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Removal of Obturation Material from Root Canals Using a Combination of Reciprocal Instrumentation and Different Final Irrigation Techniques

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ABSTRACT

Introduction: The predictability of successful non-surgical endodontic retreatment is directly related to it's ability to completely cleanse and remove obturation material from the canal system. The purpose of this study was to evaluate the removal of gutta-percha from curved canals using three final irrigation methods: passive ultrasonic irrigation (PUI) with a 20/01 E1 insert (Irrisonic); XP-endo Finisher (XPF); and Easy Clean (EC). **Methods and Materials**: Forty mesial roots of mandibular molars with an angle of curvature between 10° and 20°, two canals, and independent foramina were cut into 16-mm sections. The canals were instrumented using the Reciproc system (R25) and filled with a #25 gutta-percha cone and AH-Plus sealer by the continuous-wave condensation technique. The roots were double-sealed with Coltosol and photopolymerizable resin and stored at 37°C and 100% humidity for 30 days. They were then randomized into 4 groups (*n*=10): control (C), PUI, XPF, and EC. All specimens were scanned using cone-beam computed tomography (CBCT), and fill volume data (in square pixels) were calculated before retreatment, after retreatment, and after final irrigation. The images were analyzed using Tps Dig software 2.32 by two blinded, calibrated examiners (intra-class correlation coefficient=0.9967). The results were analyzed in BioEstat 4.0. The nonparametric Kruskal-Wallis test with Dunn's post-hoc and Friedman comparison were applied. Significance was accepted at 5% ($P<0.05$). **Results**: None of the final irrigation protocols completely removed remnants of obturation material from the root canal systems ($P>0.05$). On comparative analysis with specimens divided into thirds, all methods were found to remove material equally, with no significant differences ($P>0.05$). **Conclusion**: Based on this *in vitro* study, the additional cleaning methods tested were equivalent to each other and did not lead to an improvement in the removal of residual obturation material.

Keywords: Cone-beam Computed Tomography; Endodontic Retreatment; Gutta-Percha

Introduction

Failure of endodontic treatment leads to retreatment, either due to failures in primary filling, presence of untreated canals, improper root canal treatment or even coronal leakage. Persistent or secondary intraradicular infection is a major cause of post-treatment disease [1, 2]. Non-surgical retreatment consists of decontamination of the root canal systems to provide conditions conducive to the patient's own healing processes; thus, the greater the amount of filling material removed from the root canal system and the wider the access to the foramen, the better the cleaning, shaping, and re-obturation stages of retreatment will be [3].

Removal of root filling material during root canal retreatment is necessary to eliminate necrotic material and bacterial remnants from the root canal space. Nonsurgical root canal retreatment is indicated when the initial procedure has failed and can be corrected by improving root canal disinfection and debridement, and placing a consistent and homogeneous filling. Several techniques are available to remove obturation material, including manual, rotary, or reciprocating instrumentation; heat; solvents; and ultrasonic inserts [4, 5]. However, the literature reports that none of the retreatment techniques tested in previous studies is capable of removing remnants of obturation material completely from the root canal system [6-9]. Automated rotary and reciprocating systems have been used to remove obturation materials, and can be faster, more efficient, and safer than manual instrumentation [9-11].

Reciprocating instrumentation, although originally intended for endodontic treatment, has demonstrated satisfactory results when used for retreatment in *ex vivo* studies [11-13]. The S-shaped cross-section and M-wire alloy of the Reciproc™ system provide greater strength when removing gutta-percha from the root canal system [14].

Several supplemental irrigation techniques are also available, including passive ultrasonic irrigation (PUI), which consists of the activation of a smooth insert coupled to an ultrasound device with the objective of potentiating the effect of the irrigant by releasing additional energy through cavitation and acoustic micro-streaming. However, these phenomena are associated with the intensity of the stream generated by the ultrasonic device, the free space within the root canal, and absence of interference from the tip of the insert [15].

In an attempt to improve cleaning of the root canal system for both treatment and retreatment, the Easy Clean (EC, Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) instrument has been developed. According to the manufacturer, the EC uses reciprocating or rotary motion to mechanically activate the irrigant. The EC instrument is a 25/0.04 file made from acrylonitrile butadiene styrene (ABS) polymer, with an "aircraft wing" cross-section. It agitates the irrigation solution throughout the working length of the tooth, thus allowing better mechanical cleaning of the apical third [15-17].

The XP-endo Finisher (XPF, FKG Dentair, La Chaux-de-Fonds, Switzerland) instrument is a 25/.00 file made from NiTi MaxWire alloy which changes in shape with changes in temperature. Below 30° C, the alloy remains in the linear (predominantly martensitic) phase. When advanced into the root canal at body temperature, it undergoes transformation to the austenitic phase, in which the instrument expands to take on a spoon shape in its distal 10 mm and a diameter of 6 mm when driven in rotary motion. The alternating contraction and expansion of the instrument scrapes the walls of the canal and causes turbulent flow of the irrigant. These unique features give the instrument particular potential for adjunctive use in endodontic retreatment [18].

Recent advances in instrumentation and irrigation have improved our ability to disinfect and clean the root canal system, but removal of all obturation material in cases of retreatment is still impossible. Thus, additional cleaning techniques have been proposed [8].

The purpose of this study was to evaluate three final irrigation techniques-PUI, XP-Endo Finisher, and Easy Clean-when used in combination with reciprocating motion for removal of obturation material from curved root canals.

The null hypothesis is that these three final irrigation techniques would not provide increased removal of obturation material as compared with reciprocating instrumentation alone.

Table 1. Medians, interquartile ranges, and Kruskal–Wallis statistics (with Dunn's post-hoc test) for areas containing gutta-percha in each sample group (pixels). For comparing C, M and A thirds in each group, the Friedman test was used

	After obturation	After removal of obturation material	XP Endo	(*P*)
C	521.00 (253.12) ^{Aab}	81.75 (148.12) ^{Ba}	0.00 (11.75) ^{Ba}	<0.05
M	783.25 (322.87) ^{Aa}	59.50 (110.75) ^{Ba}	3.75 (53.62) ^{Ba}	<0.05
A	338.25 (486.87) ^{Ab}	16.75 (51.87) ^{Ba}	0.00 (8.75) ^{Ba}	<0.05
(***P***)	<0.05	0.3342	0.8105	
	After obturation	**After removal of obturation material**	**PUI**	**(*P*)**
C	588.75 (429.75) ^{Aa}	19.50 (33.87) ^{Ba}	4.00 (35.00) ^{Ba}	<0.05
M	685.00 (495.37) ^{Aa}	52.00 (117.87) ^{Ba}	31.50 (80.75) ^{Ba}	<0.05
A	335.50 (487.37) ^{Aa}	23.50 (28.75) ^{Ba}	11.75 (12.47) ^{Ba}	<0.05
(***P***)	0.0625	0.0927	0.3235	
	After obturation	**After removal of obturation material**	**Easy Clean**	**(*P*)**
C	700.25 (343.50) ^{Aab}	22.75 (31.87) ^{Ba}	3.00 (9.87) ^{Ba}	<0.05
M	772.75 (359.25) ^{Aa}	30.00 (81.12) ^{Ba}	19.35 (32.65) ^{Ba}	<0.05
A	317.50 (196.00) ^{Ab}	0.00 (39.00) ^{Ba}	0.00 (7.50) ^{Ba}	<0.05
(***P***)	<0.05	0.1615	0.0600	

Different uppercase letters in the horizontal direction and different lowercase letters in the vertical direction: statistically significant differences; C, M, A: Coronal, Medical, Apical thirds of the roots

Materials and Methods

The present study was approved by São Leopoldo Mandic Research Ethics Committee, Campinas, São Paulo, Brazil (protocol no. 2,155,858). All procedures were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Forty extracted mandibular molars were selected from a sample of 100. Plain radiographs (in buccolingual and mesiodistal views) and inspection under an operating microscope (DF Vasconcelos, São Paulo, SP, Brazil) under 12.5× magnification were used to assess teeth for the following inclusion criteria: apex completed; absence of prior endodontic treatment; and absence of root fractures, cracks, or lacerations. The patency of mesial roots containing two canals, two independent foramina, and moderate angulation (10° to 20°) (12) was confirmed visually with a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and working length established 1 mm short of the apex.

Sample preparation

Crowns were bisected at the level of cementoenamel junction (CEJ) with a diamond disc (FKG, Dentaire, La Chaux-de-Fonds, Switzerland) to standardize the mesial root length at 16 mm. A digital caliper (500 DIN 862, Mitutoyo, São Paulo, SP, Brazil) was used to confirm the dimensions of the specimens. Then, using a #1011 round diamond bur (KG Sorensen, Cotia, SP, Brazil) in a high-rotation handpiece, a groove was cut to identify the buccal and lingual canals of each mesial root. The entire procedure was performed under operating microscope visualization (D. F. Vasconcelos, São Paulo, SP, Brazil) under 12.5× magnification. Specimens were stored in 0.1% thymol (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) until use.

Primary endodontic treatment

For standardization purposes, all specimens were handled by a single endodontist with expertise in the techniques used in the study. After standardization, roots were irrigated with 5 mL 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) in a disposable syringe (BD, São Caetano do Sul, SP, Brazil) with a NaviTip 30G irrigation tip (Ultradent, Indaiatuba, SP, Brazil). The instrumentation process followed the manufacturer's recommendations. The Reciproc R25 (25/0.08) file was driven with a VDW Silver motor (VDW, Munich, Germany) in "Reciproc All" mode, performing in-and-out motions with an amplitude of 3 mm. Abundant irrigation (5 mL) was applied at each third (cervical, middle, and apical) using a 10-mL disposable syringe (BD, São Caetano do Sul, SP, Brazil) with a 10 mm-long Navi Tip 0.030 needle (Ultradent, Indaiatuba, SP, Brazil). The file was discarded after a single use per specimen. In all groups, final irrigation with 5 mL of 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) was performed for a total volume of 25 mL [15] irrigant per specimen. This was followed by sonication with 1 mL 17% ethylenediaminetetraacetic acid (EDTA) (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) for 1 min [14].

After instrumentation, the canals were dried with R25 paper points and obturated with R25 gutta-percha cones (VDW, Munich, Germany). The primary cone was coated with AH-Plus cement (VDW, Munich, Germany), compounded per manufacturer recommendations, and advanced to the full working length of the canal. Then, metal condensers (FM, M, ML) were selected and coupled to a Touch'n Heat endodontic heat source (SybronEndo, Orange, CA, USA). The heat source was activated and the gutta-percha was condensed until 5 mm short of the working length. Then, the device was switched off, cold vertical condensation allowed to occur for 5 sec, and the device fired again to break up the gutta-percha in the 5 mm apical plug and empty out the middle and cervical thirds of the canal. Then, an Obtura II gun (Spartan Obtura, Algonquin, IL, USA) was loaded with a gutta-percha bar (Odous, Belo Horizonte, Brazil) and used to obturate the remaining two-thirds of the canal gradually, followed by manual cold vertical condensation with #1/2 and #3/4 condensers (Odous, Belo Horizonte, Brazil) for 2 to 3 min.

The coronal third was sealed with two coats of Coltosol (Coltene, Altstatten, Switzerland) and Filtek Z 250 XT OA2 composite resin (3M ESPE, Ribeirão Preto, SP, Brazil). After obturation, the teeth were stored at 37 °C in a 1.5-mL graduated Eppendorf microcentrifuge tube filled with distilled water (100% humidity) (Pharmacia Macela Dourada, Ipiaú, BA, Brazil), until the endodontic cement had cured completely [3, 7].

Initial cone-beam computed tomography image analysis

At this point, the first cone-beam computed tomography scans were obtained with a Kodak 9000 extraoral imaging system (Carestream, Atlanta, Georgia, USA). The specimens were fixed in place with two sheets of base plate wax (Asfer, São Caetano do Sul, SP, Brazil), to a thickness of 10 mm. The scan parameters were: 110 kVp, 12 mA, 0.2 mm voxel size, 8 cm field of view (FOV), and 40 sec acquisition time. Sagittal and axial sections were obtained as initial volumes for quantification and three-dimensional (3D) evaluation of primary obturation.

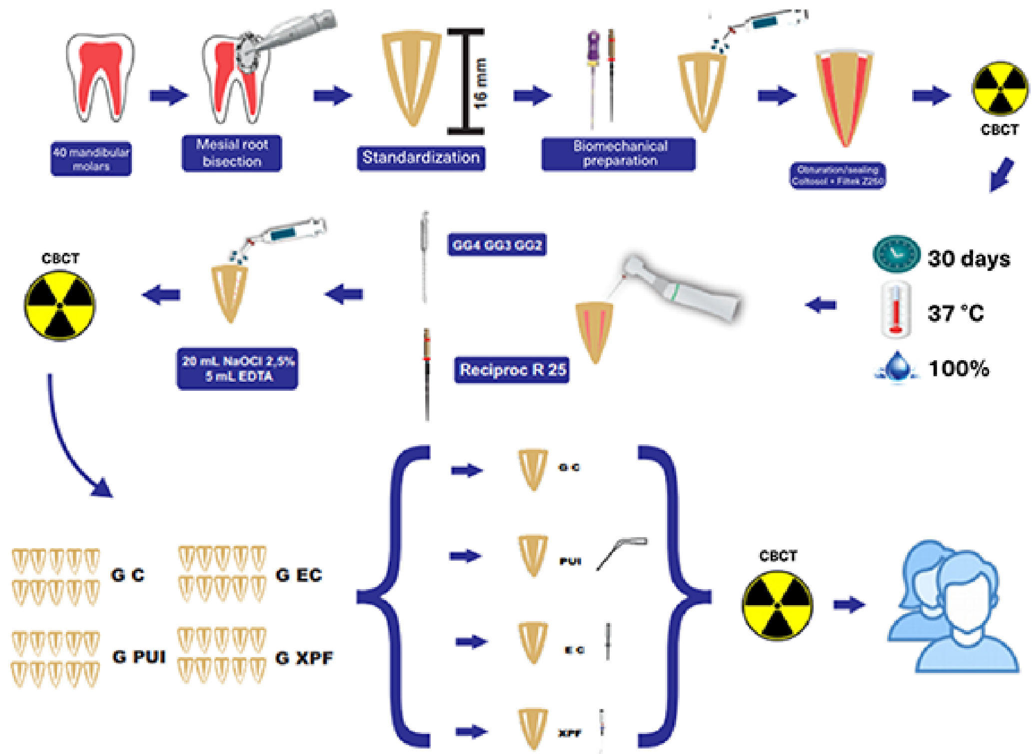

Figure 1. Schematic diagram of the study methodology has been shown

Removal of obturation material

Removal of obturation material was initially performed using #2, #3, and #4 Gates-Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland), in decreasing order and anti-curvature manner, to a mean depth of 5 mm, until the middle third. No solvents were used; only irrigation with 10 mL 2.5% sodium hypochlorite and constant aspiration. All canals were re-instrumented to Reciproc R25 patency. Removal of obturation material was considered complete when a withdrawn instrument was free of any adherent material and was visually clean when rubbed onto a sterile gauze pad. The root was observed under a dental operating microscope under 12.5× magnification and on periapical radiographs to confirm the absence of any remaining material. Final irrigation was performed with 5 mL 17% EDTA (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) for 1 min and 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil), to a final volume of 25 mL per root [15].

Midpoint cone-beam computed tomography image analysis

After removal of obturation material, all teeth were scanned again using the setting listed in item 2.3. Remnants of obturation material were quantified using TpsDig version 2.32 software (Institute of Data Analysis and Visualization (IDAV) and University of California, Davis, USA).

Final irrigation technique (PUI, XP-endo Finisher, and Easy Clean)

Random allocation of samples was performed using a computer algorithm (http://www.random.org) [7]. Teeth were allocated across four groups (*n*=10 each group): The number of specimens in each group was obtained by sample size calculation after a pilot experiment. Sample size calculation was performed by ANOVA, with a minimum difference between treatment means=3, standard error=2, number of treatments=3, statistical power=0.80, and alpha=0.05. The sample size was calculated as 10.

Control group (CG): After removal of obturation material, no additional procedures were performed other than conventional

PUI group (PUIG): Passive ultrasonic irrigation with 17%irrigation. EDTA and 2.5% sodium hypochlorite was done. The PUI was performed with the E120/0.01 Irrissonic device (Helse, Santa Rosa de Viterbo, SP, Brazil) and a 10-mL disposable syringe (BD, São Caetano do Sul, SP, Brazil) with NaviTip 30G needle (Ultradent, Indaiatuba, SP, Brazil). The sequence consisted of three 20-sec cycles of ultrasonic agitation interspersed with irrigation with 5 mL 2.5% sodium hypochlorite followed by 5 mL 17% EDTA and 5 mL 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) in each canal respectively, less than 1 mm short of the working length, under constant aspiration with a disposable endodontic suction tip (SSPlus, Maringá, Paraná, Brazil). The power of the ultrasonic device was low level (20%).

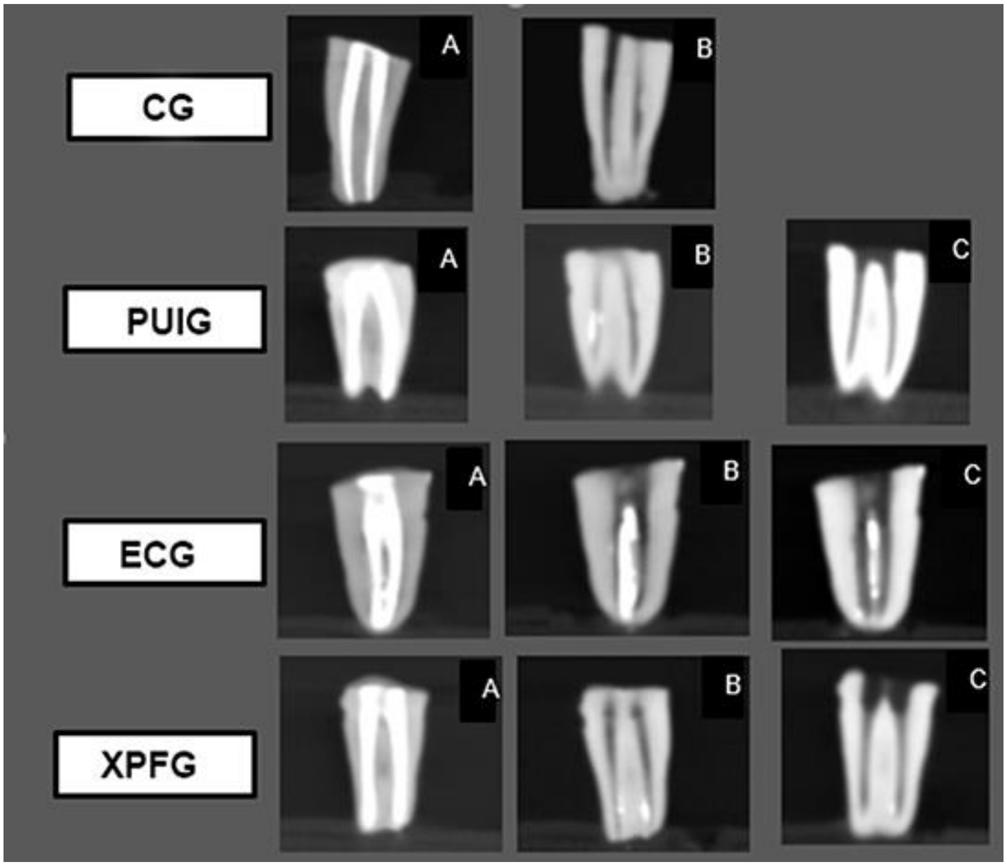

Figure 2. Sagittal cone-beam CT images of each groups in the following phases has been shown: *A*) Obturated; *B*) Removal of obturation material; *C*) Supplementary irrigation technique

Easy Clean group (ECG): The Easy Clean instrument was advanced to the full working length, driven by a VDW Silver endo motor (VDW, Munich, Germany) in "Reciproc All" mode, for three 20-sec cycles of ultrasonic agitation, interspersed by 5 mL of 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) followed by 5 mL 17% EDTA and 5 mL 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil). Fresh irrigant was used between each cycle, administered *via* a 10-mL disposable syringe (BD, São Caetano do Sul, SP, Brazil) with a NaviTip 30G needle (Ultradent, Indaiatuba, SP, Brazil). Again, constant aspiration was provided by a disposable endodontic suction tip. (SSPlus, Maringá, Paraná, Brazil). Tips were used once per root canal and discarded.

XP-endo Finisher group (XPFG): Each canal was irrigated with 2.5 mL 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) followed by 5 mL 17% EDTA and 5 mL 2.5% sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil). The XP-endo Finisher file was applied to the canal for 1 min, at 800 rpm, torque 1 N, to the full working length, using repetitive in-and-out motions at a depth of 7 to 8 mm, as recommended by the manufacturer [18].

The NaOCl was warm up in all groups. The sodium hypochlorite (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) warmed to 37°C in a glass container coupled to an analog thermometer with a suction cup and immersion heater. Upon reaching the desired temperature, the irrigant was administered through a 10-mL disposable syringe (BD, São Caetano do Sul, SP, Brazil) with Navitip 30G irrigation tip (Ultradent, Indaiatuba, SP, Brazil).

The irrigant volume and irrigation sequence were standardized, and included a final rinse with 5 mL of distilled water in all tested groups (Pharmacia Macela Dourada, Ipiaú, BA, Brazil) [15].

Final cone-beam computed tomography image analysis

After use of the final irrigation methods according to group allocation, a second cone-beam CT scan and quantification of the remaining obturation material were performed for comparisons, using TpsDig 2.32 software. The images were sent to two blinded, calibrated examiners (intraclass correlation coefficient=0.9967), who quantified remaining obturation material visible on axial and sagittal sections (Figure 1).

Statistical analysis

Data acquired through TpsDig 2.32 software (in square pixels) were evaluated and quantified by two blinded, calibrated examiners. The results were analyzed in BioEstat 4.0 and tested for normality by the Shapiro–Wilk method. The sample distribution was non-normal. Thus, the nonparametric Kruskal-Wallis test was applied, followed by Dunn's test. For comparing C, M and A third in each group, the Friedman test was used. Significance was accepted at the 5% level.

Results

All final irrigation systems-XP-endo Finisher, PUI, and Easy Clean- failed to produce greater removal of gutta-percha and AH-Plus cement in any of the analyzed thirds ($P>0.05$). When comparing C, M and A thirds in each group there was no significant differences among XP-endo Finisher, PUI, and Easy Clean ($P>0.05$) (Table 1 and Figure 2).

Discussion

In endodontic retreatment, removal of all content from the root canal system (gutta-percha, cement, and microorganisms) is necessary to allow optimal cleaning, shaping and re-obturation [1, 2].

During primary obturation of the root canal system, warm gutta-percha is condensed into inaccessible anatomical areas, which makes it difficult for instruments to reach it during retreatment. Use of the continuous wave technique (as applied in this study) for obturation may further explain the persistence of filling material in other areas of the root canal system, such as the isthmus, even after the use of additional cleaning techniques [19, 20].

No solvents were used during removal of obturation material, as previous studies have reported that this practice leads to formation of a gutta-percha slurry that strongly adheres to the walls of the root canal and dentinal tubules; it is difficult to detect and remove, and jeopardizes final cleaning [21].

Despite being developed for endodontic treatment, reciprocating instrumentation performs well in retreatment [11-13], facilitating access to the foramen and reducing the working time. The characteristics of reciprocating motion are provided by the balanced forces created by a counterclockwise rotation angle that is more acute than the clockwise angle (150° *versus* 30°). This helps the instrument move continuously toward the apex, maintaining the original shape of the curved canal and facilitating access to the foramen and removal of gutta-percha [22, 23].

To further improve cleaning and re-instrumentation up to the full working length, some authors advocate the use of instruments larger than those used in primary treatment [4, 6, 12, 15]. However, the present study demonstrated that using the same instrument (in this case, a Reciproc R25 file) for both treatment and retreatment yields quite effective removal of obturation material; the combined use of Gates-Glidden drills of decreasing size may have helped empty the cervical and middle thirds. The use of instruments with larger tips and tapers was avoided, as the premise was to actually leave some obturation material behind to be removed by the irrigation techniques we sought to test. This finding was relevant in demonstrating the effectiveness of each method for removal of the obturation material. The clinical importance of using the same instrument lies in avoiding excessive removal of dentin so as to reduce the risk of perforations, cracks, and vertical fractures.

CBCT scanning is a non-destructive, noninvasive, efficient, and sensitive method that allows three-dimensional evaluation of the root canal system and detailed visualization of root morphology. This method provides reproducible data and allows evaluation of endodontic retreatment by comparing the amount of obturation material within the root canals before and after cleaning and shaping procedures and after final irrigation, allowing visualization of small areas of residual filling materials still present on the canal walls [24, 25].

Studies have reported the use of micro-CT to analyze remnants of filling material [19, 26-28]. However, the high cost, limited availability, and impossibility of clinical use of micro-CT makes CBCT a better option. CBCT can provide accessible, affordable three dimensional visualization device both in clinical settings and for *in vitro* studies [29]. The softwares used to analyze CBCT images are effective and compatible with those used for micro-CT analyses.

As it is made of plastic, the Easy Clean instrument proved quite flexible upon contact with the walls of root canals still filled with gutta-percha. The active part of the instrument deformed and sometimes even fractured, thus jeopardizing its utility as an adjunctive instrument for endodontic retreatment [15].

It bears stressing that, in clinical practice, during retreatment, dentists combine several techniques (including radiography, magnification, solvent-embedded paper points, or simply visual and tactile examination of the instrument) to improve removal of obturation material from the root canal system. In the present study, as in previous investigations, removal was considered complete when no remnants of obturation material were visible on the instrument surface, on orthoradial or oblique radiographic views, or during the irrigation and aspiration process, at any point along the working length established before and after retreatment procedures [7, 11, 12, 24].

The PUI technique has proven effective for the removal of organic matter, planktonic bacteria, and debris, especially as compared with conventional irrigation [16]. However, it requires minimal canal taper to avoid wear by direct contact of the insert with the dentin walls, thus allowing the cavitation phenomenon and acoustic microstreaming to occur. As these phenomena are more intense at the tip of the insert, the technique should be used with caution in markedly curved canals. In the present study, there were no statistically significant differences between the tested final irrigation techniques in terms of ability to remove material in the cervical, middle, or apical thirds.

The ability of the XP-endo Finisher instrument (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) to remove gutta-percha from root canal walls may be related to its metallurgical properties and to the recommended motions, which help the operator reach otherwise inaccessible areas of the root canal system, allowing superior cleaning with less wear of root dentin. Although complete removal of gutta-percha did occur in some specimens, use of this file was not associated with significant differences when compared to the other tested instruments, contradicting previous studies in which the XPF had superior performance, especially in the apical third [18, 28]. The different results of this work in relation to Alves *et al.* [18] may be related to differences in the methodology used between the studies, Alves *et al.* [18] performed the final irrigation technique only on specimens that presented material remnants after performing computed micro-tomography. There were also differences in the selection of specimens, Alves *et al.* [18] worked with roots with an angle between 30 and 40 degrees, and this work with roots with 10 ° to 20 °.

Corroborating our findings, several previous studies using different retreatment protocols failed to achieve statistically significant removal of obturation material from root canals [4, 12, 30], contradicting other studies in which the Easy Clean and XP-Endo Finisher instruments were effective for this purpose [15, 18]. The difference between the results of this work in relation to Alves *et al* [18] is related to different methodologies used between works. Another important point that justifies the absence of significant differences is the use of circular channels in this work to compare different methods of irrigating agitation [31].

Finally, remnants of obturation material were present in 100% of specimens in our sample, regardless of the tested technique, corroborating previous findings [4, 6, 11, 28]. Several techniques in addition to conventional retreatment procedures are available to improve removal of obturation material remnants. Three of these were tested in the present study: PUI, XP-endo Finisher, and Easy Clean. Further studies are needed to evaluate the ability of these instruments, their motion protocols, and other supplementary approaches to optimize endodontic retreatment.

Conclusion

We conclude that, in the context of this *in vitro* study, the tested additional cleaning methods were equivalent in their ability to remove gutta-percha. Complete removal of gutta-percha from a curved root canal system failed to occur in any of the experimental groups.

Conflict of Interest: 'None declared'.

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