Evaluation of the Efficiency of Different Irrigation Materials to Remove the Bioceramic Sealer in Endodontic Retreatment

Abstract

Aim
This research aimed to assess the effectiveness of irrigants (phosphoric acid, EDTA, and Triton) in eliminating the bioceramic sealer and smear layer from dentinal tubules during retreatment.

Materials and Methods
Twenty-seven single roots (n=9) were collected. All samples were instrumented using the WaveOne Gold file system (Dentsply Sirona Pty Ltd, Charlotte, NC, USA). Irrigated with 5% NaOCl and 17% EDTA. Subsequently, the obturation used cold and warm techniques with Ceraseal bioceramic sealer (Meta Biomed, Republic of Korea). Pre- and post-endodontic therapy periapical X-rays were done. then incubated at 37°C in 100% humidity for two weeks. Reinstrumentation was performed using the ProTaper Gold system (Dentsply Sirona Pty Ltd, Charlotte, NC, USA). The samples were randomly divided into three groups. Group (A): Phosphoric acid 37% Group (B): EDTA 17% with ultrasonic activation Group (C): TRITON using ultrasonic activation, all samples were longitudinally sectioned using a low-speed saw (Isomet Buehler Co., USA); hereafter, chosen portions were affixed to matrices and gold-sputtered using a sputtering apparatus. The samples were examined with a scanning electron microscope (Jsm-6060LV, Jeol Ltd., Tokyo, Japan) for evaluation.

Results
The results of the bioceramic removal showed that the EDTA was statistically more effective than phosphoric acid and Triton in removing the bioceramic sealer ($p<0.05$), except for the phosphoric acid with single cone obturation reported better efficiency and Triton with single cone technique in the coronal part only, then reported reduced effectiveness significantly in the middle and apical parts ($p>0.05$).

Conclusion
This research concludes that EDTA is more successful than phosphoric acid and Triton in eliminating the bioceramic sealer and smear layer from root canals. None of the tested supplementary cleaning materials or techniques completely removed the residual filling material.

Authors

W. S. Haichal*
D. I. K. Pontoriero
E. F. Cagidiaco
G. Verniani
M. Ferrari

University of Siena, Siena, Italy

*Corresponding Author

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INTRODUCTION

Endodontic treatment involves removing a maximum number of microorganisms from the root canal and the hermetic sealing of the canal to avert the proliferation of surviving bacteria or recontamination. A prevalent cause of endodontic failure is inadequate cleaning or shaping of the root canal, which can retain microbial remnants and necrotic tissue in the apical third, potentially serving as a substrate for new bacterial growth (1,2).

According to a comprehensive analysis, the failure rates of early endodontic treatments vary between fifteen percent and thirty-two percent (3). Therefore, endodontic retreatment may occasionally be necessary; this method is still the go-to for most cases despite having considerably higher failure rates (4). Additionally, it is crucial to consider the following factors when choosing a dental material, post-fiber type, and restoration cementation technique: bioactivity (5); improved stress distribution during chewing on the dental residual structures (6); and optimal features for post-endodontic reconstruction (7). As part of a retreatment technique, the pulp cavity is emptied, the root canal is mechanically prepared, chemical-mechanical disinfection is performed, and finally, the root canal is sealed (7).

Filling materials, especially endodontic sealers, can adhere to dentin and form mechanical imbrication (8) due to their ability to enter dentinal tubules. Based on their main ingredients, bioceramic sealers, glass ionomer, epoxy resin, calcium hydroxide, zinc oxide, eugenol, and newer versions of these sealers are classified. Due to its great bioactivity and biocompatibility, endodontists have recently taken into consideration bioceramic filling sealers (9). These are bioactive and were developed to increase the quality of root canal sealing (10). A radiopacifier called zirconium oxide, calcium phosphate, calcium hydroxide, and di- and tricalcium silicate make up the bulk of these bioactive ingredients, which are designed to enhance root canal closure (11). Among their many desirable qualities, there are a slightly alkaline pH, bioactivity, biocompatibility, non-toxicity, dimension stability, sealing ability, and the prospect of increased root strength after filling (12,13).

The fact that many of these components come with their preparations already mixed facilitates the insertion. Although bioceramics have the well-known drawback of being difficult to remove from the root canal walls (14), nothing is known regarding their retreatment potential because of their adhesive qualities to dentin. The reduced success rate of endodontic retreatment might be explained, in part, by the fact that the remains act as a physical barrier between the irrigating solution and the bacteria that live in inaccessible places such as dentinal tubules, lateral canals and isthmi (15,16). Additional failure causes include new root canal filling adhesion issues caused by leftover material to radicular dentin (17). Root canal filling materials have been removed using a variety of methods, such as rotary and manual files, XP-endo Finisher R, chelating agents, ultrasonic devices, gentle waves, lasers, Endovac, heat, and solvents (18–20). There is a great deal of variation in the study outcomes because of the different approaches used. However, not a single instance showed full removal of sealer. In clinical practice, there is currently no recommended process for removing bioceramics sealer. The chelating agent is far more effective than the alternatives when it comes to removing sealer. We recommend adding a chelating agent like Triton or Dual Rinse to make the new solution gentler on dentin than traditional solvents. This might be useful for removing sealers (21–23). To evaluate the retreatability of the bioceramic sealers, the studies considered various parameters such as the ability to reach working length (WL) (24,25) and patency (24,26,27). Also documented were the times it takes to attain working length (28,29) or finish the retreatment operation (26,28,29). Methods such as digital radiography (33), scanning electron microscopy (25,30), confocal microscopy (29), micro-CT (26,29), and optical microscopy (24,31) were used to assess the material remains.

Although the methods used had their benefits, they also had their drawbacks. There is no reliable way to quantify the overall canal area using radiography or digital pictures of teeth that have been vertically sectioned since they only provide two-dimensional information about a three-dimensional environment. Another drawback is the fact that different viewers can reach different subjective assessments of the remaining content. In addition, root splitting might displace some of the filling remains (26,32,33). Conversely, the cleanliness of the open or blocked dentinal tubules may be subjectively evaluated using scanning electron microscopy (30). Micro CT can evaluate objectively the residual debris with little operator bias; it is a non-invasive and repeatable assessment approach (26). Nevertheless, it does not pick up on the relative amounts of gutta-percha and sealer residues (32). Confocal microscopy is also the only tool that can reliably show the breadth and depth of sealer penetration into dentinal tubules (29).

The aim of the study was using three distinct obturation strategies, this research aimed to determine which irrigation material was the most effective in removing the bioceramic sealer.

The tested null hypothesis was that there is no difference in the overall proportion of remaining smear layer and open dentinal tubules when three different irrigation solutions were tested.

MATERIALS AND METHODS

Teeth selection and root canal preparation

A total of twenty-seven teeth, each with one canal, were taken from the Oral Surgery Department's outpatient clinic. The samples were categorized into three groups based on the material used (phosphoric acid, EDTA, and

Triton). The obturation method (lateral compaction, single cone, or vertical compaction) will further divide each group into three subgroups. All teeth must have a fully developed apex, a root canal curvature of no more than 20 degrees, no signs of decay or previous endodontic treatment, and a minimum root length of 13 mm to be considered. The research did not include teeth that had any kind of damage, such as fractures, resorption, or open apices. At the cementoenamel junction, the teeth were being sectioned. Radiology images were taken by Durra Dental in Bietigheim-Bissingen, Germany, to verify that the root canal did not have any internal resorption or calcification (Fig.1). The teeth were cleaned using scalers, which included removing calculus and soft tissue debris. Afterward, the teeth were rinsed under a constant flow of water. A 10/15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted until its tip became visible at the apical foramen, and the working length was set 1.0 mm short of this measurement. The canal preparation included the sequential use of the WaveOne Gold file system (Dentsply Maillefer, Ballaigues, Switzerland). The concluding irrigation step included the application of 2 ml of 17% EDTA (Ogna Lab, Muggiò, Italy) for 2 minutes, followed by a final rinse with 5 ml of 5% NaOCl for 5 minutes, aimed at enhancing the elimination of inorganic and organic components.

The root canals were irrigated with saline solution (SALF SPA, Cenate Sotto, Italy), dried using paper points (Dentsply Maillefer, Ballaigues, Switzerland), and obturated employing various techniques (lateral compaction, single cone, and vertical compaction) along with Bioceramic sealer Ceraseal (Meta Biomed Co., Cheongju, Korea). The obturation procedures were validated by radiographical perspectives. To prevent excessive expression of sealer, a sphere of translucent utility wax was placed around the root tips. Using the manufacturer-supplied tips, bioceramic sealer was meticulously put into the coronal third of every channel. For two weeks at 37°C with 100% humidity, all specimens were placed in a laboratory incubator (Steinberg, nowy kisielin-innowacyjna gora Poland, EU) to ensure that the sealer had time to fully set. To keep the teeth in place and avoid the extrusion of irrigants during the endodontic operation, specimens were prepared by being immersed "in a two-piece metal muffle that contained silicone material" (Fig. 2).

Retreatment

Re-instrumentation was by the crown-down approach included using ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) to remove all of the root canal filling materials:

- Group A, consisting of 9 specimens, phosphoric acid 37% (3M, Carl-Schurz-Str. 1. 41453 Neuss – Germany) were applied for 1 minute. This includes all three subgroups, with 3 specimens each obturated using a single cone, lateral compaction, and vertical compaction, respectively.
- Group B, consisting 9 of specimens, EDTA 17% (Ogna Lab, Muggiò, Italy), was employed for 1 minute. This includes all three subgroups, with 3 specimens each, obturated using a single cone, lateral compaction,

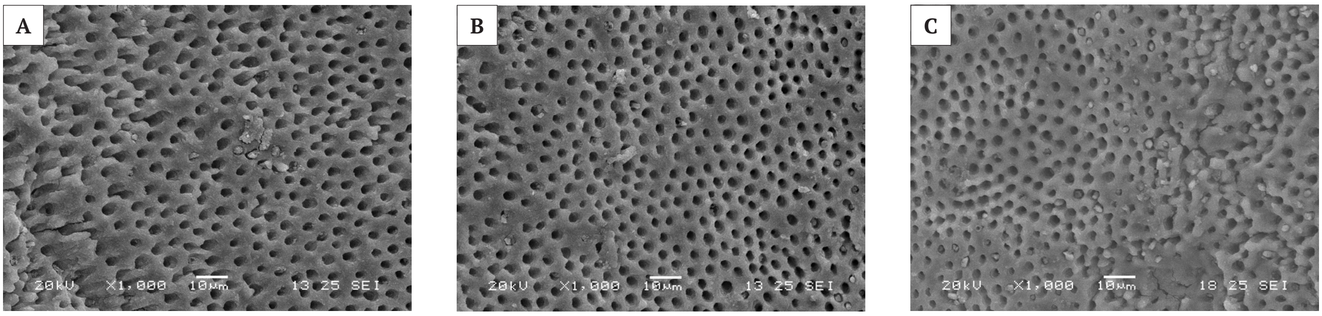


Fig. 1 SEM for the specimens irrigated with EDTA 17% were be obturated with lateral compaction technique (**A**) coronal part, (**B**) middle part, (**C**) apical part.

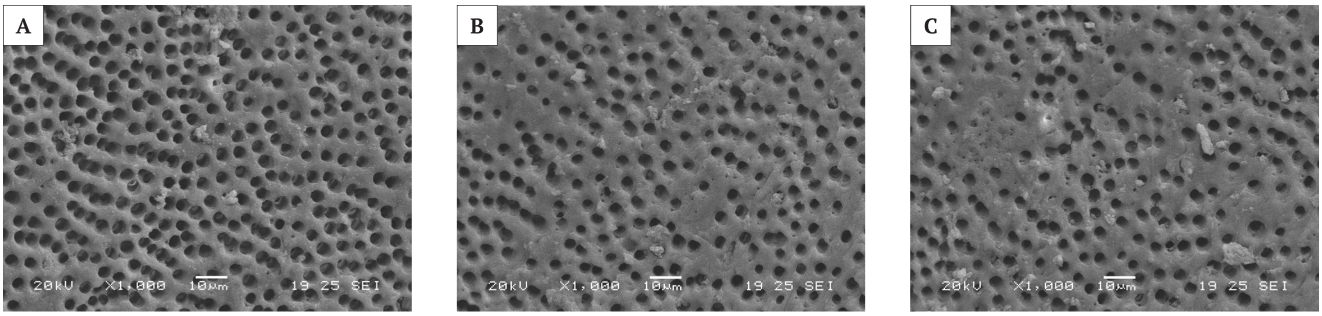
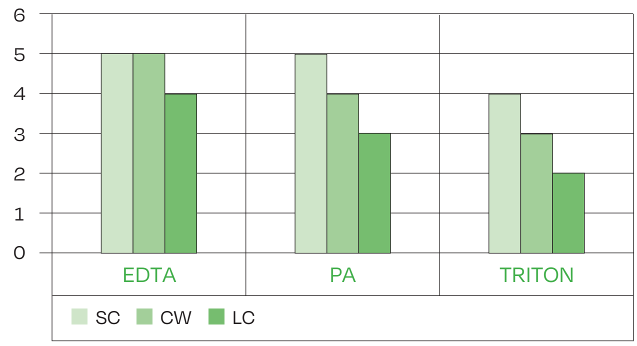
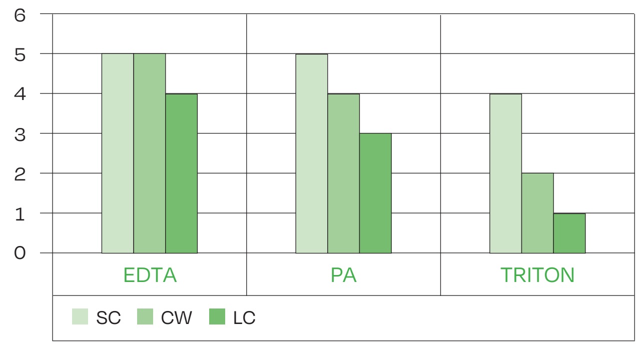


Fig. 2 SEM for the specimens irrigated with phosphoric acid 37% were be obturated with single cone technique (**A**) coronal part, (**B**) middle part, (**C**) apical part.



Tab. 1 Opened tubules (SC: Single Cone; CW Continuous Wave; LC: Lateral Condensation). The scores were: 1: "more or equal of smear layer or plugs to 50%"; 2: "less or equal of smear layer or plugs to 40%"; 3: "less or equal of smear layer or plugs to 30%"; 4: "less or equal of smear layer or plugs to 20%"; 5: "Less or equal of smear layer or plugs to 10%". The differences among the scores of the three groups are statistically significant different (p<0.01).



Tab. 2 Quantity of smear layers or plugs along the root canal walls (SC: Single Cone; CW Continuous Wave; LC: Lateral Condensation). The scores were: 1: "more or equal close tubules to 50%"; 2: "less or equal close tubules to 40%"; 3: "less or equal close tubules to 30%"; 4: "less or equal close tubules to 20%"; 5: "Less or equal close tubules to 10%". The differences among the scores of the three groups are statistically significant different (p<0.01).

and vertical compaction, respectively.

- Group C, consisting of 9 specimens, TRITON (Brasseler, Savannah, USA) were employed for 1 minute. This includes all three subgroups, with 3 specimens each obturated using a single cone, lateral compaction, and vertical compaction, respectively.

Subsequently, Passive Ultrasonic Irrigation (PUI) was executed by activating the irrigating solutions for groups B and C. The root canals were undergoing ultrasonic operation with the irrigant for 1 minute. Following the final irrigation, a 5 mL flush of saline solution (SALF SPA, Cenate Sotto, Italy) was administered to the canals to counteract further irritant effects, followed by drying with sterile paper points (Dentsply Maillefer, Ballaigues, Switzerland). The dental samples from both groups were sliced longitudinally using a low-speed saw (Isomet, Buehler Co., USA). To prevent contamination of the root canal area, the samples were not cut all the way through and were subsequently broken with a blad.

The samples were examined using a scanning electron microscope (Jsm-6060LV Scanning Electron Microscope, Jeol Ltd., Tokyo, Japan) at various magnifications of 1000x after being placed on matrices and gold-sputtered using an EMITECH K550 sputtering equipment.

Observation

Using a grading system ranging from 1 to 5, the researcher assessed the number of smear layers or plugs on the tooth surface by examining images captured under a microscope at various magnification levels (1000x).

1. "more or equal to 50%;"
2. "less or equal to 40%;"
3. "less or equal to 30%;"
4. "less or equal to 20%;"
5. "Less or equal to 10%."

Amount of obstruction of dentinal tubules found in the three groups Using the same rating system as before for debris assessment, the researcher has assessed the number of blocked tubules by observational investigations using a scale from 1 to 5. The 'amount of obstructed dentin tubules' were divided from 1 to 5:

1. "more or equal to 90%;"
2. "less or equal to 70%;
3. "less or equal to 50%;"
4. "less or equal to 20%;"
5. "Less or equal to 10%".

Two calibrated expert operators performed the microscopic observations; when their assessments differed, they re-evaluated the microscopic image jointly and reached a consensus. A statistical test (Wilcoxon and Fisher) was used to assess the collected data, with a p-value set at p<0.01.

RESULTS

Several example results related to the smear layer removal results are shown in (Table 1). EDTA was better for removing the smear layer in all the groups (p<0.05), except there was EDTA equivalent effectiveness with phosphoric acid with single cone technique. These findings were confirmed by the statistical evaluation (Wilcoxon p-value 0.01) of the difference values of three groups. For that the hypothesis of all treatment being equal was rejected.
The results of bioceramic removal are shown in (Table 2). EDTA was statistically more effective than phosphoric acid and Triton in removing the bioceramic sealer from all root canal thirds (p<0.05) (Figure 1). except the phosphoric acid with single cone obturation reported better efficiency in all canal thirds (Figure 2). Triton with single cone technique in the coronal part only was more affected (p<0.05), then reported reduced effectiveness significantly in the middle and apical parts (p>0.05) (Fig. 3).

DISCUSSION

The sealing efficacy of a sealer is associated with its solubility and its adhesion to gutta-percha. The sealing

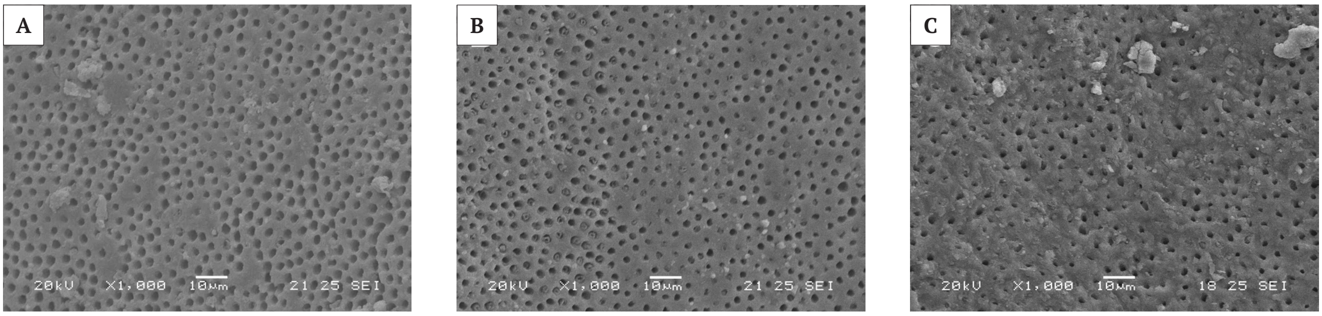


Fig. 3 SEM for the specimens irrigated with Triton were be obturated with vertical compaction technique (**A**) coronal part, (**B**) middle part, (**C**) apical part.

in contact with root canal dentin is enhanced by the capacity of bioceramic cement, owing to its calcium phosphate concentration, to adopt a crystalline form akin to that of hard biological tissues upon complete curing (34,35). Consequently, there was no significant difference in the quality of obturation when comparing single-cone, lateral condensation, and thermal techniques utilizing bioceramic sealer; the literature continues to favour the use of bioceramic cement with cold techniques and it is less inclined to endorse their application with warm techniques (36,38). Most bioceramic cements are very fluid and feature extremely minute particles, with an average size of just 0.2 µ. Due to their hydrophilic characteristics and low contact angle, third-generation bioceramic cement facilitates the easy spreading of sealer across the dentinal wall and their penetration into root dentin tubules and abnormalities (34). Hydrated calcium silicate forms hydroxyapatite when it comes in touch with phosphate-containing bodily fluids. Bioceramic sealers are quickly becoming the gold standard in endodontics, replacing the old standards that relied on a thin layer of cement and more gutta-percha (39).

The chemical link with dental substrates may have benefits for the obturated canals' sealability. However, it may also make removal exceedingly difficult if retreatment is needed (40), prior studies' heavy usage of epoxy resin sealer as a comparison (41). There is currently no retreatment strategy that has successfully removed all root canal-filling material (42,43).

Therefore, to overcome this challenge, in the present study, the evaluation was by SEM of the coronal, the middle, and the apical parts of the canals, and demonstrated that EDTA 17% for 1 minute with Passive Ultrasonic Irrigation (PUI) application showed significant difference to remove the smear layer and bioceramic sealer compared with phosphoric acid and Triton irrigation material. For that the tested null hypothesis was rejected.

The pH of the solution significantly influences the efficacy of EDTA solutions in cleansing root canals. The pH influences Ca2+ availability in several ways. The chelation efficacy of EDTA at elevated pH is shown to be superior owing to an increased ratio of ionized to nonionized molecules in the solution. At elevated pH levels, the surplus of hydroxyl groups will impede the dissociation of hydroxyapatite, hence restricting the availability of Ca2+ ions. At low or neutral pH, the binding of Ca2+ tends to enhance the dissociation of hydroxyapatite, hence increasing its availability for chelation (44).

Reports indicate that PUI promotes more efficient cleansing of the intermediate regions of the canal compared to the final few millimetres (45), even if mechanical activation of irrigants offers various advantages in root canal therapy. Consequently, the area percentage of the residual filling material was greatest in the apical third, followed by the middle, and finally, the coronal level. Two physical processes occur when waves go from the file to the irrigant: acoustic stream and irrigant cavitation. Cavitation is the distorting of preexisting bubbles in the irrigant, and the acoustic stream is the fast circular or vortex-shaped movement of the fluid around the file (46). Possible explanations include the plasticization of gutta-percha due to vibrations at the tip, which debond the sealer, and the heat produced by friction at the tip (47). Additionally, it was discovered that using 37% phosphoric acid gel for 1 minute caused an uneven etching pattern and an over-etched substrate in the root canal. As a result, the demineralization zone became too deep for the primers that were inserted afterward to fully penetrate. The high viscosity of the gel formulation likely contributed to the persistence of endodontic debris and smear layer remnants in the deeper sections of the root canal. These results indicate that the effective contact durations vary throughout the root canal surface; another research has shown that shortening etching periods and constantly re-applying the phosphoric acid gel using a micro brush may improve its effectiveness (48).

More little debris ends up in the dentinal tubules because of the difficulty in rinsing the gel formulation from the top of the post space (47). It follows that compared to a gel formulation, liquid phosphoric acid may provide reduced surface energy and improved wettability. Research on the adhesion enhancement of fibre posts has shown that the etchant cannot flow along the root canal due to the gel's high viscosity, thereby leading to spot where the smear layer remains. One possible explanation for the increased bond strength values compared to gel formulations is that the liquid formulation has better flow qualities, which allow it to reach the most problematic portions

of the post space. Possible causes of these discrepancies include variations in how the liquid phosphoric acid is applied (48,49). Although promoted as a revolutionary dual-action root canal irrigant, the current research found that Triton was less successful than EDTA and phosphoric acid in removing the bioceramic sealer and smear layer. According to prior research, Triton is just as efficient as EDTA in removing smear layers, and it also has antibacterial properties (50,51).
One investigation found that EDTA-mixed materials, such as SmearOFF (52) or etidronic acid (HEDP) [53], were less efficient than Triton alone in removing the smear layer. Additional research is required to determine Triton's surface tension. However, variations in solution penetration and surface tension may account for the observed variances in the current study.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that EDTA is more successful than phosphoric acid and Triton in eliminating the bioceramic sealer and smear layer from root canals and opening the dentinal tubules. None of the tested supplementary cleaning materials or techniques completely removed completely the residual filling material.

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