In Vitro Comparative Analysis of 2 Mechanical Techniques for Removing Gutta-Percha during Retreatment

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ABSTRACT

Objective: To compare the capacity of a reciprocating system (Endo-Gripper) and a rotary system (Profile .04) for mechanical removal of root-filling material from curved root canals in vitro.

Materials and Methods: Eighty canals (40 mesiobuccal and 40 mesiolingual) from mandibular first molars were instrumented and had their roots filled. After 6 months, 3-dimensional images of the roots were obtained by computed tomography (CT), and the volume of root-filling mass was measured. Root fillings were removed by either the reciprocating system with K-type files or the rotary system with NiTi files. The volume of filling debris remaining after the removal procedures was assessed by CT. The data were analyzed statistically by analysis of variance.

Results: Neither system completely removed the root-filling material. No significant differences were observed between the reciprocating and rotary systems in terms of the volume of filling material left within the canals after mechanical instrumentation. The volume of filling debris remaining was significantly lower for mesiolingual canals than for mesiobuccal canals.

Conclusions: Currently available mechanical systems are unable to completely remove filling material during retreatment. Use of the "threshold" function of the CT software allowed precise outlining of the remnants of filling material and calculation of its volume.

MeSH Key Words: dental instruments; gutta-percha; root canal preparation/instrumentation; root canal therapy/methods

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Over the years, nonsurgical endodontic retreatment has replaced apical surgery as the treatment of choice for cases of endodontic therapy failure. The recognition of persistent infection as the main cause of such failures has highlighted the need for procedures for cleaning and disinfecting the entire root canal system.[1]

One of the greatest technical difficulties faced by endodontists is achieving complete removal of old filling materials; this material represents a mechanical barrier that hinders

contact of irrigating solutions and intracanal dressings with the root canal walls. The complexity of the internal dental anatomy makes this procedure even more difficult.[2]

With the advent of mechanical instrumentation, new techniques have been introduced for removing filling materials from root canals. In several retreatment studies comparing the efficacy of rotary systems and hand instrumentation for removing gutta-percha,[1,3,4] none of the techniques evaluated was able to completely remove the filling material from the root canals.

Reciprocating systems are an interesting alternative for removal of root fillings in retreatment cases because they are less costly than nickel–titanium rotary systems. However, few studies have investigated the efficiency of reciprocating systems for emptying filled root canals.[1,4–6]

Various assessment methods have been used in endodontic retreatment research, such as radiography[1] and cleavage of the dental structure.[3,5,7] Computed tomography (CT) has been used in instrumentation studies[8] because it enables 3-dimensional evaluation of the root canal system before and after instrumentation.

The purpose of this in vitro study was to compare, using CT scanning, the capacity of 2 mechanical systems, one reciprocating and the other rotary, to remove root-filling material from the curved root canals of mandibular molars.

Materials and Methods

Forty extracted human mandibular first molars were collected and radiographed in a buccolingual direction with size 2 periapical films to confirm the following characteristics: full development of the roots; absence of root fillings, prosthetic pins, internal resorption, and localized or diffuse calcifications; curvature between 20° and 40°[9]; and presence of 2 distinct root canals, for a total of 80 canals. The crown of each tooth was sectioned at the cementoenamel junction, and the distal roots were removed with a water-cooled double-faced diamond disk operated at low speed. The length of the mesial roots was standardized between 14 and 16 mm, and the buccal surface of the roots was marked with a pencil.

Each root canal was explored with a #10 K-type file (Dentsply/Maillefer, Ballaigues, Switzerland), which was passively advanced into the canal until the tip of the instrument penetrated and bound to the apical foramen. Placement was confirmed by examination of the apical third of the canal with a stereoscopic magnifying lens (×40 magnification). The real length of the canal was recorded, and the working length was calculated by subtracting 1 mm from this measurement. During this procedure, the presence of 2 canals with different exits was confirmed.

Thereafter, each root canal was prepared with a crown-down technique using Flexo-File files (Dentsply/Maillefer) #40, #35 and #30, applied sequentially, with movements of insertion and rotation through 90° to the right and to the left, until there was resistance to traction. Next, root canal instrumentation was carried out with #15, #20, #25, #30, #35 and #40 K-type files according to the step-back technique; the #30 K-type file was the first instrument to bind at the working length. At each change of file size, the canals were alternately irrigated with 2 mL of 1% sodium hypochloride and 2 mL of 17% trisodium ethylenediaminetetra-acetic acid (EDTA). After chemomechanical preparation, the canals were dried with #30 absorbent paper points.

The root canals were then obturated by the lateral condensation technique, with a size 30 master gutta-percha cone, B7 accessory gutta-percha cones (Tanari Industrial, Manaus, Brazil) and zinc oxide and eugenol sealer (Endofill; Dentsply, Petrópolis, Brazil). Mesiodistal radiographs were obtained to assess the quality and apical extent of root fillings. The root canal entrances were sealed with temporary filling material (Cavit; ESPE Dental, Medizin, Germany), and specimens were stored at 37°C in 100% humidity. After 6 months, the roots were numbered randomly from 1 to 40 and placed in individual flasks, where they were kept hydrated.

Before CT images were obtained, the temporary filling material was removed from each canal entrance with a #4 carbide round bur operated at high speed; this was done to avoid interference with the root-filling readings by the radiopacity of the sealing material. On a sheet of A4 paper, a space for each root was demarcated and numbered (from 1 to 40). Each root was affixed to its assigned location with double-sided tape, buccal surface up. Three-dimensional images of the roots were obtained using a GE LightSpeed Plus multidetector CT scanner (General Electric Medical Systems, Milwaukee, Wis.). This CT scanner provides 0.6-mm-thick transverse sections at 0.6-mm increments; it is equipped with a tube that rotates at 0.8 rpm and reconstruction tools of maximum-intensity projection and volume rendering (**Fig. 1**).

After CT scanning of all specimens, the total volume of root-filling mass in each canal was obtained by Volume Analysis 2 - Voxtool 3.0.54z software (General Electric Medical Systems, Milwaukee, Wis.). The function "3D tools" in this software was chosen, and the "threshold" tool was selected. The lower limit was set at 2506 and the upper limit at 3071, and the "threshold" tool was applied. The area corresponding to the root-filling mass was outlined with a software tool, the function "display tools" was selected, and the globe icon on the display was chosen to obtain the total volume of filling material in cubic millimetres (**Figs. 2** and **3**); this value was recorded in a spreadsheet. These procedures were repeated for the mesiobuccal and mesiolingual canals in each root. The

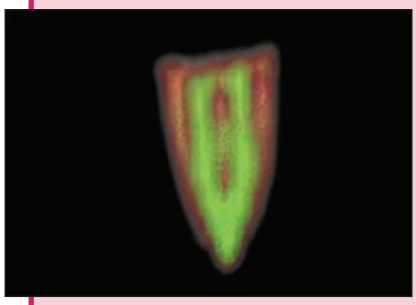

Figure 1: Computed tomography (CT) image of mesiobuccal and mesiolingual canals with root-filling material in place.

Figure 2: CT image of the filling material shown in **Fig. 1** after application of the "threshold" tool in the mesiobuccal canal (see text for further description of this tool). Calculation of the total volume of filling material is shown.

Figure 3: CT image of the filling material shown in **Fig. 1** after application of the "threshold" tool in the mesiolingual canal. Calculation of the total volume of filling material is shown.

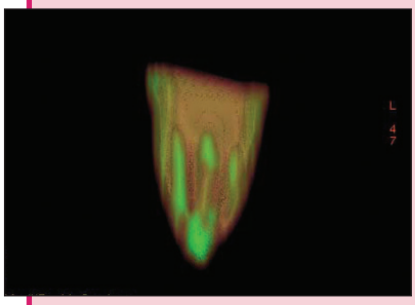

Figure 4: CT image of mesiobuccal and mesiolingual canals after removal of filling material with the Profile .04 rotary system.

Figure 5: CT image of the filling material shown in **Fig. 4** after application of the "threshold" tool in the mesiobuccal canal. Calculation of the remaining volume of filling material is shown.

Figure 6: CT image of the filling material shown in **Fig. 4** after application of the "threshold" tool in the mesiolingual canal. Calculation of the remaining volume of filling material is shown.

CT images of each specimen were transferred to an individual compact disc (CD), for a total of 40 CDs.

For stratified randomization of the sample, the specimens were assigned to 2 groups of 20 teeth each (groups A and B). Each of these groups was subdivided into 2 groups of 10 teeth (and 20 canals) each, as follows: subgroups A1 and B1 each had 20 mesiobuccal canals, and subgroups A2 and B2 each had 20 mesiolingual canals.

In preparation for removal of the root-filling material, one drop of eucalyptol solvent was applied at the canal entrance and left for 3 minutes. A path was then created within the softened gutta-percha using #25, #20 and #15 K-type files, applied sequentially, until the working length was reached. After the root canal had been negotiated and the working length reached, removal of gutta-percha continued with one of the mechanical systems under study. For subgroups A1 and B2, the root fillings were removed with the reciprocating system, and for subgroups A2 and B1, the rotary system was used, as follows:

- Subgroups A1 and B2: Removal of root-filling material with the Endo-Gripper reciprocating system (Moyco Union Broach, York, Penn.) coupled to an electric engine (Nouvag AG, Goldach, Switzerland) in association with K-type files, at 10 N torque and 13,000 rpm speed. Root fillings were removed with a crown-down technique, using #40, #35 and #30 K-type files adjusted to working length and attached to the device's handpiece. The instruments were introduced into the canals and operated with small pendulum movements along the root canal walls, with amplitude no greater than 3 mm, until the #30 K-type file reached the working length.
- Subgroups A2 and B1: Removal of root-filling material with the Profile .04 taper nickel–titanium rotary system (Dentsply/Maillefer) coupled to the same electric engine, at 10 N torque and 250 rpm speed. Root fillings were removed with a crown-down technique, using .04 Profile #40, #35 and #30 NiTi instruments (Dentsply/Maillefer), applied sequentially, with gentle in-and-out movements of small amplitude along the canal walls until resistance was felt, in such a way that the #30 NiTi file reached the working length.

Table 1 Mean percentage of original filling material remaining in the mesiobuccal and mesiolingual root canals after removal by 2 mechanical systems

	Volume of filling material remaining					
	Reciprocating system		Rotary system		Overall	
Canal	mm^3	%	mm^3	%	mm^3	%
Mesiobuccal	24.73	16.37	19.94	12.66	22.34[a]	14.64
Mesiolingual	13.99	10.32	19.11	9.96	16.68[b]	10.33
Overall	19.49	14.63	19.52	11.22	19.51	12.92

Different letters indicate statistically significant difference by analysis of variance (5% significance level).

At each change of instrument, the root canal being processed was irrigated with 2 mL of 1% sodium hypochloride, which was then aspirated; a new drop of solvent was then applied at the canal entrance. Gutta-percha removal was considered complete when no filling debris was observed on instrument flutes or in the irrigating solution; tactile perception of smooth canal walls was another indicator of completeness.

Once removal of the root-filling material was complete, the specimens were repositioned on the demarcated sheet of A4 paper, in the same places and in the same positions as for initial CT scanning. CT of the roots was repeated, and the volume of filling material remaining inside the canals was calculated and recorded as the final volume (**Figs. 4, 5** and **6**). The CT images of each root were transferred to an individual CD, for a total of 40 CDs.

The mean percentage of filling debris remaining in the mesiobuccal and mesiolingual canals was calculated. Analysis of variance (ANOVA) was used to compare the results of mechanical instrumentation techniques for removing the root-filling material, for both mesiobuccal and mesiolingual canals. The significance level was set at $\alpha = 0.05$. Data were analyzed with SPSS software, version 11 (SPSS Inc., Chicago, Ill.).

Results

Neither system was able to completely remove the filling materials from the root canals.

The mean percentage of filling debris remaining after mechanical removal was higher (but not significantly so) for the reciprocating system than for the rotary system (14.63% vs. 11.22%; $p > 0.05$) (**Table 1**).

The mean percentage of filling material remaining was significantly higher for the mesiobuccal canals than the mesiolingual canals (14.64% vs. 10.33%), irrespective of the mechanical system used ($p < 0.05$) (**Table 1**).

Discussion

The technical difficulties encountered during endodontic retreatment are due not only to the mechanical obstruction represented by the root-filling mass, but also to the complex anatomy of some root canals. The present study was intended to assess the efficiency of 2 mechanical systems for removing filling materials from the curved root canals of mandibular molars.

In this study, the crowns of the teeth were removed at the cementoenamel junction, even though this procedure does not fully reproduce clinical conditions. Decoronation was performed to ensure standardization of specimens by eliminating some variables, such as anatomy of the dental crown and access to root canals, thereby allowing more reliable comparisons between the proposed retreatment techniques.

Few studies in the specialized literature address the use of mechanical systems for removal of root fillings during endodontic retreatment. The design of the present study, comparing a reciprocating system and a rotary NiTi system, both driven by an electric engine, for removal of root-filling material, as well as the torque and speed adjustments used, were based on the methods and findings of previous investigations.[1,6]

According to Gambarini,[10] mechanical instrumentation with low torque enhances tactile sensitivity and, as a result, increases the control of rotary files during root canal preparation. This approach, used in the present study, minimizes the risk of zips, ledges and perforations during root-filling removal and also avoids breakdown of engine-driven instruments.

The use of an electric engine for activation of the reciprocating system follows the recommendations of Yared and others.[11] Those authors stated that, because systems driven by compressed air lack torque control, the torque may be altered when the rotation speed is changed.

Several methods have been proposed for assessing the amount of filling debris remaining inside root canals after endodontic retreatment. Currently used methods include longitudinal cleavage of the teeth[2]; association of longitudinal and transverse cleavage for separate evaluation of the cervical, middle and apical thirds[3,7]; cleavage associated with photographic records[12,13]; and cleavage and photography in conjunction with radiographic examination.[5] However, the validity of these methods is debatable because longitudinal cleavage of the teeth may result in displacement of the filling debris that is to be

evaluated, which would compromise the accuracy of the measurements.

Therefore, in an attempt to remove the bias introduced by the loss of material during cleavage of specimens, less invasive methods for quantitative assessment of removal of filling material have been proposed.[1,6] In both of the cited studies, gutta-percha was removed and radiographs of the canals were then obtained and digitized. The images obtained were magnified several times, and the canal areas with filling debris were outlined and measured using specific tools available in AutoCAD software. This is a more appropriate method because it avoids errors arising from the loss of filling debris, but computer-assisted evaluation also has its limitations; in particular, radiographic images provide only 2-dimensional information about a 3-dimensional structure. An ideal method to quantitatively assess the amount of debris left inside root canals after removal procedures should generate 3-dimensional images. Another limitation is that the software cannot calculate areas of objects with irregular outlines and therefore analyzes only the largest areas.

More recently, the use of CT in endodontic research has enabled 3-dimensional appraisal of treatments performed within the root canal system. This noninvasive method allows detailed visualization of the morphological features and does not require destruction of the teeth. Up to now, this method has been used to assess the internal anatomy of the teeth,[14–17] the quality of root canal preparations[9,18] and root canal obturation.[19]

In the present study, CT was used to assess the volume of filling material that remained inside root canals after mechanical removal. Using the "threshold" function of the CT software, it was possible to precisely outline the remnants of the filling material and to calculate its volume in cubic millimetres.

The use of mandibular molars allowed individual evaluation of the mesiobuccal and mesiolingual canals. These canals have distinct characteristics, such as the degree of root flattening in a mesiodistal direction and variable curvature, which made it possible to assess how the anatomic peculiarities of each type of canal affected the removal of root-filling material by the techniques under study. Stratified randomization of the sample allowed a homogeneous assignment of the mesiobuccal and mesiolingual canals and enabled reliable evaluation of the techniques in both canals. After application of the removal techniques, a higher percentage of filling material remained in the mesiobuccal canals than in the mesiolingual canals. This finding can be explained by the anatomic complexity of the mesiobuccal canals, which makes retreatment procedures more difficult.

Neither of the systems used in this study afforded complete removal of the filling material. In addition, there was no statistically significant difference between the reciprocating system with K-type files and the rotary system with Ni-Ti files with respect to the total percentage of filling debris that remained. It should be stressed, however, that both systems efficiently removed the gutta-percha fillings. These findings are consistent with the results for the entire root canal obtained in previous studies.[1,6]

In the earlier investigations,[1,6] in which the amount of filling material remaining was assessed separately in each third of the canal, a greater amount of filling debris remained in the apical third than in the middle and cervical thirds, irrespective of the technique used. Masiero and Barletta[1] reported that a rotary system yielded remarkably more effective removal of filling remnants in the apical third than the other techniques evaluated.

However, if such evaluations were to be carried out in the curved root canals of mandibular molars, as in the present study, different results might be observed, mainly because the cervical and middle thirds of these roots are considerably flattened in the proximal direction. Instruments that are positioned centrally within the canal, like rotary files, may not remove root fillings adequately and should therefore be complemented by hand instrumentation.

Further investigation, using CT as an assessment methodology within a comprehensive analysis of removal of root-filling material from each third of the tooth, might elucidate the issues that remain unclear.

Conclusions

Neither of the systems tested here completely removed the filling material from inside root canals, and there were no significant differences between the reciprocating and rotary systems with regard to the volume of filling material left inside the canals after mechanical instrumentation. There was a significantly lower volume of filling material remaining in mesiolingual canals than in mesiobuccal canals.

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