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ORIGINAL ARTICLE

Does the ultrasonic activation of sealer hinder the root canal retreatment?

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Abstract

Objectives To evaluate if the ultrasonic activation of sealer hinders the root canal retreatment.

Materials and methods Thirty mandibular premolars were prepared using the ProTaper Universal system (Dentsply) until the instrument F3 (0.30/0.09). The canals were distributed into 2 groups ($n = 15$), according to the filling technique: NUact group - sealer without ultrasonic activation + gutta-percha cones and Uact group - sealer with ultrasonic activation + gutta-percha cones. The canals were re-instrumented with Largo burs, followed by the instrument R50 (0.50/0.05) of the Reciproc system. The time required to perform re-instrumentation was recorded (s). The roots were longitudinally cleaved, and the total area of root canal and remaining filling material were quantified (%). The ANOVA test was applied to the data and complemented by Student's *t* test ($P < 0.05$).

Results Uact group had higher percentage of remaining filling material than NUact group ($P < 0.05$). When the root thirds were considered, there was statistically significant difference only for Uact group at the apical third ($P < 0.05$). There was no difference between groups regarding the time required to perform re-instrumentation ($P > 0.05$).

Conclusions Ultrasonic activation of sealer leads to a higher percentage of remaining filling material attached to the root canal walls. However, it did not affect the retreatment time.

Clinical significance Ultrasonic activation increases sealer penetration into dentinal tubules, improving its resistance to dislodgement. However, there is no scientific evidence to prove if ultrasonic activation of sealer hinders its removal when root canal retreatment is necessary.

Keywords Root canal sealer · Ultrasonic activation · Reciproc system · Root canal retreatment

Introduction

Ultrasonic activation is widely used to improve the effectiveness of irrigating solutions [1, 2]. The transmission of acoustic energy from an insert submitted to ultrasonic activation increases the penetration ability of the irrigant solution into hard-to-reach areas of the root canal, such as dentinal tubules, isthmuses, and apical deltas [1, 2]. Studies have reported that ultrasonic activation is also capable of increasing the penetration of root canal sealers into the dentinal tubules [3–5], with reduction of voids and better adaptation of the filling material to the dentine walls [3–5].

When the root canal treatment does not achieve the expected success, the most conservative alternative is the non-surgical retreatment [6, 7]. Root canal retreatment consists of filling material removal, followed by new cleaning, shaping, and obturation of the root canal to promote periapical tissues regeneration [6, 7].

Several techniques and instruments may be used for filling material removal; however, none of them is able to completely

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remove it from the root canal [6, 7]. Therefore, it is expected that procedures used to increase the sealing ability of the root canal sealer, as the ultrasonic activation [3–5], hinder its removal if root canal retreatment is necessary. Ultrasonic activation increases the penetration of the sealer into the dentinal tubules, improving its resistance to dislodgement [3–5]. However, there is no scientific evidence to prove if ultrasonic activation of the sealer hinders its removal when root canal retreatment is necessary.

Therefore, the purpose of this in vitro study was to evaluate if ultrasonic activation during obturation hinders the root canal retreatment. The null hypothesis tested was that root canals obturated with and without ultrasonic activation of the sealer would present similar amount of remaining filling material after their re-instrumentation.

Materials and methods

Samples selection

Initially, the sample size calculation was performed for the analysis with $\alpha = 0.05$ and 95% testing power considering an effect size = 0.80. The number of repetitions was set at 15 per group.

Following prior approval from the Research Ethics Committee (Protocol No. 2.828.981 - CAAE: 89512818.7.0000.5016), thirty sound freshly extracted mandibular premolars were selected for the study. The selected teeth were extracted from young patients for orthodontic reasons and had fully formed apices and only one straight root canal. Next, the teeth were carefully inspected under magnification (× 4). Teeth with signs of cracks and fractures, internal calcifications, or carious lesions were discarded from the final sample. Tomographic and radiographic analyses confirmed the anatomic features of the teeth for their inclusion or exclusion in the study. In addition, the root canal's diameter was pre-operatively standardized, with an initial apical diameter correspondent to a size 15 K-file. After, the teeth were properly disinfected by immersion them in 0.5% chloramine T solution at a temperature of 4 °C for 48 h, followed by washing under running water for 24 h. Next, the teeth were stored in receptacles (Bioplast, Porto Alegre, RS, Brazil) containing 100 mL of distilled water and kept at a temperature of 5 °C until use.

Biomechanical preparation

The crowns of the teeth were sectioned transversely at the cementoenamel junction with a double-sided diamond disc (Fava, São Paulo, SP, Brazil), mounted at a low-rotation device (Model 605; Kavo, Joinville, SC, Brazil), under copious water cooling. The root length was standardized at 17 mm. A size 10 K-file (Dentsply-Maillefer, Ballaigues, Switzerland) was placed in the canal until the visualization of its tip at the apical foramen. The working length (WL) was determined by subtracting 1 mm from this measurement.

The root canals were manually prepared with the ProTaper Universal system (Dentsply-Maillefer), by the crown-down technique. The instruments S1 (0.18/0.02) and SX (0.19/0.035) were used for pre-flaring of the cervical third. S1 (0.18/0.02) and S2 (0.20/0.04) instruments were used to prepare the middle third and F1 (0.20/0.07), F2 (0.25/0.08), and F3 (0.30/0.09) for apical finishing. The root canal irrigation was performed with 2 mL of 2.5% sodium hypochlorite solution (Biodynamics, Ibiporã, PR, Brazil) at each instrument change for 1 min, with the aid of a 30-gauge needle (NaviTip, Ultradent Products Inc., South Jordan, UT, USA) introduced 2 mm up to the WL. At the end of the biomechanical preparation, 3 mL of 17% ethylenediaminetetraacetic acid (EDTA, Biodynamics) was applied for 3 min, followed by final irrigation with 3 mL of 2.5% sodium hypochlorite solution for 3 min [8].

Root canal filling

Initially, the root canals were dried with sterile absorbent paper cones (Dentsply-Maillefer). AH Plus (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), an epoxy resin-based sealer, was mixed in accordance with the manufacturer's recommendation. After, the specimens were randomly distributed into two experimental groups ($n = 15$), according to the filling technique (lateral compaction), as follows:

- NUact group (no ultrasonic activation): A precision needle coupled to a 1 mL hypodermic syringe was used to place the sealer into the root canal, until it was completely filled. Then, a medium-sized gutta-percha master cone (Dentsply-Maillefer) was inserted into the root canal until the WL. FM size gutta-percha accessory cones (Dentsply-Maillefer) were inserted into the root canal and laterally compacted with a size M finger spreader (Dentsply-Maillefer), until it was no longer possible to insert more cones into the root canal. Next, the excess of filling material was removed with a heated plugger (Odous de Deus, Belo Horizonte, MG, Brazil), and then, vertical compaction was performed with a cold plugger.
- Uact group (ultrasonic activation): A precision needle coupled to a 1-mL hypodermic syringe was used to place the sealer into the root canal, until it was completely filled. Then, passive ultrasonic agitation of the sealer with a smooth and straight ultrasonic insert (0.20/0.02) (TRA-12, Trinks, Campinas, SP, Brazil), coupled to a low-power (10%) ultrasonic device (Dabi Atlante, Ribeirão Preto, SP, Brazil), was performed for 20 s. At the end of the ultrasonic activation of the sealer, the root canal filling was performed as described in the NUact group.

Finally, each specimen was individually radiographed in the buccolingual and mesiodistal directions to evaluate the quality of the root canal filling. Root canals with voids and gaps between sealer and gutta-percha cones and/or gaps between filling material and root canal walls were discarded from the final sample and replaced. The entrance of the root canals was sealed with a provisional restorative material (Coltosol, Coltene, Switzerland), and the specimens were stored under 100% humidity at 37 °C for 30 days to allow complete setting of the root canal sealer.

Root canal retreatment

Root canal filling removal was initially performed with sizes 1 (0.70) and 2 (0.90) Largo burs (Dentsply-Maillefer) in the cervical third of the root canals (first 4 mm). The Largo burs were used to get into the gutta-percha and to allow the action of the subsequent instruments [6, 7]. The root canals were then re-instrumented with the Reciproc R50 instrument (0.50/0.05) (VDW GmbH, Munich, Germany), coupled to a 6:1 contra-angle handpiece (Sirona SN S 12345, VDW GmbH), driven by an electric motor (VDW SILVER, VDW GmbH) in mode "RECIPROC ALL." The instrument was gradually introduced into the root canal, in a slow in-and-out pecking motion, performing three movements with a maximum amplitude of 3 mm, following the manufacturer's instructions. Gentle apical pressure was applied to the instrument, combined with brush movements against the root canal walls. After each advance in the apical direction, the instrument was removed from the root canal for cleaning with a sterile gauze, followed by irrigation with 2 mL of 2.5% sodium hypochlorite solution for 1 min. Re-instrumentation was performed until the instrument reached the WL, and no evidence of filling material was noted on the instrument surface. Each R50 instrument was used for re-instrumentation of only one root canal. All procedures were performed by only one operator, specialist in endodontics.

Root canal filling removal analysis

Initially, longitudinal grooves were produced on the buccal and lingual surfaces of the roots with a double-sided diamond disc (American Burrs, Palhoça, SC, Brazil). Then, the roots were gently divided into two halves with the aid of a Lecron spatula (Quinelato, Rio Claro, SP, Brazil) to avoid the dislodgement of the remaining filling material from the root canal walls. The teeth were photographed with a digital camera (Sony Cyber-shot DSC-W530, Sony Brazil, São Paulo, SP, Brazil) coupled to an operating microscope (Alliance, Sao Carlos, SP, Brazil), under × 16 magnification (Fig.1a).

The acquired images were individually transferred to a computer, and the area of the roots hemi-section was divided into three portions: cervical, middle, and apical (Fig. 1b). Then, the outer contour of each root canal hemi-section (Fig. 1c) and the areas containing the remaining filling material were delineated (Fig. 1d). The areas corresponding to the root

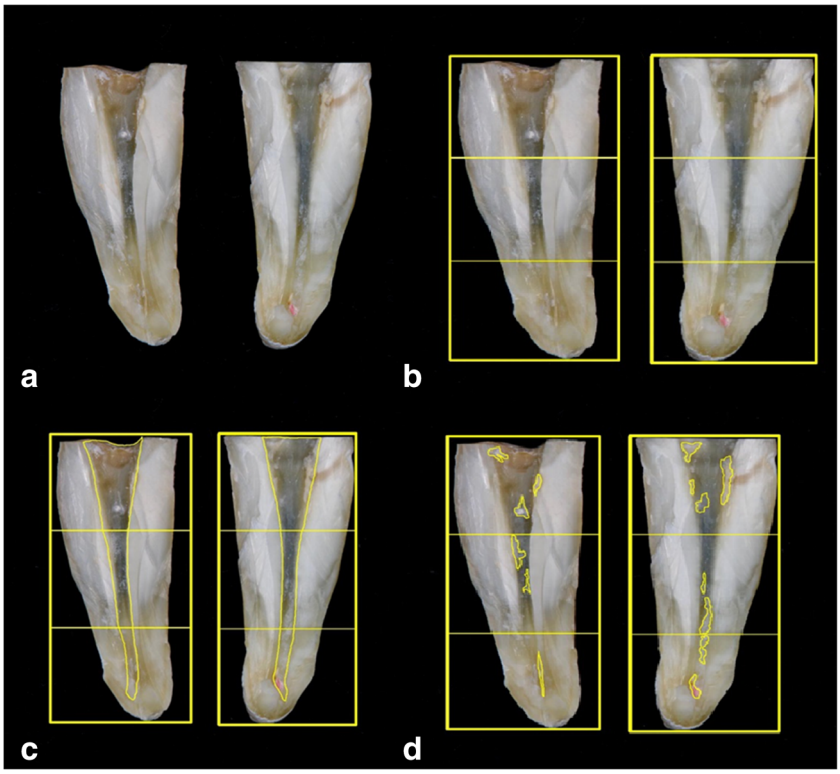

Fig. 1 Representative images of specimen from experimental group. **a** Root cleaved into two halves. **b** Root hemi-section divided into three portions: cervical, middle, and apical. **c** Outer contour of the root canal hemi-section. **d** Root canal areas with remaining filling material attached to the dentine walls

canal and the remaining filling material were measured with the aid of the Image Tool 3.0 software (Image Tool, University of Texas Health Science Center, San Antonio, CA, USA) by a properly calibrated operator [6, 7]. The amount of remaining filling material attached to the root canal walls and the total area of the root canal were expressed in mm^2. The data obtained in mm^2 were transformed into percentages for comparison between groups [6, 7].

Root canal filling removal duration

The time required for re-instrumentation of the root canals was considered from the moment of introduction of the R50 instrument inside the root canal, until the recovery of the WL. The digital chronometer (Oregon Scientific-Sl928 m, Portland, OR, USA) was stopped each time the instrument was removed from the root canal for cleaning and restarted as preparation continued. Time measurements were expressed in seconds (s).

Statistical analysis

The dataset had a normal distribution (D'Agostino and Pearson test, $P > 0.05$). The one-way ANOVA test was initially applied to the data for comparison among experimental groups (amount of remaining filling material and time required for re-instrumentation) and complemented by the post hoc Student's t test ($P < 0.05$). The two-way ANOVA test for independent factors (groups and root thirds) was used when the different root thirds were considered in the analysis and also complemented by the same post hoc test mentioned above ($P < 0.05$). The GraphPad Prism 4.0 Software program (GraphPad Software, La Jolla, CA, USA) was used to perform the statistical analysis.

Results

None of the experimental groups had complete filling material removal. When the total area of the root canal hemi-section was considered, Uact group had significantly higher mean value of remaining filling material in comparison with the NUact group ($P = 0.003$) (Table 1).

When the root thirds were considered in the analysis (cervical, middle, and apical), Uact group had significantly higher mean value of remaining filling material at the apical third than the NUact group ($P = 0.002$). There was no statistically significant difference between the experimental groups when the cervical ($P = 0.06$) and middle ($P = 0.106$) root thirds were compared. Only the Uact group had statistical difference among the different root thirds. The apical third had higher mean value of remaining filling material than the cervical and middle thirds ($P = 0.008$), which presented similar results ($P > 0.05$) (Table 1).

Regarding the time required for re-instrumentation of the root canals, both groups had statistically similar values ($P = 0.446$), as shown in Table 2.

Table 1 Mean values (%) and standard deviation (±) of the amount of remaining filling material in the different groups, considering the total area of the root canal and the different root thirds

Total area	NUact	Uact
	26.74 ± 9.80^{A}	40.43 ± 13.62^{B}
Root third	NUact	Uact
Cervical	$22.69 \pm 3.11^{A,a}$	$32.44 \pm 3.87^{A,a}$
Middle	$27.43 \pm 3.05^{A,a}$	$36.37 \pm 4.40^{A,a}$
Apical	$30.08 \pm 4.21^{A,a}$	$52.49 \pm 5.34^{B,b}$

Different uppercase letters in lines and lowercase letters in columns mean significant statistical difference ($P < 0.05$)

Discussion

The purpose of this study was to evaluate if the ultrasonic activation of the sealer during root canal filling hinders the root canal retreatment. Based on the results obtained, the null hypothesis tested was rejected, as the group in which ultrasonic activation was performed had larger amount of remaining filling material attached to the root canal walls after re-instrumentation. However, retreatment time of both experimental groups was similar.

The ultrasonic activation promotes turbulence on the activated solution, with a constant increase and decrease of the hydrostatic pressure [1, 2, 4]. This phenomenon leads to the formation of cavitation bubbles, which in turn, increases the temperature and pressure of the medium [1, 2, 4]. According to Wiesse et al. [4], the heat generated during ultrasonic activation reduces the viscosity of epoxy resin-based root canal sealers, as the one used in the present study (AH Plus), increasing their flowability. The decrease of sealer's viscosity promotes a greater interaction between its filler particles (inorganic part) and organic matrix, improving significantly its cohesive resistance [4, 9, 10]. In addition, the increased pressure generated by the ultrasonic activation pushes the sealer

Table 2 Mean values (s) and standard deviation (±) of the time required for root canal re-instrumentation in the different groups

Groups	Time
NUact	374.2 ± 35.49^{A}
Uact	413.8 ± 37.11^{B}

Different uppercase letters mean significant statistical difference ($P < 0.05$)

against the root canal walls, leading to a better interfacial adaptation between the filling material and root dentine, with effective filling of the root canal irregularities and dentinal tubules, forming more pronounced resinous tags [3–5]. Longer resinous tags with greater density promote an effective mechanical interlocking, improving the filling material retention [4, 5].

Several studies have reported the high bond strength of AH Plus sealer to root dentine and gutta-percha [4, 5, 9, 10]. AH Plus is able to form a chemical interaction with the collagen of the dentine substrate through bonding between its epoxy rings and the amine groups present in the exposed collagen network [4, 9, 10]. Therefore, as performed in the present study, the application of 17% EDTA solution prior to root canal filling when this class of sealer is used is fundamental for a proper dentine mineralized content removal and exposure of the collagen fibril network [9, 10].

On the other hand, studies have also reported controversial results regarding the ultrasonic activation of root canal sealers [11]. Dash et al. [11] demonstrated that the use of Lentulo spiral may promote greater penetration of root canal sealer into the dentinal tubules than ultrasonic activation. According to these authors, the centrifugal force, in which the sealer is submitted during the Lentulo spiral action, is more effective than the ultrasonic waves [11]. The ultrasonic activation only drives the sealer along the insert length [11], creating nodes that compromise the sealer's penetration into the dentinal tubules [11].

In the present study, all specimens presented remaining filling material attached to the root canal walls after re-instrumentation, irrespective of whether or not ultrasonic activation was performed. This finding is in agreement with the previous studies which have reported that no root canal retreatment technique is able to completely remove the filling material from the root canal [6, 7, 12–16]. The amount of remaining filling material observed after re-instrumentation of the root canals may also be explained by the anatomical complexity of the mandibular premolars [16]. These teeth have a significant mesiodistal root flattening, as well as the high incidence of isthmus areas, which hinders proper instrumentation and, consequently, their cleaning and disinfection [16]. Despite ultrasonic activation may improve the sealing ability of sealers in root canals of higher anatomical complexity [3–5], their retreatment is more challenging, as observed in the present study.

It is valid to emphasize that no ultrasonic activation of the irrigating solutions was performed in this study during the root canals preparation or re-instrumentation, which may also have contributed to the significant amount of remaining filling material observed after root cleavage. Also, no solvent was used, as previous studies have reported negative results regarding its use [15–17]. In addition to the toxicity of some products, such as chloroform, the softened gutta-percha may adhere to the root canal walls, hindering its removal, especially in root canals of complex anatomy [17, 18].

Regarding the amount of remaining filling material observed in the different root thirds, significant difference was found for the apical third only for Uact group. The apical third is the most critical area for proper root canal cleaning [19, 20], and the ultrasonic activation of the sealer may have contributed to the greater material retention, although this area has a smaller number of dentinal tubules in comparison with the cervical and middle thirds [21]. According to Dash et al. [11], sealer penetration into the dentinal tubules is lower in the apical third, even after ultrasonic activation. Because of the constriction of the apical area, the ultrasonic insert does not properly touch the root canal walls, and it does not produce the necessary nodes for acoustic streaming and cavitation [11]. Conversely, Alcalde et al. [12] demonstrated by confocal microscopic analysis that ultrasonic activation of an epoxy resin-based sealer increased its intratubular penetration, especially in the isthmus area, which corroborates the findings of our study, as the amount of remaining filling material attached to the root canal walls in the ultrasonic activated group was significantly greater at this root portion.

Furthermore, the action of irrigation solutions in this area is less efficient due to the greater difficulty of instruments access [22, 23]. Previous studies have also reported that the apical third had the largest amount of remaining filling material attached to the root canal walls after retreatment [14, 24, 25], once again, corroborating the findings of the present study.

No significant difference was found for the time required for retreatment between the experimental groups, which may be explained by the use of the same single-file system for re-instrumentation of all root canals [14, 22], irrespective of ultrasonic activation or not of the root canal sealer. Studies have reported that reciprocating single-file systems has an adequate performance during root canal retreatment [6, 7]. However, the findings of the present study suggest that retreatment of root canals previously filled with ultrasonic activation of the sealer should be preferably performed with a system of larger number of instruments, making the filling material removal more effective.

Despite the limitations of this in vitro study, it can be concluded that ultrasonic activation of the sealer hinders the root canal retreatment, leading to a higher percentage of remaining filling material attached to the root canal walls after its re-instrumentation. In the present study, a microscopic analysis was performed to assess the presence of remaining filling material attached to the root canal walls. Therefore, further studies must be carried out to correlate the depth of sealers penetration into the dentinal tubules and root canal retreatment.

Authors' contribution The authors of the present study declare that they have contributed significantly and are in agreement with the manuscript content.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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