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Efficacy of xylene and passive ultrasonic irrigation on remaining root filling material during retreatment of anatomically complex teeth

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Abstract

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Aim To evaluate the volume of remaining filling material in the mesial root canals of mandibular molars after root canal retreatment with different procedures performed sequentially.

Methodology The mesial root canals of 12 human first mandibular molars were instrumented using the BioRace system until a size 25, .06 taper instrument. The mesial roots were filled with gutta-percha and AH-Plus using a vertical compaction technique. The specimens were scanned using microcomputed tomography with a voxel size of 16.8 μm before and after the retreatment procedures. To remove the filling material, the root canals were enlarged until the size 40, .04 taper instrument. The second step was to irrigate the root canals with xylene in the attempt to clean the root canals with paper points. In the third step, the passive ultrasonic irrigation technique (PUI) was performed using 2.5% sodium hypochlorite. The initial and residual filling material volume (mm^3) after each step was evaluated from the 0.5 to 6.5 mm level. The obtained data were expressed in terms of percentage of residual filling material. Statistical analysis was performed using the Friedman test ($P < 0.05$).

Results All specimens had residual filling materials after all retreatment procedures. Passive ultrasonic irrigation enhanced the elimination of residual filling material in comparison with the mechanical stage at the 0.5–2.5 mm and 4.5–6.5 mm levels ($P < 0.05$). No significant difference was found between xylene and PUI methods.

Conclusions Filling materials were not completely removed by any of the retreatment procedures. The use of xylene and PUI after mechanical instrumentation enhanced removal of materials during endodontic retreatment of anatomically complex teeth.

Keywords: endodontic retreatment, micro-CT, passive ultrasonic irrigation, solvent.

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Introduction

Ideally during root canal retreatment, all existing filling material should be removed because it may contain microorganisms that can interfere with effective distribution of irrigants and prevent adaptation of the new filling material. Several techniques have been used for removing the original root canal filling, including manual hand files and rotary files (Beasley *et al.* 2013). Solvents have also been used to help in the clearing of residual debris within the root canal (Gluskin *et al.* 2008).

Passive ultrasonic irrigation is a technique that aims to improve the cleaning of the root canal space.

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The use of ultrasound for retreatment purposes has been reported (Friedman *et al.* 1993); however, the use of passive ultrasonic irrigation (PUI) to improve the removal of filling materials has not been completely addressed. The aim of this study was to evaluate the percentage of remaining filling material in mesial root canals of mandibular molars after retreatment with three different procedures performed sequentially. The null hypothesis was that the addition of xylene and passive ultrasonic irrigation as additional steps do not increase the removal of filling material in comparison with that achieved by mechanical instrumentation.

Materials and methods

Extracted first mandibular molars were used. The inclusion criteria were mesial roots with Vertucci Type II classification (Vertucci 1984), curvatures between 10 and 30 degrees (Schneider 1971) and a single foramen. The anatomy was confirmed after micro-CT scanning (SkyScan 1174v2; SkyScan, Kontich, Belgium). The parameters used were 50 kV, 800 mA, 0.7 step size rotation and 16.8 μm voxel resolution. The digital data were further elaborated by reconstruction software (NReconv1.6.4.8; SkyScan). Based on the three-dimensional reconstructions of the root canals, twelve mandibular molars were included.

Root canal preparation and filling

Standard access cavities were performed using high-speed diamond burs (1014; KG Sorensen, Cotia, SP, Brazil). The working length was established by introducing a size 10 K-file until it could be seen through the apical foramen, this length was measured, and the working length was set 0.5 mm short of that length. The root canals were prepared using BioRaCe NiTi rotary instruments (FKG Dentaire, La Chaux-de-Fonds, Switzerland) until the BR3 instrument (size 25, .06 taper), using a X-Smart electric motor (Dentsply Maillefer, Ballaigues, Switzerland) at 500 rpm. All canals were irrigated immediately after each file with 1 mL of 2.5% sodium hypochlorite (NaOCl). After the instrumentation process, the canals received a final irrigation of 2 mL of 2.5% NaOCl. The solution was agitated using passive ultrasonic irrigation with a size 20, .01 taper E1-Irrissonic file (Capelli e Fabris Ind., Santa Rosa do Viterbo, SP, Brazil) attached to a Jet Sonic ultrasonic device (Gnatus, Ribeirão Preto, SP, Brazil). The file was used according to the manufacturer's instructions at a power setting of 20%. The E1-Irrissonic file was positioned 2 mm from the working length and activated for 20 s. This procedure was repeated for a total of 1 min (van der Sluis *et al.* 2007). The smear layer was removed with 2 mL of 17% EDTA for 3 min, and then, a 3 mL flush of distilled water was used as the final rinse, and the canals were dried with paper points (Dentsply Maillefer).

For the root canal filling procedures, a size 25, .06 taper gutta-percha cone (K3; SybronEndo, Orange, CA, USA) with adequate tug-back was selected. The gutta-percha point was coated with AH Plus sealer (Dentsply Maillefer) and inserted into the full working length. The excess material was seared off using the Elements Obturation Unit (SybronEndo) and condensed with a hand plugger 1 mm below the canal orifice. Next, the Elements Obturation Unit was preset to 200 °C, and the System B plugger (0.06 taper) was inserted into the root canal in a continuous wave of condensation within 4 mm from the working length (down-pack). Afterwards, the gutta-percha was condensed using Buchanan hand pluggers (SybronEndo). The backfill procedure was performed with the extruder hand piece of the Elements Obturation Unit and 23-gauge needle tips containing gutta-percha at a temperature of 200 °C and condensed at the orifice level with hand pluggers. All the teeth were then stored for 7 days at 37 °C and 100% humidity to allow the full setting of the sealer. Periapical radiographs of each tooth were taken to confirm the apical extent and homogeneity of the root canal filling. Then, the samples were scanned using the micro-CT system (SkyScan 1174, SkyScan) to obtain the initial volume of the filling material. For this purpose, the data were reconstructed and the CTan software (CTan v1.11.10.0, SkyScan) was used for the volume (mm^3) measurements of the radiopaque material.

Retreatment

The retreatment procedure was divided into three separate steps: (1) root canal filling removal and mechanical enlargement, (2) use of xylene and paper points (Gluskin *et al.* 2008) and (3) use of passive ultrasonic irrigation in conjunction with 2.5% sodium hypochlorite. After each step, the root canal was submitted to micro-CT scanning using the previously described parameters. Extracted teeth were mounted in a phantom head to reproduce clinical conditions. All laboratory retreatment procedures were carried

out with the aid of an operating microscope (M900; D.F. Vasconcellos, Valença, RJ, Brazil) at 5× magnification and were performed by the same operator.

Step 1
An aliquot of 0.5 mL of xylene was placed into the pulp chamber for 2 min to soften the gutta-percha at the cervical level of the root. Afterwards, size 15 and 20 manual K-files were used to create a glide path until the working length. Then, root canal instrumentation was achieved with BioRaCe BR3 size 25, .06 taper, BR4 size 35, .04 taper and BR5 size 40, .04 taper instruments used at 600 rpm, in cycles of four short vertical movements up to the working length. After use of each instrument, the canals were irrigated with 2 mL of 2.5% NaOCl. Then, 15 and 20 pre-curved K-files were used until there was no visual evidence of residual filling materials that could be seen with the operating microscope. No procedural errors were detected.

Step 2
The root canals were irrigated with 2 mL of xylene solvent for 1 min, and then, the root canals were dried with paper points in an attempt to remove additional remnants of the filling material. This procedure was repeated three times.

Step 3
In the third step, PUI was employed. Using a 27-gauge needle at 2 mm short of the working length, 2 mL of 2.5% NaOCl was delivered into the canal and pulp chamber. Then, PUI was used with an E1-Irrisonic size 20, .01 taper placed 2 mm from the working length with an up-and-down motion for 20 s. This procedure was repeated for a total of 1 min (van der Sluis *et al.* 2007).

MicroCT scanning procedures

Each tooth was scanned four times as follows: after the root canal filling and after each step of the root canal retreatment. Silicone moulds were created to allow for scanning teeth in the same position after each step. The same scanning parameters used to sample selection were adopted for all specimens. The digital data were further elaborated by reconstruction software (NReconv1.6.4.8, SkyScan). The CTan software was used for measuring the volume of filling material (mm^3) after each step. For each sample, the volume of the obturation was calculated at three levels: apical 1: between 0.5–2.5 mm, apical 2: between 2.5–4.5 mm and middle third 4.5–6.5 mm. The percentage of residual filling material after retreatment procedures was expressed in terms of the percentage of the initial root filling volume.

Statistical analysis

Based on a pilot study conducted with 5 teeth, the minimum sample size was estimated as seven teeth per group ($\alpha = 0.05$, $\beta = 0.20$, power statistics = 0.95), but 12 teeth were finally used to improve statistical analysis and compensate potential losses of samples during the study.

The preliminary analysis of the remaining filling material data did not show normal distributions (D'Agostino & Person normality test). Statistical analysis was performed using the Friedman test, and the Dunns test was used for the *post hoc* analysis. The significance level was set at 5%. The Prism 5.0 software (GraphPad Software Inc, La Jolla, CA, USA) was used as the analytical tool.

Results

All specimens had residual filling material after all retreatment procedures. Median, minimum and maximum values of the percentage of remaining filling material at the different root levels are shown in Table 1. Overall, within the retreatment measures, the passive ultrasonic irrigation stage enhanced the elimination of residual filling material in comparison with the mechanical stage at the 0.5–2.5 mm and 4.5–6.5 mm levels ($P < 0.05$). No significant difference was found between the xylene and PUI methods. The micro-CT reconstruction images (Fig. 1) show remaining filling material along the root canal after the last retreatment procedure.

Discussion

Root canal retreatment aims to completely remove existing filling material, because it is a physical barrier that could block or decrease the activity of irrigation solutions and intracanal medicaments on the infected dentine of the root canal space.

The anatomy of the root canal system and the quality of the initial root filling are important aspects that need to be considered during retreatment procedures. There is no consensus on which type of instruments are more efficient for retreatment procedures.

Table 1 Percentages of remaining filling material volume (median, minimum and maximum) at different root canal levels

	Mechanical cleaning	Post-xylene	Post-PUI
0.5–2.5 mm	33.39 (14.71–52.63)[a]	19.76 (11.19–38.10)[ab]	19.64 (4.11–35.94)[b]
2.5–4.5 mm	38.38 (8.79–74.16)[a]	22.86 (5.49–76.40)[a]	20.73 (7.66–74.16)[a]
4.5–6.5 mm	25.45 (0.77–50.54)[a]	19.85 (0.77–52.72)[ab]	17.40 (0.77–43.48)[b]

Different letters in each row indicates statistical differences ($P < 0.05$).
PUI, passive ultrasonic irrigation.

Some studies indicate that hand files remove more filling material (Zmener *et al.* 2006, Hammad *et al.* 2008), whilst in others, the NiTi rotary systems were more effective (Schirrmeister *et al.* 2006b, Rödig *et al.* 2012) or show no difference between them (Fenoul *et al.* 2010).

The mesial root of the mandibular molars has a high incidence of isthmuses (Villas-Bôas *et al.* 2011), and this irregular geometry of the root canal space can influence the ability of the instruments or techniques to remove filling material that was able to originally flow into these areas. Considering that

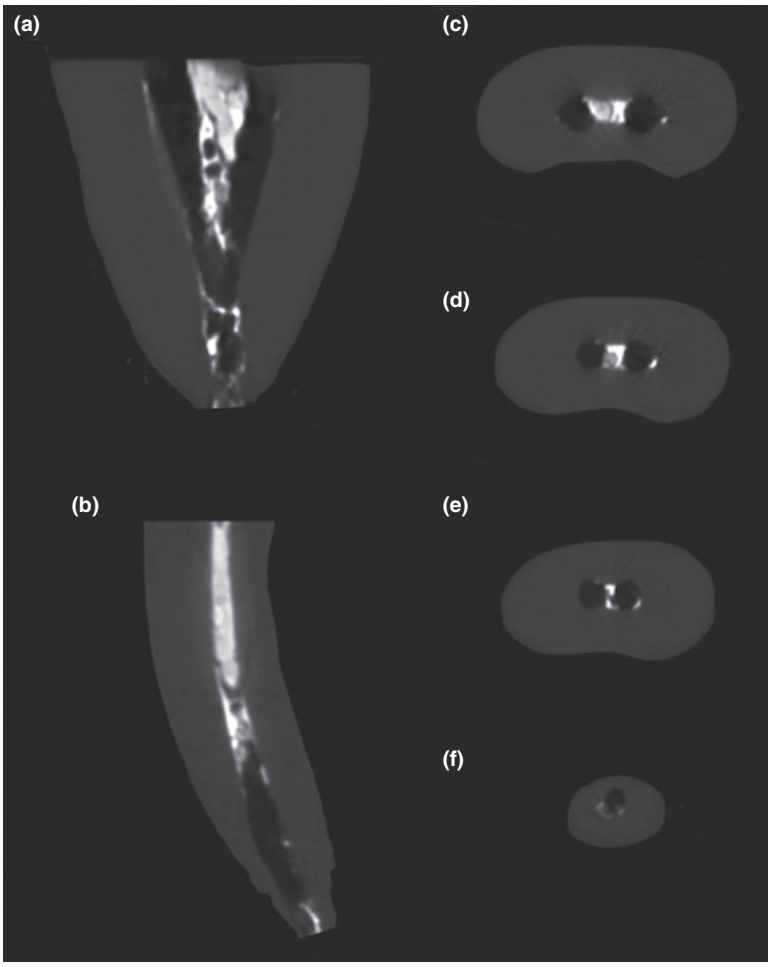

Figure 1 Microcomputed tomography reconstructions of a representative sample at the end of the retreatment procedures. Coronal and sagittal slices at the isthmus level are shown in (a–b). Transaxial slices at 6.5 mm (c), 4.5 mm (d), 2.5 mm (e) and 0.5 mm (f) are also shown. Note the inability of the mechanical, chemical and physical procedures to eliminate residual filling material at the isthmus level.

mechanical cleaning of the entire root canal system can only be achieved in 60% of the root canal surface (Paqué *et al.* 2009), the ability to efficiently eliminate residual material during the retreatment appears to be similar. The literature suggests that mechanical cleaning could be more influenced by anatomy and less influenced by the design of the instruments (Siqueira *et al.* 2013).

In this study, the specimens were selected according to an initial micro-CT analysis of the root canal anatomy that established they were Vertucci's Type II canals (Vertucci 1984). Two separate canals that leave the pulp chamber and join short of the apex to form one canal form this configuration.

The results showed that it was not possible to completely remove the existing root filling, which is in agreement with previous studies (Zmener *et al.* 2006, Hammad *et al.* 2008, Roggendorf *et al.* 2010, Abramovitz *et al.* 2012, Ma *et al.* 2012, Rödig *et al.* 2012, Solomonov *et al.* 2012). The null hypothesis was rejected. The use of ultrasonic agitation with sodium hypochlorite did significantly improve the removal of the filling material in comparison with mechanical cleaning in two segments of the root canal (0.5–2.5 mm and 4.5–6.5 mm). The use of xylene did not enhance root canal cleanliness; however, this procedure probably contributed to the performance of PUI. In this study, the solvent was not ultrasonically activated, but Wilcox (1989) showed no difference between ultrasonic cleaning using solvent (chloroform) and sodium hypochlorite.

Passive ultrasonic irrigation has the potential to enhance the removal of pulp tissue and dentine debris from remote areas of the root canal system untouched by endodontic instruments (van der Sluis *et al.* 2007). However, there are no reports on the effect of passive ultrasonic irrigation in retreatment procedures. Gutarts *et al.* (2005) showed that the use of ultrasonic irrigation, following root canal cleaning and shaping, for 1 min, improved canal and isthmuses cleanliness. Jiang *et al.* (2011) reported that higher ultrasonic intensity enhanced the cleaning efficacy of PUI, due to higher amplitude of the oscillating file that produced the greatest amount of acoustic streaming. From the results of this study, the protocol showed positive results even when using the ultrasonic intensity of 20%. However, more research is needed to clarify the cleaning efficacy of different ultrasonic intensities as well as the irrigation time and volume of irrigant during retreatment procedures.

The results showed that root canals filled with the warm vertical technique in complex anatomies, submitted to retreatment, are difficult to properly clean. The use of an operative microscope provides better detection of residual root filling material (Schirrmeister *et al.* 2006a), but in the mesial root canals of the mandibular molars, visualization with a higher magnification is limited to the cervical and middle third due to the curvature of the root canal system (Cunningham & Senia 1992).

Conclusions

Existing root filling material was not completely removed by any of the retreatment procedures. The use of additional procedures after the mechanical instrumentation such as xylene and PUI improved the removal of material during retreatment of anatomically complex teeth.

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