Enhancing debris removal in curved canals: a comparative evaluation of XP-endo Finisher and Passive Ultrasonic Irrigation

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Research Article

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Abstract

Objectives

The study aimed to compare the efficacy of XP-endo Finisher and Passive Ultrasonic Irrigation (PUI) in removing hard tissue debris from curved canals.

Materials and methods

Thirty-four mandibular molars with Vertucci's type II mesial canals were scanned in microcomputed tomography before and after preparation with HyFlex EDM, and accumulated hard tissue debris was quantified. Subsequently, the teeth were randomly divided into two groups according to the supplementary procedure: PUI with the Ultra-X insert or XP-endo Finisher. After the intervention, the specimens underwent another scanning. Two separate analyses were conducted, one for the total canal and another for the isthmus area. Unpaired and paired T-tests were used for inter- and intergroup comparisons, with a significance level set at 5%.

Results

Both supplementary methods reduced the amount of debris compared to the initial volume. Remarkably, the XP-endo Finisher achieved a significantly higher percentage of debris removal (71% for the total canal and 74% for the isthmus areas) compared to PUI (41% for the total canal and 52% for the isthmus area) ($P < 0.05$).

Conclusions

Both supplementary approaches reduced the amount of hard tissue debris from canal preparation, still XP-endo Finisher showed a higher reduction compared to PUI ($p < 0.05$).

Clinical relevance:

None of the supplementary methods rendered canals completely free of hard tissue debris. However, the supplementary approach with XP-endo Finisher resulted in lower levels of hard tissue debris than PUI in curved canals with isthmuses.

Introduction

The intricate anatomy of the root canal system poses challenges to achieving effective cleaning and disinfection. In infected canals, anatomical complexities like isthmuses, apical deltas, lateral canals, and irregularities can harbor dentine debris, pulp remnants, and microorganisms, serving as a nutrient source and shelter for bacteria, perpetuating intracanal infections [1, 2]. For instance, isthmuses occur in 65% of the mesial roots from mandibular molars [3].

Various supplementary irrigation approaches have been employed to enhance the penetration of irrigating solutions into anatomical complexities, thereby improving root canal disinfection and cleaning. These strategies encompass sonic or ultrasonic devices and rotary instruments designed to agitate the irrigating solution [1, 4, 5].

The XP-endo Finisher, crafted from MaxWire nickel-titanium alloy by FKG Dentaire (La Chaux de Fonds, Switzerland), displays remarkable adaptability within the root canal. Transforming its shape from straight-martensitic to spoon-shaped at body temperature, this instrument's elasticity and shape memory effect aid in expansion and contraction during rotation, enhancing cleaning and disinfection. This dynamic behavior optimizes root canal treatments by reaching challenging areas and agitating the irrigant [1, 6].

Passive ultrasonic irrigation (PUI) gained popularity among clinicians, showing improved root canal cleaning when used as a supplementary approach after canal preparation (Suila, Minu 2019; Liang *et al.* 2022). Despite these promising results, complete dentine debris removal remains a challenge. Recently, a cordless ultrasonic activator, Ultra X (Eighteeth, Sifary Medical Technology, Changzhou City, China), was introduced to the market. This device boasts a 45kHz frequency and utilizes a 20.02 or 25.02 ultrasonic insert. According to the manufacturer, these inserts were specially designed to smear layer and dentine debris removal, biofilm disruption, and clean complex areas such as isthmus.

Hard tissue debris removal was initially assessed using scanning electron microscopy [7]. However, microcomputed tomography (micro-CT) is currently regarded as the gold standard method for this purpose due to its ability to provide detailed quantifiable 3D images and allow multiple sequential analyses without sample destruction [8–10]. In this context, this study aimed to compare the effectiveness of XP-endo Finisher and Passive Ultrasonic Irrigation (PUI, with Ultra-X device and insert) in removing hard tissue debris from curved canals connected by isthmuses.

Material and methods

Sample calculation, selection, and preparation

The Institutional Ethics Committee approved the study protocol. A power calculation was performed using G*Power 3.1 software (Heinrich Hein University, Dusseldorf, Germany), with $\alpha = 0.05$ and $ß = 0.95$, applying the chi-square test family and variance statistical test. The minimum sample size required for each group was 11 samples per group. Hence, 17 specimens were included in each group to account for potential losses during the study.

Thirty-four mandibular molars with Vertucci's type II mesial roots (two individual canals that start from the pulp chamber and join apically in a single canal) [11] and moderate curvature (10–24º) [12] were selected. All teeth had complete rhizogenesis and no previous endodontic treatment, resorptions, or root fractures. The teeth were scanned using a SkyScan 1174 micro-CT device (Bruker micro-CT, Kontich, Belgium) to confirm the internal Vertucci’s configuration and for posterior teeth pair-matching by groups.

Then, conventional coronal access was performed with high-speed rounded diamond bur #1013 (FKG-Sorensen, São Paulo, SP) and Endo- Z bur (Dentsply, Maillefer, Switzerland).

The root canals were explored with #10 K-type files until the instrument tip was visualized at the apical foramen, and the working length (WL) was established by subtracting 1 mm. After that, the apical foramen of each root was sealed with Topdam (FGM, Joinville, SC, Brazil) to create a closed-end system [1].

Micro-CT parameters and pair-matched sample

Subsequently, the teeth were scanned in a micro-CT device (SkyScan 1174v2, Bruker, Kontich, Belgium) using the following parameters: 0.5º rotation step, 360º around the vertical axis, 9.9 µm pixel size, and 1-mm-thick aluminum filter. The NRecon v.1.7.4.6 software (Bruker micro-CT, Kontich, Belgium) was used to reconstruct the images using the following parameters: beam hardening correction set at 50%, ring artifact correction of 5, and smoothing value of 0. The CTAn software (v1.6.6.0, Bruker Micro-CT, Kontich, Belgium) was used to binarize images and analyze the three-dimensional parameters of surface area and volume of the initial internal canal morphology. This analysis allowed the sample pairing by similar volume into two experimental groups of 16 teeth each (PUI or XP-Endo Finisher).

Root canal preparation

The canals were instrumented using the HyFlex EDM system (Coltene, Whaledent, Switzerland) in the sequence recommended by the manufacturer (25/.12, 10/.05, and 25/~). The instruments were operated at 500 rpm and 2.5 N/cm, except the *glide path* instrument (10/.05), activated at 300 rpm and 1.8 N/cm. A VDW Silver electric motor (VDW, Munich, Germany) was used to drive the instruments. Before the preparation and after using each instrument, the canals were irrigated with 2 mL 2.5% sodium hypochlorite (NaOCl) for 30 seconds with a NaviTip 30G needle (Ultradent, South Jordan, USA). The total volume of NaOCl used during the preparation was 8 ml.

After root canal preparation, all teeth were submitted to another micro-CT scan with the same previously mentioned parameters. Then, the teeth were subjected to either PUI or XP-Endo Finisher supplementary procedures. Before the adjunct steps, the canals were irrigated with 2 mL 2.5% NaOCl with a 30G NaviTip needle (Ultradent, South Jordan, USA) introduced 2 mm below the CT. All supplementary procedures were performed at 37ºC inside a heater cabinet (800-Heater; PlasLabs, Lansing, MI).

PUI

A total of 2 mL 2.5% NaOCl solution, preheated at 37°C, was used to irrigate the root canal for 30 seconds before PUI. Subsequently, an Ultra X Silver insert #20/02%, measuring 21 mm in length, was inserted until it reach the WL and activated for 1 minute at 45 kHz using a portable ultrasonic device (Ultra X, Eighteeth). After canal aspiration, they were irrigated with 2 mL of 17% EDTA, heated to 37° C, and ultrasonically activated for 1 minute. This protocol was repeated once more for each irrigant, resulting in a total of 4 mL of NaOCl and 4 mL of EDTA irrigation.

XP-endo Finisher

The XP-endo Finisher instrument was coupled to the VDW Silver motor, cooled with refrigerant gas (Endo Ice Spray, Maquira, Maringá, Brazil), and removed from the plastic tube in rotation. Next, 2 mL 2.5% NaOCl solution, preheated at 37°C, was used to irrigate the root canal for 30 seconds. The instrument was then inserted into the canal and operated for 1 minute at 800 rpm, 1 N/cm, using up-and-down movements (7- to 8-mm-long) up to WL. After aspiration, the canals were irrigated with 2 mL 17% EDTA, agitated by XP-endo Finisher for 1 minute. This protocol was repeated once more for each irrigant, resulting in a total of 4 mL of NaOCl and 4 mL of EDTA irrigation. Each instrument was used for only one tooth (2 canals) and discarded. Following the supplementary approaches, all teeth were scanned again in the micro-CT using the previously described parameters.

Micro-CT analysis

Post-preparation and post-supplementary image models were obtained by the CTAn v1.6.6.0 program (Bruker Micro-CT) and converted from the .BMP format to the .NRRD format in the Image J 1.50d software (National Institutes of Health, Bethesda, MD). Then, they were registered in the Slicer v1 software 5.1.2 (www.slicer.org) with a custom combination of a rigid registration module based on image intensity similarities with an accuracy greater than one voxel.

The volume (mm^3) and surface area (mm^2) of the isthmus region and the entire root canal length were measured. Also, the amount of hard tissue debris was calculated by the Image J software v. 1.49. Hard tissue debris was considered a material with a density similar to dentin in regions previously occupied by empty spaces and quantified by the intersection of images before and after the final irrigation protocols. Hard tissue debris quantification involved assessing the difference in volume between unprepared and prepared root canal space through post-processing procedures. This difference was expressed as a percentage of the total canal system volume after preparation. CTvol v 2.2.3.0 program (Bruker Micro-CT) allowed the establishment of color codes (green to preoperative unprepared canal surface area, gray for instrumented canals, and blue for hard tissue debris) and graphic visualization of 3D models.

Statistical analysis

Intergroup data analysis was conducted to assess whether the supplementary methods had significant differences in hard tissue debris removal. The Shapiro-Wilk test revealed normality between the groups regarding the results obtained from debris accumulation. Unpaired and paired T-tests were used for inter- and intergroup comparisons. All analyses were processed using the Prism 9.5.1 program (GraphPad Software, Inc., La Jolla, CA, USA). The level of significance of the test was 5%.

Results

There were no significant differences between the initial volume and surface area of the root canal in both groups, revealing an adequate tooth pairing ($P > 0.05$). The XP-endo Finisher was significantly more effective in removing hard tissue debris from the canals than PUI ($P < 0.05$). The mean percent of debris removal was 71% for XP-endo Finisher and 41% for PUI. Considering only the isthmus areas, XP-endo Finisher removed significantly more debris from isthmuses than PUI, 74% and 52%, respectively ($P < 0.05$) (Table 1 and Fig. 1).

Table 1
Mean and standard deviation of the initial and final volume of debris (mm3) after additional procedures and the total removal percentage.

	Initial volume	Final volume	% removed
Total canal			
PUI	4.13 ± 1.09^{aA}	2.41 ± 0.88^{aB}	41.08 ± 16.99^{a}
XP-endo Finisher	4.25 ± 1.03^{aA}	1.11 ± 0.88^{bB}	71.33 ± 24.19^{b}
Isthmus			
PUI	2.16 ± 0.56^{aA}	0.95 ± 0.47^{aB}	52.02 ± 24.48^{a}
XP-endo Finisher	2.01 ± 0.53^{aA}	0.50 ± 0.30^{bB}	74.12 ± 15.48^{b}
Lowercase and capital letters show intra- and intergroup differences, respectively.			

Discussion

The present study evaluated the efficacy of two supplementary approaches in removing hard tissue debris. For this, mandibular first molars were chosen because they present the highest prevalence of endodontic treatment and frequently possess isthmuses in their mesial root, representing one of the most challenging root canal anatomies for cleaning and disinfection [13, 14]. Data from a systematic review revealed the presence of isthmus communications averaged 54.8% on the mesial roots from mandibular molars [13]. In addition to investigating the complex root canal anatomy and testing a new ultrasonic device and insert for PUI, our study stands out for another crucial aspect – adopting a significantly improved micro-CT isotropic resolution. This advancement represents a notable difference compared to previous studies [4, 15]. By utilizing this enhanced resolution, we obtained more detailed and accurate three-dimensional images of the root canal system. This higher level of precision allowed us to make more reliable identification and quantification of the hard tissue debris, leading to more robust and meaningful findings.

Dentine debris accumulation can significantly impact the success of endodontic treatments, especially in infected canals, where microorganisms may thrive and maintain apical periodontitis [16, 17]. Moreover, hard tissue debris can hinder irrigants' proper flow and distribution during canal preparation [18, 19]. Despite the remarkable progress in endodontic techniques, recent studies have consistently reported substantial levels of hard tissue debris accumulation, ranging from 14.5–42.5% [8, 20]. The present findings revealed an even superior level of debris accumulation in the PUI group, with a mean of 59%, contrasting with the XP-endo, with a mean of 29%, proving that some supplementary cleaning approaches could be ineffective in more complex anatomies.

The hard tissue debris accumulation is closely associated with the intricate root canal anatomy. For instance, isthmuses, which are narrow areas connecting root canals, are often left untouched by instrumentation and potentially unaffected by irrigants, rendering them ideal reservoirs for debris accumulation [21]. Besides, canal curvature is another anatomical challenge that jeopardizes debris removal [22]. Given this context, it is essential to employ supplementary approaches to enhance the penetration and distribution of irrigants in such difficult-to-reach regions [23, 24]. For instance, our findings demonstrate that approximately half of the debris amount was accumulated in the isthmus area following root canal preparation.

In the present study, although no tested supplementary approaches could completely remove the hard tissue debris from the root canal system, corroborating previous studies [15, 25], they significantly reduced their amount. The XP-endo Finisher showed the highest debris reduction compared with PUI, not only for the total canal but also for the separate analysis of the isthmuses. This outcome could be attributed to its superior ability to distribute the irrigant compared to the PUI technique, as documented in a previous study [26]. The XP-endo Finisher likely achieves this due to its expanded action and high-speed rotation, which may agitate the irrigant solution more effectively. However, further investigations are needed to confirm this hypothesis.

In contrast to the present findings, two previous studies [15, 27] did not observe significant differences in hard tissue debris removal when comparing PUI and XP-endo Finisher. However, it's important to note that both of these studies utilized a less challenging canal configuration, Vertucci's class I, which lacks the complexity seen in the present study (Vertucci's class II), characterized by the presence of isthmuses. This suggests that the efficacy of these supplementary procedures may vary depending on the complexity of the root canal anatomy, particularly in cases involving isthmuses. Such distinctions provide valuable insights for optimizing debris removal strategies in diverse endodontic scenarios.

Conclusion

When testing XP-endo Finisher and PUI with Ultra X insert in the mesial root of mandibular molars with curvatures and isthmuses, both supplementary approaches reduced the amount of hard tissue debris resulting from canal preparation. However, the XP-endo Finisher demonstrated a significantly higher reduction compared to PUI. Despite this, no tested supplementary approaches could completely remove the debris from the root canal system or isthmus areas.

Declarations

Author contribution

Warley O. Silva — Teeth selection and preparation, root canal preparation, data collection, and manuscript writing (first draft)

Pablo Amoroso-Silva — Statistical analysis

Patrícia Olivares — Teeth selection and preparation

Murilo Priori Alcade-Teeth selection and preparation

Flávio R. F. Alves — manuscript writing and revision

Marília F. Marceliano-Alves — Study concept/design, supervision, and microtomographic analyses

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Not applicable.

Conflict of interest

The authors declare no competing interests.

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Figures

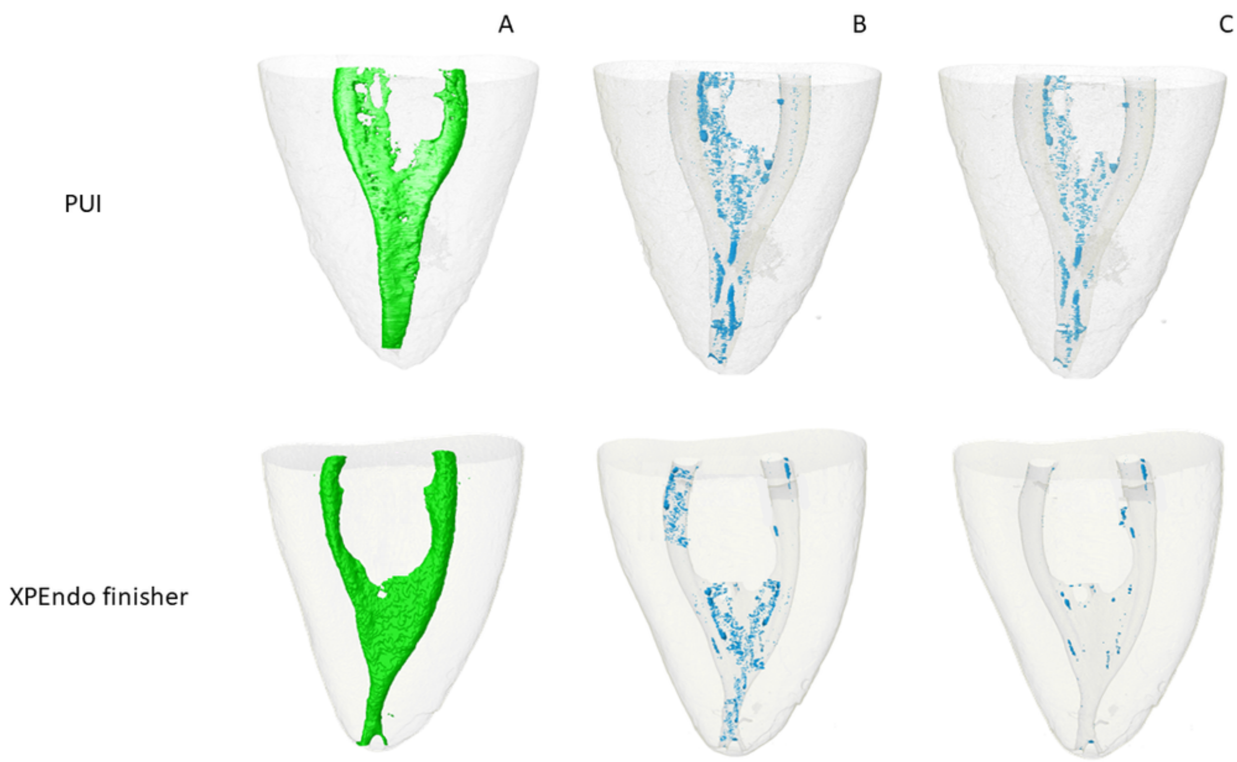

Figure 1

3D micro-CT images: (A) before chemical-mechanical preparation; (B) after preparation with the Hyflex EDM system; and (C) after supplementary approach with Ultra-X tip in PUI and XPEndo finisher.