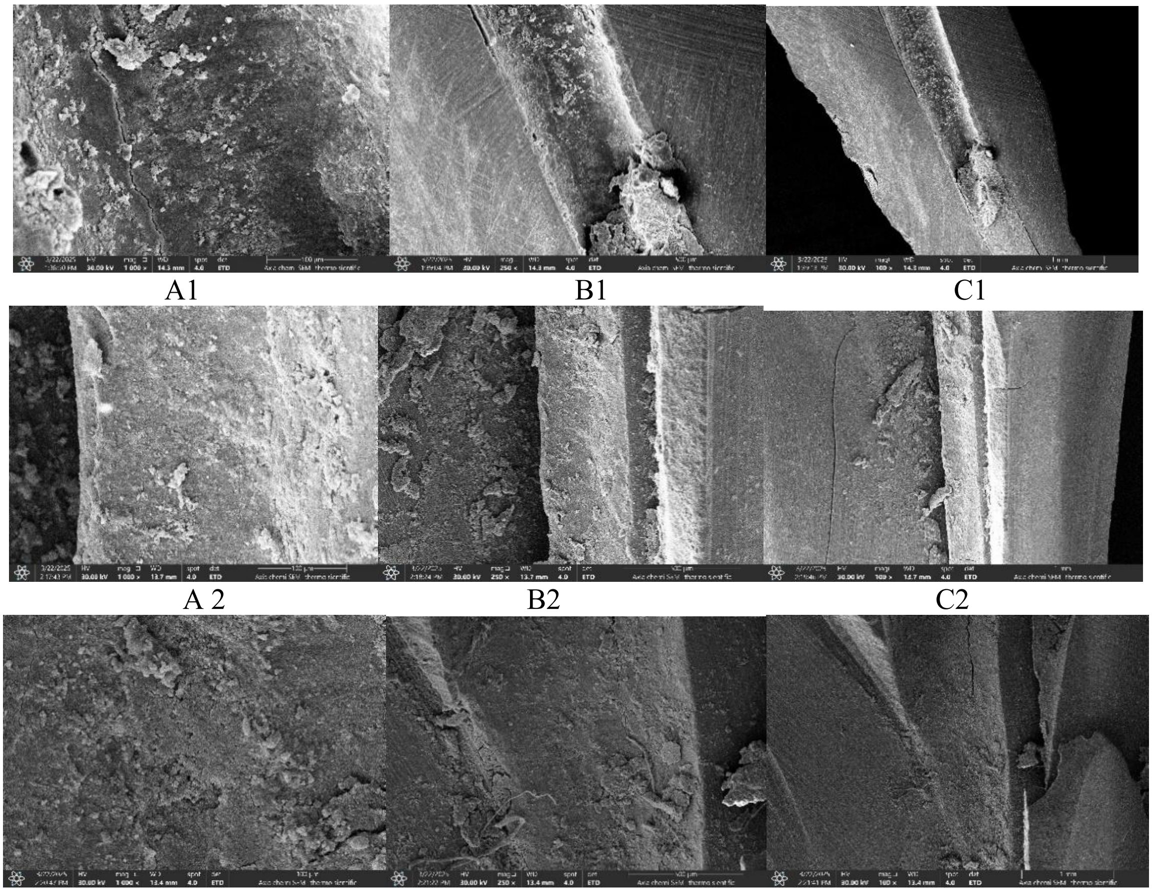

Figure 3. image of SEM for Control group (files only), with three area apical, middle and coronal at 100×, 250×, and 1000× magnifications. Apical third (A1–C1), middle third (A2–C2), coronal third (A3–C3).

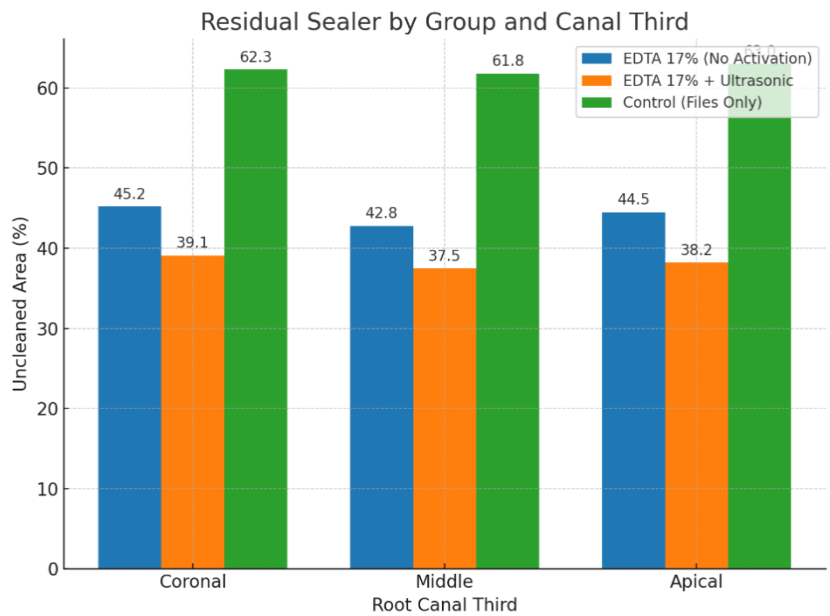

Figure (4) remanent sealer by group and canal thirds

Table 1. Overall mean percentage of uncleaned areas

Group	N	Mean %	SD	SE	Min	Max
Control (Files only)	30	65.2	3.1	0.6	60.5	70.0
EDTA 17% (No activation)	30	47.3	2.8	0.5	42.0	52.0
EDTA 17% + Ultrasonic activation	30	39.8	2.5	0.5	35.5	44.5

References

1. Alalaf N, Alkhalidi M. Comparative assessment of root canal sealer's apical sealing ability. Al-Rafidain Dent J. 2022;22(1):124-135. doi:10.33899/rdenj.2022.129250.1077.

2. Hassoon S, Nayif M, Thiab K. The influence of irrigation with different solutions on apical microleakage of root canals. Al-Rafidain Dent J. 2023;23(1):65-75. doi:10.33899/rdenj.2023.178376.

3. Attash I, Al-Ashou W. Push-out bond strength evaluation for different endodontic sealers: a comparative study. Al-Rafidain Dent J. 2022;22(2):301-312. doi:10.33899/rdenj.2022.130209.1105.

4. Jassim M, Dawood A, Holden J, Reynolds E. The effect of bioceramic-based root canal sealers on the cell viability and cytotoxicity of human periodontal ligament fibroblast cell line (an in vitro study). Al-Rafidain Dent J. 2025;25(1):1-15. doi:10.33899/rdenj.2024.152429.1272.

5. Kapralos V, Böcker J, Vach K, Altenburger M, Proksch S, Karygianni L. On the biocompatibility of endodontic sealers. Swiss Dent J. 2022;132(9):586-597. doi:10.61872/sdj-2022-09-01.

6. Paz JER, Costa PO, Souza AAC, de Oliveira IM, Falcão LF, Falcão CAM, et al. Bone repair in defects filled with AH Plus sealer and different concentrations of MTA: a study in rat tibiae. Restor Dent Endod. 2021;46(4):e48. doi:10.5395/rde.2021.46.e48.

7. Chopra V, Davis G, Baysan A. Physico-chemical properties of calcium-silicate vs resin-based sealers: a systematic review and meta-analysis of laboratory-based studies. Materials (Basel). 2022;15(1):229. doi:10.3390/ma15010229.

8. Li J, Chen L, Zeng C, Liu Y, Gong Q, Jiang H. Clinical outcome of bioceramic sealer iRoot SP extrusion in root canal treatment: a retrospective analysis. Head Face Med. 2022;18(1):28. doi:10.1186/s13005-022-00332-3.

9. Kim SR, Kwak SW, Lee JK, Goo HJ, Ha JH, Kim HC. Efficacy and retrievability of root canal fillings using calcium silicate-based and epoxy resin-based root canal sealers with matched obturation techniques. Aust Endod J. 2019;45(3):337-343. doi:10.1111/aej.12323.

10. Estivalet MS, de Araújo LP, Immich F, da Silva AF, Ferreira NS, da Rosa WLO, et al. Bioactivity potential of bioceramic-based root canal sealers: a scoping review. Life (Basel). 2022;12(11):1853. doi:10.3390/life12111853.

11. Aksel H, Küçükkaya Eren S, Askerbeyli Örs S, Serper A, Ocak M, Çelik HH. Micro-CT evaluation of the removal of root fillings using the ProTaper Universal Retreatment system supplemented by the XP-Endo Finisher file. Int Endod J. 2019;52(7):1070-1076. doi:10.1111/iej.13094.

12. **Crozeta BM, Silva-Sousa YTC, Leoni GB, Mazzi-Chaves JF, Fantinato T, et al.** Micro-computed tomography study of filling material removal from oval-shaped canals using rotary, reciprocating, and adaptive motion systems. *J Endod.* 2016;42(5):793–797. doi:10.1016/j.joen.2016.02.005.

13. Arul B, Suresh N, Sivarajan R, Natanasabapathy V. Influence of volume of endodontic irrigants used in different irrigation techniques on root canal dentin microhardness. Indian J Dent Res. 2021;32(2):230-235. doi:10.4103/ijdr.IJDR_709_18.

14. Gandhi M, Tandon S, Vijay A, Kalia G, Rathore K. Clinical assessment of various obturating techniques for primary teeth: a

comparative study. J Clin Diagn Res. 2017;11(7):ZC48-ZC51. doi:10.7860/JCDR/2017/25818.10194.

15. Tomer AK, Gupta R, Ramachandran M, John AG, Raina AA, Behera A, et al. Comparison of the apical sealing ability of calcium hydroxide, MTA, and silicone-based sealers. *Int J Appl Dent Sci.* 2018;4(1):3-5. doi:10.1159/000450577.

16. Bernardes RA, Campelo AA, Silva DS, Pereira LO, Duarte MAH, Moraes IG, et al. Evaluation of the flow rate of 3 endodontic sealers: Sealer 26, AH Plus, and MTA Obtura. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;109(1):e47-e49. doi:10.1016/j.tripleo.2009.08.038.

17. Kamil SS. Assessment of apical microleakage of three-based endodontic sealers. Tikrit J Dent Sci. 2024;12(2):265-271. doi:10.25130/tjds.12.2.2.

18. Hassoon SN, Al-Sabawi NA, Al-Sabawi MR. Effect of irrigation with different solutions on push-out bond strength of root canal obturation materials. *Tikrit J Dent Sci.* 2023;11(1):31-40. doi:10.25130/tjds.11.1.4.

19. Kamil SS, Al-Sabawi NA. Measurement of residual material remaining in root canals retreated by different rotary systems. *Tikrit J Dent Sci.* 2021;9(1):57-65. doi:10.25130/tjds.9.1.8.

20. Kwak SW, Koo J, Song M, Jang IH, Gambarini G, Kim HC. Physicochemical properties and biocompatibility of various bioceramic root canal sealers: in vitro study. J Endod. 2023;49(7):871-879. https://doi.org/10.1016/j.joen.2023.05.013

21. De-Deus G, Silva EJ, Souza E, Versiani MA, Zuolo M. Shaping for Cleaning the Root Canals: A Clinical-Based Strategy. Cham: Springer Nature; 2021.

22. Capar ID, Ozcan E, Arslan H, Ertas H, Aydinbelge HA. Effect of different final irrigation methods on the removal of calcium hydroxide from an artificial standardized groove in the apical third of root canals. J Endod. 2014;40(3):451-454. doi.org/10.1016/j.joen.2013.10.019

23. Machado R, Garcia LFR, da Silva Neto UX, Cruz-Filho AM, Silva RG, Vansan LP. Evaluation of 17% EDTA and 10% citric acid in smear layer removal and tubular dentin sealer penetration. Microsc Res Tech. 2018;81(3):275-282. doi:10.1002/jemt.22976.

24. **Ajina MA, Shah PK, Chong BS, et al.** Critical analysis of research methods and experimental models to study removal of root filling materials. *Int Endod J.* 2022;55(Suppl 1):119-152. doi:10.1111/iej.13650

25. Siqueira JF Jr, Rôças IN**.** Present status and future directions: microbiology of endodontic infections. *Int Endod J.* 2022;55(5):512–530. doi:10.1111/iej.13677..

26. Kharouf N, Sauro S, Eid A, Zghal J, Jmal H, Seck A, et al. Physicochemical and mechanical properties of premixed calcium silicate and resin sealers. J Funct Biomater. 2022;14(1):9. doi:10.3390/jfb14010009.