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Original Research Article

Efficiency of ultrasonic, sonic and mechanical complementary cleaning methods in the removal of filling material remaining of oval curved canals

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Abstract

Objective: The aim of this study was to compare efficacy in removing filling material remaining in oval and curved canals using different complementary cleaning methods. **Material and methods:** Sixty single-rooted tooth with oval shaped canal with curvature were prepared up to size 25 and .08 taper, filled and subsequently retreated. The teeth were then scanned in micro-CT and divided into 6 groups (n = 10) according to the complementary cleaning method: CUI with Irrisafe, CUI with NiTiSonic, PUI with Irrisafe, PUI with NiTiSonic, Eddy and XP-endo Finisher R. After, the teeth were newly scanned in micro-CT. The volume of the filling material remaining before and after the application of the complementary methods was calculated and then calculated the percentage of material removed total and in the apical region. Data were submitted to the Kruskal-Wallis, Dunn and Wilcoxcon tests with a significance level of 5%. **Results:** No suplementary cleaning method completely removed the remaining of filling material, however, all significantly reduced the volume, both in the apical region and in the total root canal ($p<0.05$). There was no significant difference among the groups tested, regardless of the region analyzed ($p>0.05$). **Conclusion:** No method was effective in completely removing the remaining filling material. All complementary cleaning methods significantly reduce the volume of material, with no difference among them.

Introduction

During endodontic retreatment it is desirable that all filling material be removed to perform an adequate cleaning of the root canal system and thereafter a good filling. However, this is still a challenge, especially in more complex cases such as oval and curved canals [10, 21]. Several complementary cleaning methods have been proposed with the aim of enhancing the removal of filling material and the cleaning of root canals [4, 13, 21].

Ultrasound Activated Irrigation (UAI) is a proposed method to improve the cleanliness of the root canal system after endodontic treatment and retreatment [6, 11, 13]. It consists of activating the irrigation solution using a specific instrument that induces acoustic flow and cavitation. There are different types of ultrasonic tips to be used during this step, such as the Irrisafe 20/.00 non-cutting insert (Satelec Acteon, Mérignac, France) and the NiTiSonic 20/.02 insert (Ultradent Products Inc, South Jordan, Utah), manufactured in nickel-titanium (NiTi) especially for curved canals due to its flexibility [4, 26].

The UAI can be performed intermittently (passive ultrasonic irrigation - PUI) and continuous (continuous ultrasonic irrigation – CUI) [7, 21]. However, the literature is controversial as to the real benefits of UAI in endodontic retreatment, where some authors affirm that there is a significant improvement in the removal of filling material [3, 21, 24], while others claim to have no difference [8, 24].

Thus, other complementary cleaning methods have recently been manufactured to enhance the cleaning of the root canal system. Eddy (VDW, Munich, Germany) is a polymer tip activated by sonic vibrations by a conventional air scaler operating at a frequency of 6000 Hz [12, 31]. Studies have shown that Eddy is effective in removing biofilm and smear layer and improved organic tissue dissolution and filler material removal during retreatment [8, 12, 16, 26, 28].

In addition, the XP-endo Finisher R instrument (30./00) (FKG Dentaire, La Chaux-de-Fonds, Switzerland) was specifically developed to improve cleaning during endodontic retreatment [5, 18]. This instrument is manufactured with a specific NiTi alloy called MaxWire (Martensite-Austenite ElectropolishFleX) which allows the instrument to expand at body temperature, improving its range [5, 11].

As in the literature there is still no consensus on the best method to improve cleaning during retreatment and taking into account the necessity and difficulty of removing remaining filling material during retreatment, especially in complex anatomies, the aim of the present study was to compare the effectiveness in removing filling material in oval and curved canals from the following complementary cleaning methods: CUI with Irrisafe, CUI with NiTiSonic, PUI with Irrisafe, PUI with NiTiSonic, Eddy and XP-endo Finisher R. The null hypotheses tested were:

I – Complementary cleaning methods do not improve the removal of remaining filling material in oval and curved canals;

II – There is no difference among the complementary cleaning methods in the ability to remove filling material remaining in oval and curved canals.

Material and methods

The present study was approved by the Human Research Ethics Committee (process number: 88418518.4.0000.5417) and was conducted according to the principles of the 1996 Declaration of Helsinki on good clinical practice standards.

Sample size calculation

G * Power v3.1 for Mac (Heinrich Heine, Universität Düsseldorf, Dusseldorf, Bundesland, Germany) was used for sample calculation, and the Wilcoxon-Mann-Whitney test was selected from the T test family. Data from a previous study [21] were used and the effect size of the present study was established (=1.80). An alpha type error of 0.05, a beta power of 0.80, and an N2/N1 ratio of 1 were also established. A total of 10 specimens per group were indicated as the optimal size needed for significant differences.

Sixty single-rooted Premolars with oval shaped canal with the curvature of 20 to 35º according to the method of Schneider [22] were initially selected on the basis of radiographs taken in the buccolingual and mesiodistal directions (Microimaging, Indaiatuba, São Paulo) and stored in 0.1% thymol solution (Pharmacia Specifica, Bauru, São Paulo, Brazil).

Chemical-mechanical preparation

After conventional coronary access with high-speed spherical diamond burs, a K 10 and 15 type files (Dentsply Maillefer, Baillagueis, Switzerland) was introduced into the canal until its tip was

visualized through the apical foramen, with the aid of stereomicroscope with 30x magnification (Carl Zeiss Vision GmbH, Hallbergmoos, Germany). A silicone cursor was positioned on the incisal edge of the crown and this measurement was considered the actual size of the tooth. From this measurement, 1mm was subtracted to obtain the working length.

Then, the canal was filled with 2.5% sodium hypochlorite (NaOCl) solution and instrumented with a ProDesign Logic RT 25/.08 file (BassiEndo, Belo Horizonte, Brazil) in a rotational movement of 400 rpm and 2 N of torque. At the end, the canal was washed with 10 ml of distilled water and dried with a size 25 absorbent paper cone. Each instrument was used on 3 teeth and then discarded.

The obturation was performed using Tagger's hybrid technique and AHPlus endodontic Sealer (Dentsply Maillefer). A 25/.08 gutta percha cone and two fine accessory cones (Dentsply Maillefer) were placed in the canal and the McSpadden #40 (Dentsply Maillefer) condenser activated. After filling the teeth were stored in an oven at 37oC at 100% relative humidity for 30 days.

Retreatment procedure

The teeth were then submitted to endodontic retreatment with Reciproc 25/.08 and 40/.06 instruments. Subsequently, the canals were irrigated with 10 ml of saline solution using syringe and 30-gauge needle (NaviTip, Ultradent Products Inc.) for 1 minute and scanned in a micro-CT SkyScan 1174v2 (Bruker-microCT, Kontich, Antwerp, Belgium) with the following parameters: 0.5-mm aluminum filter, 19.6μm pixel size, 50kV, 800mA, rotation step of 0.6º, rotation of 360º around the vertical axis and resolution of 1024 1304. A silicone mold was made for each tooth to ensure scanning in the same position so as not to interfere in the subsequent analysis.

For group distribution, statistical analysis was performed confirm homogeneity (Shapiro-Wilk; $p>0.05$). Then, the teeth were divided into 6 groups ($n = 10$) according to the complementary cleaning method:

CUI with Irrisafe – The Irrisafe 20/.00 tip insert (Satelec Acteon) was positioned centrally in the root canal 1 mm before the working length and driven for 1 minute using an ultrasonic device (P5 Newton; Satelec Acteon) at power 7. Ultrasonic agitation was performed for 1 minute concomitantly with irrigation with saline solution.

CUI with NiTiSonic – The NiTiSonic 20/.02 tip insert (Ultradent Products Inc.) was positioned centrally in the root canal 1 mm before the working length and driven for 1 minute using an ultrasonic device (P5 Newton; Satelec Acteon) at power 7. Ultrasonic agitation was performed for 1 minute concomitantly with irrigation with saline solution.

PUI with Irrisafe – The canal was irrigated with 2mL and the Irrisafe 20/.00 tip insert (Satelec Acteon) was positioned 1 mm before working length and activated for 20 seconds using an ultrasonic device (P5 Newton; Satelec Acteon) at power 7. This procedure was performed 3 times.

PUI with NiTiSonic – The canal was irrigated with 2mL and the NiTiSonic 20/.02 tip insert (Ultradent Products Inc) was positioned 1 mm before working length and activated for 20 seconds using an ultrasonic device (P5 Newton; Satelec Acteon) at power 7. This procedure was performed 3 times.

Eddy – The canal was irrigated with 2 ml and the Eddy 25.04 (VDW) was positioned 1 mm before working length and activated for 20 seconds using a sonic device (Sonic Borden 2000N KaVo Kerr, Joinville, SC, Brazil) making up and down movements with an amplitude of 4mm according to the manufacturer's recommendations. This procedure was performed 3 times.

XP-endo Finisher R – The canal was irrigated with 2 ml and the XP- endo Finisher R 30.00 instrument (FKG) was used in an endodontic motor (VDW) with a speed of 1000 RPM and 1 Ncm of torque making slow and smooth movement of 7-8 mm, starting 1 mm before the working length. This procedure was performed 3 times.

At the end, the canals were irrigated with 4 ml of saline solution. All protocols of agitation of the irrigating solution were performed at 37ºC, immersing the teeth fixed in a muffle, in a histological bath with distilled water (Lupetec, São Carlos, São Paulo, Brazil) and monitored by a thermometer (Aquarium Thermometer ADT-01F, Jin Li Jia Electromechanical Limited Company, China).

The canals were then dried with absorbent paper cones 40/.06 (Dentsply Maillefer) and scanned again into the micro-CT SkyScan 1174v2 (Bruker-microCT), following the same parameters used previously.

Micro-CT analyses

The images of each specimen from the three scans were reconstructed with a ring artifact correction of 4, a beam hardening correction of 45%, and smoothing of 5 (NRecon v.1.6.9.16; Bruker-microCT). DataViewer software (Bruker-microCT) was used to co-register the 3D models of the pre- and postoperative images with a custom combination of a rigid registration model based on image intensity similarities with accuracy greater than 1 voxel.

After the binarization process, the software CTAn v.1.14.4 (Bruker-microCT) was used for three-dimensional (3D) evaluation of the volume (mm 3) of filling material of the apical region, which comprises the last 4 mm, and the total volume, which comprises the last 10 mm of the canal. The volume of filing material removed after the complementary cleaning methods was calculated and expressed as a percentage.

CTVol v.2.2.1 software (Bruker-microCT) was used for visualization and qualitative assessment of the root canal system configuration.

Statistical analysis

The statistical analysis was performed using GraphPad Prism 5 software (La Jolla, CA, USA). The data were subjected to D'Agostino-Pearson test to verify if there was a normal distribution. Kruskal-Wallis and Dunn non-parametric tests were used for comparison among the groups and the Wilcoxcon test for intragroup analysis. The level of significance was 5%.

Results

The median, minimum and maximum values of the remaining filling material volume and percentage of removal promoted by the complementary cleaning methods are shown in table I. It can be observed that, in the apical and total regions, there was no significant difference among the groups in relation to the volume of filling material remaining before the application of the complementary cleaning method, showing a correct sample pairing ($p>0.05$). Regarding the percentage of filling material removed by the complementary methods, it was observed that there was no difference among the groups ($p>0.05$).

Table I – Median, minimum and maximum values (in parentheses) of the volume in mm3 and the percentage of remaining filling material removed after the use of the different complementary cleaning methods.

Complementary methods	Regions	Remaining filling material before complementary methods (mm3)	Remaining filling material after complementary methods (mm3)	Remaining filling material with complementary methods (%)
CUI Irrisafe	Total	0.93 (0.1-4.5)^{aA}	0.80 (0.1-4.4)^{B}	6.17 (2.2-77.5)^{a}
CUI NiTiSonic		1.83 (0.1-7.6)^{aA}	1.62 (0.1-6.9)^{B}	8.18 (1.1-47.1)^{a}
PUI Irrisafe		1.38 (0.3-4.4)^{aA}	1.26 (0.2-4.1)^{B}	10.82 (3.9-52.7)^{a}
PUI NiTiSonic		1.61 (0.1-4.3)^{aA}	1.41 (0-3.9)^{B}	13.39 (1.4-79.1)^{a}
EDDY		0.96 (0.1-2.2)^{aA}	0.75 (0.1-1.9)^{B}	19.18 (9.1-48.9)^{a}
XP-endo Finisher R		1.25 (0.1-4.1)^{aA}	1.19 (0.1-4.1)^{B}	4.80 (1.3-63.3)^{a}
CUI Irrisafe	Apical	0.08 (0-0.2)^{aA}	0.05 (0-0.1)^{B}	17.38 (1.1-58.3)^{a}
CUI NiTiSonic		0.14 (0.01-2.1)^{aA}	0.11 (0-2.1)^{B}	18.98 (1.2-99.1)^{a}
PUI Irrisafe		0.19 (0.02-0.7)^{aA}	0.14 (0.01-0.7)^{B}	28.46 (8.1-85.3)^{a}
PUI NiTiSonic		0.12 (0.01-0.8)^{aA}	0.07 (0-0.8)^{B}	50.76 (2.2-99.5)^{a}
EDDY		0.09 (0.01-0.2)^{aA}	0.05 (0.01-0.1)^{B}	45.22 (1.1-97.5)^{a}
XP-endo Finisher R		0.10 (0.01-0.2)^{aA}	0.09 (0-0.2)^{B}	15.64 (1.4-33.3)^{a}

Different lowercase letters in the same column indicate significant difference among groups, according to the region analyzed (P<0.05)

Different capital letters on the same line indicate significant difference within the same group (P<0.05)

In the intra-group analysis, it was observed that, independently of the analyzed region, all the complementary cleaning methods significantly reduced the volume of remaining filling material ($p<0.05$) (figure 1).

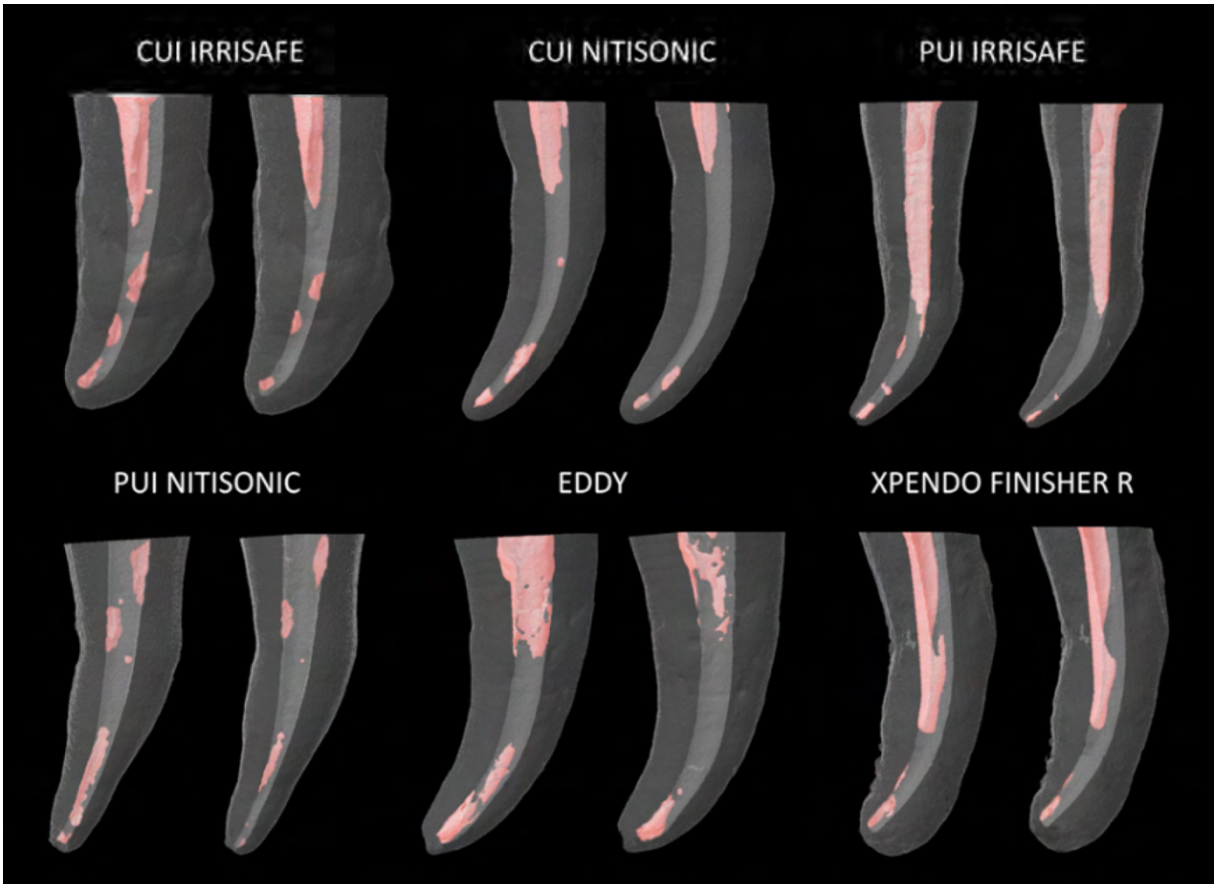

Figure 1 – Representative three-dimensional reconstruction of the root canals after the application of complementary cleaning methods. In light pink the remaining filling material

Discussion

This in vitro study used micro-CT analysis to measure the volume (mm^3) of remaining filling material after using supplementary cleaning methods. Our first null hypothesis was rejected because all the methods reduced the volume of the remaining filling material, when compared to baseline volumes (after re-treatment procedures) and to the final volume (after supplementary cleaning) (p<0,05). Our second null hypothesis was confirmed because there was no significant difference among cleaning methods in the removal capacity of residual filling material (p>0.05).

The homogeneity of the samples was obtained with micro-CT which allows a nondestructive approach that reconstructs samples on a micrometric and real scale [20, 21]. Anatomical complexities play a crucial role in endodontic research. Curved canals present a challenge for the clinician to perform complementary cleaning methods [10, 21] and rotary files perform a round preparation, not touching the polar zones of oval canals that can retain remnants of filling material, debris and bacteria [2, 27].

As well as other studies of endodontic retreatment have shown, no cleaning method was effective in completely removing the residual filling material [3, 6, 10, 16, 18, 21, 24]. However, all complementary cleaning methods significantly reduced the amount of residual filling material, regardless of the region analyzed (p<0.05) (table I). These results corroborate several studies in which curved canals were used and it was observed that different methods of agitation of the irrigation solution contributed to the reduction in the amount of filling material after retreatment [6, 18, 19, 21]. Even if the results of the present study demonstrated that residual filling material still remained in the root canals, it is important to emphasize the need to use a complementary cleaning method after retreatment.

This study also demonstrated that no significant difference among the cleaning methods in the removal capacity of residual filling material (p>0.05).

UAI in a passive (PUI) or continuous way (CUI) has been one of the most widely used and researched irrigation methods [4, 7]. In view of this, several inserts with different designs, sizes and materials have been developed. In the present study, there was no difference between the types of inserts (NiTiSonic – NiTi, Irrisafe, stainless steel) as well as the activation protocol (passive or continuous way).

Those methods activate the irrigating solution by the formation of cavitation and acoustic microstreaming and presents low effectivity of cut and remove dentin and filling material [11, 15, 19, 21, 30]. Therefore, in spite of the CUI seems to be related to a greater efficiency because of the activation and irrigation concomitantly, there is a shortage of studies in the literature that evaluate this method, and there are studies that show better results [4] and worse than PUI [7]. In the present study, CUI significantly reduced the amount of material remaining, but there were no significant differences with the other groups and the percentage of removal was lower than PUI and Eddy.

The Eddy instrument presented a significant reduction in the amount of remaining filling material, corroborating with the results found by Kaloustian *et al*. [16]. The effectiveness of this instrument is related, according to the manufacturers, to the formation of cavitation and acoustic streaming within the irrigant produced by the high frequency (6000 Hz) to which the polymer tip (Eddy) is used [16]. However, this effect is still not well defined since Macedo *et al*. [17] demonstrated that sonic devices do not produce cavitation due to low frequency. However, new studies need to be conducted because the Eddy instrument (6000 Hz) is used at a frequency significantly higher than that tested in the previous study (190 Hz) [17].

As with the other groups, the XP-endo Finisher R was related to a reduction in the volume of filling material, both in the apical region and in the whole canal. These results corroborate with other studies that observed great efficiency of this instrument that was specially fabricated for this stage [5, 11, 18, 23, 29]. However, the reduction percentage in this study was lower than those obtained in these previous studies, regardless of the region analyzed. These results may be related to the methodology used such as the characteristic anatomical of the teeth used. Regarding the effectiveness of XP-endo Finisher R, the results should be related to the type of alloy that the instrument is manufactured (MaxWire; FKG) that has the ability to increase its contact area when it is in body temperature leading to a greater mechanical action of the instrument on the walls of the root canal [9, 11, 23].

Other studies should be conducted in order to find ways to further optimize the removal of this remaining filling material as a way to obtain an increase in success rates in endodontic retreatment. Maybe, instruments that touch more effectively against canal walls or the combination of methods may result in a more effective removal in other study [20], where a specific ultrasonic insert was developed to mechanically remove the remaining filling material.

Conclusion

Despite the limitations of this study, its concluded that none of the additional cleaning methods were able to completely remove the remaining filling material. All methods were effective in reducing the amount of filling material, with no difference among them.

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