Micro–Computed Tomography Study of Filling Material Removal from Oval-shaped Canals by Using Rotary, Reciprocating, and Adaptive Motion Systems

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Abstract

Introduction: This study evaluated filling material removal from distal oval-shaped canals of mandibular molars with rotary, reciprocating, and adaptive motion systems by using micro–computed tomography. **Methods:** After cone-beam computed tomography scanning, 21 teeth were selected, prepared up to a size 40 file, root filled, and divided into 3 groups (n = 7) according to the filling material removal technique: group PTUR, ProTaper Universal Retreatment combined with ProTaper Universal F2, F3, F4, and F5 files; group RP, Reciproc R50 file; and group TFA: TF Adaptive 50.04 files. The specimens were scanned preoperatively and postoperatively to assess filling material removal by using micro–computed tomography imaging, and the percent volume of residual filling material was calculated. **Results:** The statistical analysis showed the lowest percent volume of residual filling material at the coronal third in all groups ($P < .05$). There was no significant difference among the systems in the coronal third ($P > .05$). In the middle third, group TFA (31.2 ± 10.1) showed lower volume of residual filling material than group RP (52.4 ± 14.1) ($P < .05$). In the apical third, groups TFA (44.8 ± 20.6) and PTUR (48.6 ± 16.8) presented a lower percent volume of filling material than group RP (70.6 ± 7.2) ($P < .05$), as confirmed by the qualitative analysis. **Conclusions:** The use of the adaptive motion increased the amount of root filling removed in the middle and apical thirds compared with the reciprocating motion. However, no technique was able to completely remove the filling material from the canals. *(J Endod 2016;42:793–797)*

Key Words

Computed microtomography, reciprocating motion, Retreatment, TFA adaptive

Failure in root canal treatment is usually related to the presence of residual bacteria (persistent infection) or reinfection of an endodontically treated tooth (secondary infection) because of inadequate cleaning, disinfecting, shaping, and filling of the root canal system, leaving endodontic retreatment as the first therapeutic alternative (1). The primary goal of root canal retreatment is to treat the infectious process by removing the filling material and eliminating debris and microorganisms associated with apical periodontitis (2–4).

With the advent of mechanized instrumentation, different techniques have been proposed for endodontic retreatment by using nickel-titanium rotary systems (3, 5–7) and reciprocating systems (8–12). However, none of the various techniques and file systems tested in the numerous studies were able to completely remove the filling material from inside the canals (3, 5, 7–9, 11–15).

The TF Adaptive system (SybronEndo, Orange, CA), which has an innovative kinematics that automatically adapts to instrumentation stress, was recently launched in the market. This system is designed to permit switching from a continuous clockwise motion, when the instrument is not subjected to stress within the canal, to an interrupted reciprocation motion, when undue tensions are generated by dentin during instrumentation. The adaptive motion varies from 600° clockwise/0° counterclockwise up to 370° clockwise/50° counterclockwise, depending on the intracanal stresses produced on the instrument (16, 17).

Recent studies have shown that the combination of rotary and reciprocating motion (adaptive motion) permits greater centralization of the instrument inside the canal (16, 18, 19) and reduces dentinal crack formation during instrumentation (20, 21) when compared with rotatory and reciprocating systems. Capar et al (17) evaluated the effectiveness of rotary instruments used with rotational or adaptive motion in the removal of root canal filling material from mandibular molars and found better results with the adaptive motion. However, there are few studies evaluating the use of this kinematics in endodontic retreatment (17). Thus, the aim of this study was to evaluate the removal of filling material from distal oval-shaped canals of mandibular molars with

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rotary, reciprocating, and adaptive (alternated rotational and reciprocating motion) motion systems by using micro–computed tomography (micro-CT).

Materials and Methods

Selection of Teeth

After Ethics Committee approval (Protocol no. 2012/146.661), 60 extracted human mandibular molars with a patent and single canal in the distal root, fully formed apex, no internal calcifications, and no previous endodontic treatment were selected on the basis of clinical and radiographic examinations from a pool of extracted teeth. The teeth were stored in individual plastic vials containing 0.1% thymol solution and were washed in running water for 24 hours before use. For standardization purposes, all teeth were scanned with a cone-beam computed tomography device (I-Cat; Kavo-Imaging Science, Hatfield, PA) to identify distal roots with a single, straight, oval canal. Oval-shaped canals were considered when the buccolingual diameter was 2 times larger than the mesiodistal diameter at 5 mm from the root apex (22–24). According to these inclusion and exclusion criteria, 21 mandibular molars were selected for the study.

SigmaPlot 11.0 statistical software (Systat Software Inc, San Jose, CA) was used for sample size calculation that was based on the following pre-established parameters from a pilot study: minimum detectable difference between means equal to 0.40 and coefficient of variation equal to 0.20. An alpha-type error of 0.05, power beta of 0.8, and number of groups (within subjects) of 2 were considered. With these results, the estimated minimum sample was found to be 6 specimens per group. The statistical power analysis before the experiments resulted in a value of 0.742.

Preparation of Specimens

The crowns were removed and ground coronally to establish a uniform 14-mm root length for all teeth. To eliminate interoperator variability and biases, a single experienced operator performed all procedures.

Subsequently, coronal third enlargement was performed with Gates-Glidden drills sizes 1, 2, and 3 (Dentsply Maillefer, Ballaigues, Switzerland), and apical patency was determined by inserting a size 10 K-file (Dentsply Maillefer) into the root canal until its tip was visible at the apical foramen, and the working length (WL) was set 1.0 mm short of this measurement. The root canal was prepared by the crown-down technique to the WL at a speed of 350 rpm with the use of a torque control endodontic motor (VDW Silver; VDW GmbH, Munich, Germany) by using the K3 (SybronEndo) sequence as follows: #25/.08, #25/.06, and #25/.04. All files were used passively, and apical enlargement was performed by using #25.06, #30.04, #35.02, and #40.02 files. At each instrument change, the root canal was irrigated with 2 mL 2.5% NaOCl. A final rinse was performed with 2 mL 17% EDTA for 5 minutes followed by 2 mL distilled water for 1 minute, and the canals were dried with paper points (Dentsply Maillefer).

Canal Filling

The root canals were filled with gutta-percha (main cone size 40) and an epoxy resin-based sealer (AH Plus; Dentsply DeTrey GmbH, Konstanz, Germany) by using the Tagger hybrid technique. The roots were radiographed in ortho-radial and mesiodistal directions to ensure consistency of the root filling procedure and absence of voids in the filling mass. The canal access was sealed with a temporary restorative material (Coltosol; Vigodent, Ulm, Baden Wuerttemberg, Germany), and the specimens were stored in 100% humidity at 37°C for 2 weeks. To simulate the thermal changes occurring in the mouth, the specimens were subjected to thermocycling (1000 cycles) between 5°C and 55°C with 30-second dwell time.

Retreatment Procedures

The specimens were matched on the basis of initial volume of the filling material and randomly assigned to 3 groups (n = 7) by using a computer algorithm program (http://www.random.org) according to the filling removal technique: group PTUR (ProTaper Universal Retreatment D1, D2, and D3 files combined with ProTaper Universal F2, F3, F4, and F5 files; Dentsply Maillefer, Tulsa, OK), group RP (Single file Reciproc 50.05; VDW GmbH), and group TFA (Single file TF Adaptive 50.04; SybronEndo).

Group PTUR: Rotary Motion

The instruments were used in continuous clockwise rotation by using a gentle in-and-out pecking motion with 500 rpm speed and 2 N/cm torque (VDW Silver; VDW GmbH). Instrument D1 (size 30, taper 0.09) was used for filling removal in the coronal third, followed by instrument D2 (size 25, taper 0.08) in the middle third, and instrument D3 (size 20, taper 0.07) at the WL. Filling removal was completed with ProTaper instruments F2 (size 25, taper 0.08), F3 (size 30, taper 0.09), F4 (size 40, taper 0.06), and F5 (size 50, taper 0.05) used sequentially.

Group RP: Reciprocating Motion

The Reciproc 50.05 file was introduced into the canal until resistance of the filling material was felt and then activated in reciprocating motion generated by a 6:1 contra-angle handpiece (Sirona, Bensheim, Germany) powered by an electric motor (VDW Silver). The file was moved in the apical direction by using an in-and-out pecking motion with approximately 3-mm amplitude by using light apical pressure combined with brushing action against the lateral canal walls. After 3 pecking motions, the instrument was removed from the canal and carefully cleaned. This protocol was repeated until the instrument reached WL.

Group TFA: Adaptive Motion

The TFA 50.04 file was introduced into the canal until resistance of the filling material was felt and then activated in the adaptive motion generated by the M4 handpiece (Axxis; SybronEndo) powered by an electric motor (Elements Motor; SybronEndo, Copel, TX), with the torque and speed determined by the manufacturer. The file was moved by using an in-and-out pecking motion with light apical pressure combined with brushing action against the lateral canal walls. After 3 pecking motions, the instrument was removed from the canal and carefully cleaned. This protocol was repeated until the instrument reached WL.

For all groups, each instrument was discarded after use in 2 canals. Between each preparation step, irrigation was performed with disposable syringes and 30-gauge NaviTip needles (Ultradent, South Jordan, UT) introduced up to 2 mm short of the WL by using 2 mL 2.5% NaOCl. In all groups, no solvent was used, and filling material removal was considered complete when there was no evident filling material on the instrument.

Micro-CT Scanning and Evaluation

The specimens were scanned preoperatively and postoperatively to assess filling material removal from the root canals by using a micro-CT device (SkyScan 1174v2; Bruker-microCT, Kontich, Belgium) with the following parameters: 50 kV, 800 mA, isotropic resolution of 16.7 μm, and 360° rotation. The images were reconstructed by using NRecon v.1.6.3 software (Bruker-microCT), and CTAn v.1.15.4 software (Bruker-microCT) was used for determining the preoperative and postoperative filling material volumes (mm^3). The residual filling material was calculated as a percentage.

Qualitative 2-dimensional and 3-dimensional (3D) analyses of the localization of the residual filling material according to the canal thirds were performed on micro-CT cross sections and 3D models by using Data Viewer v.1.5.1 64-bit (Bruker-microCT) and CTVol v.2.3.1 (Bruker-microCT), respectively.

Statistical Analysis

The data were examined for normal distribution (Shapiro-Wilk test, $P > .05$) and homogeneity of variance (Levene test, $P > .05$). One-way analysis of variance was performed in a split-plot arrangement, with the plot represented by mechanized motion systems and the subplot represented by the root thirds. All pairwise multiple comparison procedures were performed by using the Tukey test.

Results

The mean percentages of residual filling material in the groups are shown in Table 1. Remaining filling material was observed in all specimens.

Considering the entire root canal, group TFA (29.3 ± 19.0) presented a significantly lower mean percent volume of residual filling material compared with group RP (43.9 ± 28.1) ($P < .05$), but no significant difference was found compared with group PTUR (35.4 ± 19.8) ($P > .05$).

Considering the volume of filling material by thirds, significantly lower mean percent volume of residual filling material was found in the coronal third ($P < .05$). In the coronal third, no statistically significant difference was observed among the groups ($P > .05$). In the middle third, the use of the adaptive motion (31.2 ± 10.1) resulted in a significantly lower mean percent volume of remaining filling material compared with the reciprocating motion (52.4 ± 14.1) ($P = .05$). The group PTUR presented similar volume of residual filling material to groups TFA and RP ($P > .05$). In the apical third, the residual volume of filling material was significantly lower in groups TFA (44.8 ± 20.6) and PTUR (48.6 ± 16.8) than in group RP (70.6 ± 7.2 mm) ($P < .05$).

The 3D reconstruction of micro-CT images revealed residual filling material in all root canals, regardless of the retreatment technique (Fig. 1). In groups TFA and PTUR, action of the instruments was observed in all canal thirds, including the apical region. On the other hand, higher percentage of residual filling material was observed in the apical region in group RP (Fig. 1, cross-sectional images).

Discussion

Removal of the root canal filling material is a major step in endodontic retreatment because it permits effective action of instruments and irrigating solutions on the debris and microorganisms associated with apical periodontitis (10, 25). Several methods have been used for quantification of filling material remaining in the canals after endodontic retreatment, including radiographic imaging (14), longitudinal cleavage of the roots for microscopic analysis or photographic records (3, 12), and CT (13). Micro-CT imaging was used because it is recognizably an excellent nondestructive high-resolution imaging method that provides a highly accurate quantitative 3D analysis of filling material volume (in mm^3) before and after use of the instruments (8, 9, 26, 27), allowing for calculating the percentage of filling material left in the canals after retreatment.

To obtain an even distribution of specimens in the groups, minimizing the critical effect of root canal anatomy and increasing the validity of the experiment (28), cone-beam computed tomography scanning was performed to allow the selection of teeth with a single, oval-shaped distal canal according to a buccolingual diameter of the canal 2 times larger than that of the mesiodistal diameter (24, 29). After instrumentation and root filling, the initial volume of filling material as analyzed by micro-CT was used to obtain a stratified distribution of specimens in the groups.

Oval-shaped canals represent a challenge to any mechanized system for both preparation of canals and removal of filling material from root-filled teeth (22, 23, 27, 30, 31) because the flattened areas of the canal are not touched by the instruments (30). The reason for using oval-shaped canals in the present study was to test the different types of motion (rotary, reciprocating, and adaptive) in a critical condition for filling material removal. Other studies used circular canals for evaluation of different mechanized systems during retreatment (12, 14, 25, 26).

For all systems evaluated in this study, filling removal was performed up to a size 50 instrument (final diameter) because the canal had been prepared up to a size 40 instrument at the WL. Therefore, retreatment allowed an increased staging around 100 μm as in other studies (12).

The results of the present study showed that none of the systems were able to completely remove the filling material from the root canals (Fig. 1). Considering the volume of material remaining in the entire root canal, group TFA provided significantly better results than group RP and similar to group PTRU. In a recent study, Capar et al (17) found a lower mean volume of residual filling material by using ProTaper Universal Retreatment instruments in adaptive motion compared with continuous rotation during retreatment of mesial canals of mandibular molars. It may be assumed that the adaptive motion was more efficient than the rotary motion in their study because of the greater taper of the ProTaper instruments used in adaptive kinematics, eg, tapers .09, .08, and .07, compared with the taper .04 of the TFA single file used in our study. For Burklein and Schafer (2), the greater the taper of the instrument was, the greater the removal capacity and expansion of the root canal were.

Regarding the evaluation of the volume of residual filling material in the 3 canal thirds, there was no statistically significant difference among the groups in the coronal third. On the other hand, in the middle and apical thirds, group TFA showed lower mean values than group RP. These results were confirmed in the qualitative analysis, which revealed more filling material in the apical region in group RP, followed by groups PTUR and TFA. The lower volume of filling material in groups PTUR and TFA could be related to the fact that rotational motion may increase coronal transportation of debris (2) and consequently avoid filling material compression in the apical region, whereas the reciprocating motion causes the instrument to progress forward continuously and might push debris toward the apex (32).

In general, these results suggest that the greater filling removal capacity of the TFA system could be attributed to the combination of continuous rotation and reciprocating motion, where the first motion

TABLE 1. Mean Percent Volume of Residual Filling Material in Root Canals after Use of the Rotary (PTUR), Reciprocating (RP), and Adaptive (TFA) Motion Systems

Canal third	PTUR	RP	TFA
Coronal	17.4 ± 10.8 Aa	8.6 ± 3.3 Aa	11.3 ± 4.0 Aa
Middle	40.1 ± 17.4 ABb	52.4 ± 14.1 Bb	31.2 ± 10.1 Ab
Apical	48.6 ± 16.8 Ab	70.6 ± 7.2 Bc	44.8 ± 20.6 Ab
Total	35.4 ± 19.8 AB	43.9 ± 28.1 B	29.3 ± 19.0 A

Uppercase letters in rows and lowercase letters in columns indicate statistically significant difference (Tukey test, $P < .05$).

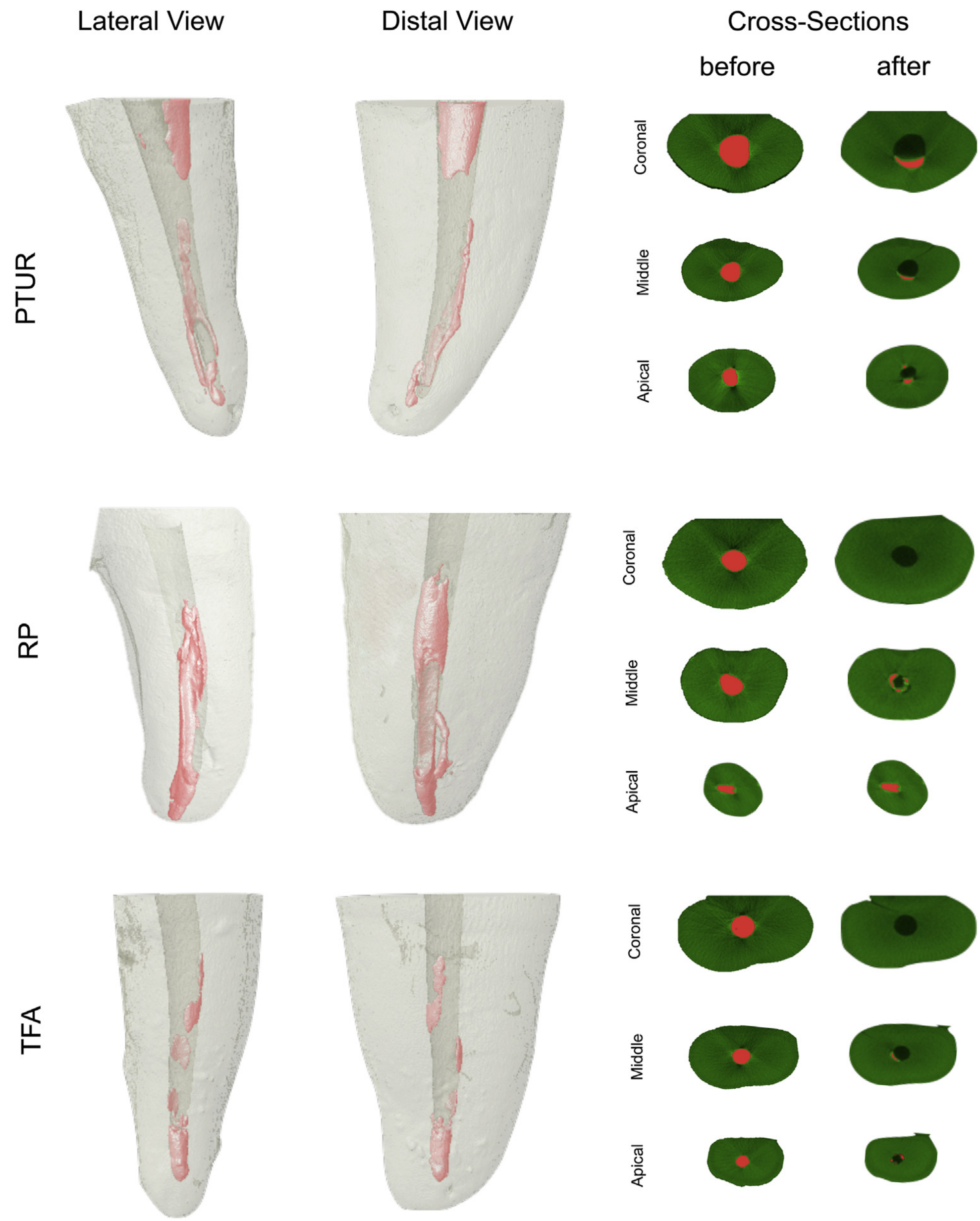

Figure 1. Lateral and distal views of representative 3D micro-CT reconstructions of the distal root canal of mandibular molars showing residual filling material (pink) after use of the rotary (PTUR), reciprocating (RP), and adaptive (TFA) motion systems. Cross-sectional images from the coronal, middle, and apical distal root thirds before and after retreatment show filling material (red) in the canals.

promotes cutting of the filling material and the second motion promotes displacement of material in the coronal direction (17). According to the qualitative and quantitative outcomes, it may be concluded that the adaptive system provided the greatest removal of filling material from the middle third and was similar to the rotary system in the apical third.

On the basis of the results of this laboratory study, the use of the adaptive motion increased the amount of root filling removed compared with the reciprocating motion in the middle and apical thirds. However, no technique was able to completely remove the filling material from the root canals.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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