Micro–computed Tomographic Assessment of Supplementary Cleaning Techniques for Removing Bioceramic Sealer and Gutta-percha in Oval Canals

Andrea Volponi, DDS, MSc, Rina Andréa Pelegrine, DDS, MSc, PhD,* Augusto Shoji Kato, DDS, MSc, PhD,* Carolina Pessoa Stringheta, DDS, MSc,* Ricardo Tadeu Lopes, BSc, MSc, PhD,† Aline Saddock de Sá Silva, BSc, MSc, PhD,† and Carlos Eduardo da Silveira Bueno, DDS, MSc, PhD**

ABSTRACT

Introduction: The aim of this study was to conduct a micro–computed tomographic assessment of the effectiveness of 3 supplementary cleaning techniques in reducing the residual volume of gutta-percha and a bioceramic sealer after performing endodontic retreatment procedures in teeth with oval canals. **Methods:** Thirty-six mandibular premolars were instrumented with the ProTaper Next system (instruments X1–X3; Dentsply Maillefer, Ballaigues, Switzerland) and filled with gutta-percha and Bio-C Sealer (Angelus, Londrina, PR, Brazil) using the single-cone technique. The teeth were reinstrumented with the Reciproc R40 instrument (VDW, Munich, Germany) and divided into 3 groups according to the supplementary cleaning technique used ($n = 12$): ultrasonic-assisted irrigation (UAI), EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK) irrigation (EAI), or the XP-endo Finisher R system (XPR; FKG Dentaire, La Chaux-de-Fonds, Switzerland). Micro–computed tomographic imaging was used to quantify the residual volume of filling material. One-way analysis of variance complemented by the Tukey test was used to perform the statistical analysis ($P < .05$). **Results:** Significant reductions were obtained in the residual filling material after supplementary cleaning ($P < .05$). XPR (47.5%) led to significantly greater ($P < .05$) filling material removal than UAI (16.6%) or EAI (22.6%). The removal values of the 2 latter systems were not significantly different. **Conclusions:** XPR was more effective than UAI and EAI in removing filling material in mandibular premolars with oval canals. None of the tested supplementary cleaning techniques completely removed the residual filling material. *(J Endod 2020;46:1901–1906.)*

KEY WORDS:

EndoActivator; endodontic retreatment; ultrasonic-assisted irrigation; XP-endo Finisher R

SIGNIFICANCE

The use of a supplementary irrigation cleaning technique with the XP-endo Finisher R system was associated with the removal of a significantly greater amount of residual filling material than the use of passive ultrasonic-assisted irrigation or irrigation with the EndoActivator system after performing endodontic retreatment procedures in oval canals. None of the techniques completely removed the root canal filling residual obturation material.

Nonsurgical endodontic retreatment is the first option when conventional treatment fails[1] because it favors elimination of the microorganisms responsible for persistent infection[2,3]. However, complete removal of filling material during root canal retreatment using conventional techniques and instruments is not possible[4,5] because of anatomic complexity, especially in oval canals where irregularities are more frequent. Remnants of filling material and microorganisms can compromise the final retreatment outcome[6].

Mechanized systems and supplementary sonic and ultrasonic irrigation techniques have been developed for the removal of filling material[5,7,8]. The technique most frequently reported is ultrasonic-assisted irrigation (UAI), also known as passive ultrasonic irrigation[9,10]. Its action is based on cavitation and acoustic streaming at 30 kHz, promoted by the vibration of thin, smooth metallic ultrasonic inserts (Fig. 1).

From the *Faculdade São Leopoldo Mandic, Instituto de Pesquisa São Leopoldo Mandic, Endodontia, Campinas, São Paulo, Brazil; and †Laboratory of Nuclear Instrumentation, Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering, Federal University of Rio de Janeiro, Rio de Janeiro, Rio de Janeiro, Brazil

Address requests for reprints to Dr Carlos Eduardo da Silveira Bueno, Faculdade São Leopoldo Mandic, Instituto de Pesquisa São Leopoldo Mandic, Endodontia, Rua Dr José Rocha Junqueira 13, Campinas, SP, Brazil 13045-755.
E-mail address: carlosesbueno@terra.com.br

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The EndoActivator system (Dentsply Tulsa Dental Specialties, Tulsa, OK) uses a hydrodynamic phenomenon by which its flexible polymer tip (Fig. 1) agitates irrigants through sonic waves at 1–6 kHz[11–13]. Few studies have tested the effectiveness of this system in retreatment cases[5,14].

The XP-endo Finisher R instrument (XPR; FKG Dentaire, La Chaux-de-Fonds, Switzerland) is manufactured with the MaxWire alloy, which undergoes a phase transformation (martensitic to austenitic) when exposed to body temperature that causes the final millimeters of the instrument to take on a "spoonlike" shape (Fig. 1). According to the manufacturer, this spoon shape allows the instrument to reach irregular areas without changing the original shape of the canal. Recent studies have shown its effectiveness in removing filling material after endodontic retreatment procedures[8,15–17].

Tricalcium silicate–based (or "bioceramic") sealers have been studied for their biocompatibility and bioactive properties. Their setting reaction can produce hydroxyapatite on their surface and form taglike structures inside the dentinal tubules[18].

iRoot SP (Innovative BioCeramix, Vancouver, Canada) and EndoSequence BC (Brasseler USA, Savannah, GA) sealers were the pioneers in this segment and represent a type of sealer that has been trending in the market in recent years. Premixed Bio-C Sealer (Angelus, Londrina, PR, Brazil) was launched in 2018 and is composed of calcium silicates, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, dioxide silicone, and a dispersing agent[19]. Some studies have evaluated instrumentation techniques to remove such sealers from dentinal walls[7,20–24]. However, few have tested supplementary cleaning techniques to optimize the removal of this material[23,25,26].

The aim of this study was to use micro–computed tomographic (micro-CT) imaging to compare the effectiveness of 3 supplementary cleaning techniques in removing filling material after endodontic retreatment in oval canals: UAI, EndoActivator irrigation (EAI), or XPR. The residual gutta-percha and sealer were measured before and after performing the supplementary cleaning techniques. The null hypothesis was that no significant differences were present among the 3 techniques in their effectiveness in removing gutta-percha and bioceramic sealer.

MATERIALS AND METHODS

Specimen Selection and Initial Canal Preparation

This study was approved by the local institutional research ethics committee (approval no. 3.499.465). Sample size calculation was performed using the analysis of variance test and considered an effect size of 0.551 (obtained from a pilot study with $n = 3$), a significance level of 5%, and a test power of 80%. The calculation performed with G*Power v. 3.1.9.4 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany)[27] indicated that a minimum of 36 specimens ($n = 12$) would be required.

Mandibular premolar teeth, recently extracted for periodontal and orthodontic reasons, were donated by patients and kept in a 0.1% thymol solution under refrigeration for a maximum period of 3 months before use in the study. The teeth were radiographed in the mesiodistal and buccolingual directions, and 36 mandibular premolars were selected after applying the following inclusion criteria: teeth with oval canals (buccolingual diameter twice as large as the mesiodistal diameter as of 5 mm short the root apex), fully formed roots, no calcifications, no internal or external resorption, no fractures or previous endodontic treatment, a single root canal, straight roots or roots with curvature angles of up to 5° measured using the Schneider method[28], and an apical diameter equivalent to a #15 K-type file (Dentsply Maillefer, Ballaigues, Switzerland).

The crowns were sectioned with a double-sided diamond disc (KG Sorensen, Cotia, SP, Brazil) at low speed and water-cooled to standardize the specimen length to 16 mm. A #15 K-type file (Dentsply Maillefer) was inserted into the canal until its tip was visible at the apical foramen. The working length (WL) was established 1 mm short of the apical foramen. All procedures were performed using an operating microscope (Zeiss Opmi Pico; Carl Zeiss, Oberkochen, Germany) under 13× magnification by a single endodontic specialist trained to use the instrumentation and supplementary cleaning systems.

The canals were prepared with files X1 (17/.04), X2 (25/.06), and X3 (30/.07) of the ProTaper Next system (Dentsply Maillefer) coupled to the X-Smart Plus engine (Dentsply Maillefer) and operated in "ProTaper Next" mode at a speed of 300 rpm and torque of 2.0 Ncm. Instrumentation was performed in the crown to apex direction by introducing the file into the canal with 3 in-and-out movements using a brushing action on the withdrawal stroke. After each cycle of 3 movements, the debris on the instrument was cleaned with 70% alcohol–soaked gauze. This procedure was repeated until the 3 instruments (X1–X3) reached the WL. Foraminal patency was maintained by inserting a #15 K-type file (Dentsply Maillefer) 1 mm beyond the WL at each instrument change. The canal was irrigated with a 2.5% sodium hypochlorite (NaOCl) solution using a disposable syringe and a 30-G NaviTip needle (Ultradent, South Jordan, UT) positioned 2 mm short of the WL; 20 mL solution was used per specimen. The files were used for only 1 canal.

After instrumentation, the canals were irrigated with 2 mL 17% EDTA solution (Fórmula & Ação, São Paulo, SP, Brazil) using an E1 Irrisonic 20/.01 insert (Helse Ultrasonic, Santa Rosa do Viterbo, SP, Brazil) coupled to an ultrasound unit (NSK; Nakanishi, Tochigi, Japan) operated at 20% power. The insert was positioned 2 mm short of the WL, and the solution was activated in 3 cycles of 20 seconds and refreshed for each cycle, as reported in a previous study[29]. Another irrigation was performed with 2.5% NaOCl following the same activation protocol used for 17% EDTA. The canals were dried with paper points (Dentsply Maillefer).

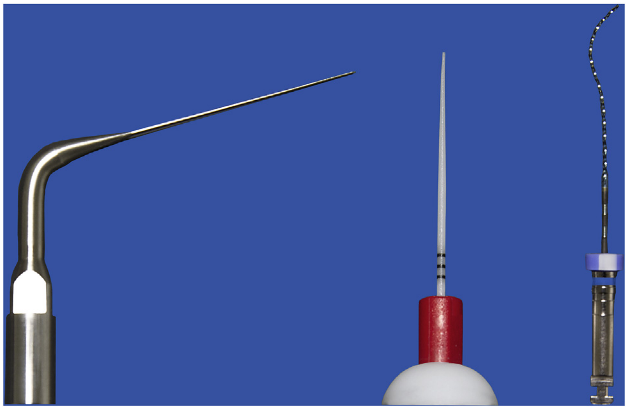

FIGURE 1 – Instruments used for the supplementary cleaning techniques performed in the study. (*Left*) Irrisonic insert (20/.01), (*center*) EndoActivator tip (25/.04), and (*right*) XPR (30/.00).

Root Canal Obturation

The canals were obturated with X3 gutta-percha cones (Dentsply Maillefer) and Bio-C Sealer using the single-cone technique. The sealer paste was introduced into the canal, and the middle and apical thirds were filled. The gutta-percha cone was coated with the sealer and immediately placed into the canal up to the WL. Excess gutta-percha was removed with a hot plugger, and cold vertical compaction was performed. The pulp cavity was cleaned with cotton dipped slightly in 70% alcohol and then sealed with Coltosol (Coltene, Altstätten, Switzerland). The specimens were kept in 100% humidity at 37°C for 4 weeks to allow complete setting of the sealer.

Root Canal Retreatment

Retreatment procedures were performed using files from the Reciproc R40 (40/.06) system (VDW, Munich, Germany) coupled to the X-Smart Plus motor (Dentsply Maillefer) operated in "Reciproc" mode. The instrument was inserted into the canal with 3 in-and-out cycles of 3 mm using a brushing motion on the withdrawal stroke. After every 3 cycles, the instrument was removed and cleaned with 70% alcohol–soaked gauze, and the canal was irrigated with 2.5% NaOCl, totaling 20 mL of solution per specimen. This procedure was performed until the R40 file reached the WL and foraminal patency could be maintained with a #15 K-type file (Dentsply Maillefer). Each Reciproc instrument was used on a single specimen. Retreatment was considered complete when no filling material was observed on the instrument or suspended in the irrigating solution viewed at 13× under an operating microscope (Carl Zeiss). The canals were dried with paper points (Dentsply Maillefer).

Supplementary Cleaning Techniques

Each specimen was submitted to a micro-CT scan to quantify the volume of filling material before the cleaning techniques were performed. The specimens were then ranked according to volume and randomly distributed (www.random.org) into 3 volume-matched experimental groups ($n = 12$) according to the supplementary cleaning technique applied.

Group UAI

The canals were irrigated with 2 mL 17% EDTA using an E1 Irrisonic 20/.01 insert (Helse) coupled to an ultrasound unit (NSK) operated at 20% power. The insert was positioned 2 mm short of the WL with vertical in-and-out movements, and the irrigating solution was activated in 3 cycles of 20 seconds and refreshed after each cycle, as reported in a previous study[29]. Subsequently, the canal was aspirated and irrigated with 2.5% NaOCl following the same activation protocol used for 17% EDTA.

Group EAI

The irrigants were used following the same protocol described for the UAI group, but their sonic activation was performed with the EndoActivator blunt, flexible polymer tip (25/.04) coupled to a handpiece operated at 10,000 cycles/min with vertical in-and-out movements 2 mm short of the WL.

Group XPR

An XPR instrument (30/.00) was coupled to the X-Smart Plus motor and driven at 800 rpm with 1 Ncm torque; slow in-and-out movements of 7–8 mm were applied up to the WL. The same irrigation protocol used for the other groups was followed.

All the supplementary cleaning techniques were performed at 37°C inside a cabinet containing a heater and controlled by a thermometer. Finally, all the specimens were dried with paper points.

Micro-CT Imaging

A SkyScan High Energy 1173 apparatus (Bruker microCT, Kontich, Belgium) was used to obtain micro-CT scans for each canal at 3 time points during the study: after root canal obturation and before and after performing the supplementary cleaning techniques. The scanning parameters were as follows: 70 kV, 114 mA, 1.0-mm-thick Al filter, 16.5-μm pixel size, and 360° rotation with 0.5° steps. The images were reconstructed in cross sections using NRecon v. 1.7.0.4 software (Bruker microCT). After reconstruction, CTAn v. 1.16.4.1 software (Bruker microCT) was used to select the region of interest and to perform binarization and image segmentation. Ctvox software v. 3.2.0.0. (Bruker microCT) was used for viewing and analyzing 2-dimensional and 3-dimensional images. The analyses were conducted on the entire root canal, and the volumes were determined before and after completion of the supplementary cleaning techniques. In addition, the volume of filling material removed (in mm^3 and percentage) was calculated.

Statistical Analysis

Compliance with the requirements of normal distribution and homoscedasticity of the data was evaluated, and the square root function was applied to perform the required transformation. One-way analysis of variance was used to compare the residual volumes of filling material before and after performing the supplementary techniques as well as to evaluate the effectiveness of filling material removal. The Tukey test was used in the multiple comparisons. The statistical calculations were performed using SPSS 23 software (IBM Corp, Armonk, NY); a 5% level of significance was adopted.

RESULTS

Figure 2*A–C* shows the 3-dimensional reconstructions of representative specimens from the 3 study groups. Superimpositions were performed to show the removal of filling material promoted by the supplementary cleaning techniques tested.

No significant difference was observed among the residual volumes found for the 3 study groups before ($P > .05$) or after ($P > .05$) performing the supplementary irrigation techniques (Table 1). However, the volume of residual filling material removed was significantly affected by the techniques tested ($P < .05$). The volume removed by XPR was significantly greater than the amounts removed by UAI or EAI, which were not significantly different (Table 1). The removal percentages ($P < .05$, Table 1) differed significantly, with the same trend.

DISCUSSION

The 3 cleaning techniques promoted significant removal of residual filling material from the root canals; however, the percentage of residual volume of filling material for the XPR group was significantly lower than that observed for the UAI and EAI groups. Therefore, the null hypothesis was rejected. The tip of the XPR instrument takes on a "spoon shape" at body temperature, which seemed to enable broader canal contact and greater obturation material removal. The 3 techniques tested rely on different mechanisms of action, and the instruments involved have different designs; the results of the present study suggest that the shape of the XPR instrument was more decisive than the vibration frequency of the UAI and EAI techniques. Furthermore, the XPR instrument can be inserted up to the WL, unlike the instruments for the ultrasonic and sonic techniques tested.

A previous study also using the micro-CT method found that the XPR instrument was superior to UAI[17], and others found that all of the supplementary cleaning methods tested (XP-endo Finisher, XPR, and UAI) had a significant effect on the removal of residual filling material after retreatment procedures, corroborating the results of the present

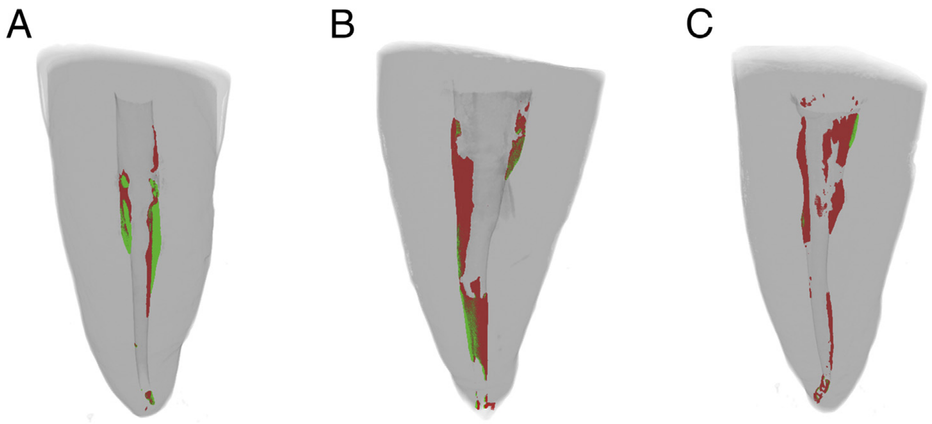

FIGURE 2 – Three-dimensional reconstructions of representative specimens from the 3 study groups showing the residual volume of filling material before (in *red*) and after (in *green*) performing each supplementary cleaning technique tested. (*A*) UAI (group UAI), (*B*) EndoActivator irrigation (group EAI), and (*C*) XPR (XPR group).

study[8,15–17]; however, Campbello et al[15] tested the XPR only in the apical 5 mm of the mesial canal with and without use of a solvent. Herein, the supplementary cleaning techniques were tested on the entire length of the root canal without solvent.

Micro-CT imaging is a nondestructive method and allows accurate analysis of the residual volume of filling material in the same specimen at different stages of the experiment, unlike the method of cleaving the specimen and submitting its root canal to direct observation[30,31]. Furthermore, the micro-CT method significantly reduces the interpretation bias inherent in the direct observation method by ruling out both examiner variability and any improper specimen manipulation during cleavage[30].

UAI had a positive impact on the removal of filling material but was significantly less effective than XPR. Because UAI action is based on the formation of acoustic streaming and cavitation[29], the ultrasonic insert must not touch the root canal walls and must remain 2 mm short of the WL to allow circulation of the irrigating liquid and ensure maximum efficiency. UAI was developed to remove the smear layer, which is not as compact as filling material, and cavitation may not be sufficient to displace the filling material in retreatment cases. De-Deus et al[17] observed that UAI promoted the removal of filling material after reinstrumentation but less effectively than XPR (12.8% vs 32.8%, respectively), corroborating the results of the present study. Martins et al[5] observed that neither UAI nor EAI had a positive impact on the removal of filling material. These authors used a zinc oxide eugenol–based sealer, which is more easily removed by mechanized instrumentation than tricalcium silicate–based materials during the first steps of retreatment[7]; this could render the contribution of any supplementary technique less evident. In the present study, EAI significantly reduced the amount of residual filling material, but it was less effective than XPR. The hydrodynamic phenomenon promoted by the blunt, flexible polymer tip of the EndoActivator was seemingly less successful in removing obturation material, especially in regions containing anatomic irregularities.

Even though the 3 cleaning techniques were able to remove significant amounts of residual filling material, none of them succeeded in producing entirely debris-free root canals, as reported in previous investigations[5,15,17]. Because any amount of remaining debris or bacteria, in principle, could be enough to compromise retreatment, the search for increasingly more effective cleaning techniques should be ongoing.

A tricalcium silicate–based sealer was used in this study because this class of material has been reported to induce the formation of hydroxyapatite tags, thereby contributing to its sealing abilities[18] and ultimately rendering it more difficult to remove. The results reported in the literature on this subject are controversial. A previous study concluded that bioceramic sealers were more difficult to remove than sealers based on epoxy resin[22], whereas others found opposite results[21,32]. These discrepancies may be associated with methodological differences, namely the use of different rotary instruments, different brands of bioceramic sealers, and different tooth types. In addition, the bioceramic sealer used in the present study is a newly launched material; its properties of adhesion to dentinal walls still require further

TABLE 1 - Means and Standard Deviations of the Residual Volumes of Filling Material (in mm^3) and the Amount of Filling Material Removed (in mm^3 and Percentage) before and after Applying the Supplementary Cleaning Techniques and according to the Study Group

	Volume of residual filling material		Filling material removed	
Study group	**Before**	**After**	**Volume (mm^3)**	**Percentage (%)**
UAI	2.426 (1.688)	1.993 (1.369)	0.433 (0.350)^B	16.6 (6.5)^B
EAI	1.764 (1.160)	1.375 (1.085)	0.389 (0.457)^B	22.6 (21.1)^B
XPR	2.794 (1.950)	1.462 (1.338)	1.331 (1.100)^A	47.5 (29.3)^A

EAI, irrigation with the EndoActivator system; UAI, ultrasonic-assisted Irrigation; XPR, XP-endo Finisher R system.
Means followed by different letters within each column indicate a statistically significant difference among groups.

investigation so that accurate comparisons can be made with the results of other studies.

It is important to look into techniques that can optimize the removal of bioceramic sealers in retreatment procedures. Further investigation is warranted to compare cleaning methods and provide scientific support for the development of techniques that can remove the different types of endodontic filling materials more effectively.

CONCLUSIONS

Cleaning with the XPR instrument was more effective in removing residual Bio-C sealer and gutta-percha from oval canals than the other supplementary techniques tested. None of the techniques completely removed the residual root canal filling material.

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The authors deny any conflicts of interest related to this study.

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