Efficacy of CM-Wire, M-Wire, and Nickel-Titanium Instruments for Removing Filling Material from Curved Root Canals: A Micro–Computed Tomography Study

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Abstract

Introduction: The aim of this *ex vivo* study was to evaluate the removal of filling material after using CM-wire, M-wire, and nickel-titanium instruments in both reciprocating and rotary motions in curved canals. **Methods:** Thirty maxillary lateral incisors were divided into 9 groups according to retreatment procedures: Reciproc R25 followed by Mtwo 40/.04 and ProDesign Logic 50/.01 files; ProDesign R 25/.06 followed by ProDesign Logic 40/.05 and ProDesign Logic 50/.01 files; and Gates-Glidden drills, Hedström files, and K-files up to apical size 30 followed by K-file 40 and K-file 50 up to the working length. Micro–computed tomography scans were performed before and after each reinstrumentation procedure to evaluate root canal filling removal. Statistical analysis was performed with Kruskal-Wallis, Friedman, and Wilcoxon tests ($P < .05$). **Results:** No significant differences in filling material removal were found in the 3 groups of teeth. The use of Mtwo and ProDesign Logic 40/.05 rotary files did not enhance filling material removal after the use of reciprocating files. The use of ProDesign Logic 50/.01 files significantly reduced the amount of filling material at the apical levels compared with the use of reciprocating files. **Conclusions:** Association of reciprocating and rotary files was capable of removing a large amount of filling material in the retreatment of curved canals, irrespective of the type of alloy of the instruments. The use of a ProDesign Logic 50/.01 file for apical preparation significantly reduced the amount of remnant material in the apical portion when compared with reciprocating instruments. *(J Endod 2016;42:1651–1655)*

Key Words

Controlled memory wire, curved root canals, micro-computed tomography, reciprocating systems, root canal retreatment, rotary systems

Significance

Complete removal of filling material is recommended to enable root canal disinfection in retreatment. Canal curvatures represent a challenging clinical situation, and reciprocating and rotary instruments have been used because they are safe and effective in removal of filling material.

When root canal treatment fails, nonsurgical retreatment should be considered a primary treatment approach because it offers a more favorable long-term outcome compared with endodontic surgery (1, 2). During retreatment procedures, the removal of all filling material is recommended to enable root canal disinfection and allow periradicular healing (2–4).

Several techniques have been used for removing root-filling materials, including hand files, burs, and rotary instruments (4–12). Nickel-titanium (NiTi) rotary systems have been used in endodontic retreatments because of their safety, efficiency, and ability to remove filling material faster than hand files (8, 13, 14). Reciprocating instruments have shown favorable results in retreatment procedures when used with a brushing motion against the root canal walls to remove filling material (8–12, 15).

Thermomechanical treatment of NiTi files provides significant benefits with regard to the efficacy and safety of endodontic instruments (16). Several thermal treatments of NiTi alloys such as M-wire and CM-wire have been used to optimize the microstructure of NiTi alloys because they have great influence on the reliability and mechanical properties of NiTi files (16–18). M-wire instruments were developed by transforming a NiTi wire in the austenite phase into the R-phase, an intermediate phase formed during the transformation from martensite to austenite on heating, and reverse transformation on cooling. CM-wire instruments are mainly in the martensite phase and have been manufactured by means of a special thermomechanical process that controls the memory of the material. This makes the files extremely flexible and resistant to cyclic fatigue and reduces procedural errors such as ledges and instrument fracture in curved canals (16, 19). Several properties of austenite NiTi and martensite NiTi are different.

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0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2016.08.012

CM-wire files do not have shape memory, as opposed to what is found with conventional forms of NiTi files (16).

Recently, reciprocating and rotary files, ProDesign R (25/.06) and ProDesign Logic 40/.05 (Easy Equipamentos Odontológicos, Belo Horizonte, MG, Brazil), respectively, were introduced. According to the manufacturer, these files present a different hybrid design and CM heat treatment. Furthermore, the manufacturer introduced a new rotary file for apical preparation that has a CM-wire size 50 and taper 01. As far as we know, there are no studies about the use of CM-wire instruments for the removal of filling materials in retreatment procedures.

The aim of this study was to use micro–computed tomography (micro-CT) imaging to evaluate the percentage of remaining filling material in maxillary lateral incisors with apical curvature after retreatment with 3 different procedures performed sequentially. The null hypotheses were that ProDesign R and ProDesign Logic 40/.05 CM-wire files, which present more flexible alloy, would have the same ability to remove filling material during retreatment when compared with M-wire and NiTi files, and that ProDesign Logic 50/.01 file, which is a less tapered instrument made from CM-wire, would increase the removal of material in apical portion of the root canal.

Materials and Methods

Teeth Selection

The sample calculation was performed by using the G*Power v3.1 for Mac (Heinrich Heine, Universität Düsseldorf) by selecting the Wilcoxon–Mann-Whitney test of the *t* test family. The data of a previous study of retreatment that used uniradicular teeth (20) were used, and the effect size in the present study was established (=1.60). The alpha-type error of 0.05, a beta power of 0.95, and a ratio N2/N1 of 1 were also stipulated. A total of 8 samples per group were indicated as the ideal size required for noting significant differences. Ten samples per group were used because an additional 20% was calculated to compensate for possible accidents such as instrument separation that might lead to sample loss.

Maxillary lateral incisors with completely formed apices were used for this study. Sixty-five teeth were digitally radiographed in buccolingual and mesiodistal directions, and canal curvatures were measured in both directions according to the method of Schneider (21). Thirty teeth presenting apical curvature between 20° and 35° and 19–22 mm in length were selected.

Root Canal Preparation and Filling

Access opening was performed by using diamond burs. The working length was established by introducing 10 K-file until its tip was visible at the apical foramen, and the working length was set 1.0 mm short of this measure. The root canals were prepared by using ProTaper Universal instruments (Dentsply Maillefer, Ballaigues, Switzerland) up to instrument F1 by using X-Smart electric motor (Dentsply Maillefer) at 300 rpm. The canals were irrigated with 1 mL 2.5% sodium hypochlorite, and a final rinse was performed with 5 mL 17% EDTA for 3 minutes. The canals were flushed with saline solution, dried with paper points, and obturated by the lateral compaction of gutta-percha cones and zinc oxide and eugenol–based sealer (Endofill; Dentsply Ind Com Ltda, Petrópolis, RJ, Brazil). Buccolingual and mesiodistal radiographs were taken to confirm that all specimens had well-compacted fillings extending to 1 mm short of the apex. Coronal accesses were sealed with temporary filling material (Coltosol; Coltene-Whaledent, Cuyahoga Falls, OH), and the teeth were stored at 37°C and 100% humidity for 30 days to allow complete setting of the sealer. After this, the samples were scanned by using the micro-CT system (SkyScan 1174v2; Bruker-microCT, Kontich, Belgium) with 50 kV, 800 mA, 1.0 step size rotation, and 19.7 μm voxel resolution. The data were elaborated by reconstruction software (NRecon v.1.6.3; Bruker-microCT), and the CTan software (Bruker-microCT) was used for measuring the volume (mm^3) of the radiopaque material.

Retreatment

For retreatment procedures an operating microscope (M900; D. F. Vasconcellos, Valença, RJ, Brazil) at ×5 magnification was used. All specimens were prepared by the same operator. The teeth were divided into 3 groups, each with similar characteristics, to ensure homogeneity between the groups.

In the Reciproc group (n = 10 teeth), root fillings were removed by using R25 Reciproc files (25/.08) (VDW, Munich, Germany) with the respective Reciproc program of the VDW Silver electric motor.

In the Mtwo group, reinstrumentation was performed with Mtwo rotary files size 40, 0.04 taper (VDW) by using the respective Mtwo 40/.04 program of the VDW Silver electric motor.

In the Logic 50/.01 group A, reinstrumentation was performed with ProDesign Logic 50/.01 rotary files (Easy Equipamentos Odontológicos) size 50, 0.01 taper used at 350 rpm and 1.5 N/cm torque.

In the ProDesign R group (n = 10 teeth), root fillings were removed by using ProDesign R files (Easy Equipamentos Odontológicos) size 25, 0.06 taper by using the Reciproc program of the VDW Silver electric motor.

In the Logic 40/.05 group, reinstrumentation was performed with ProDesign Logic rotary files (Easy Equipamentos Odontológicos) size 40, 0.05 taper used at 500 rpm and 2.5 N/cm torque.

In the Logic 50/.01 group B, reinstrumentation was performed with ProDesign Logic 50/.01 rotary files (Easy Equipamentos Odontológicos) size 50, 0.01 taper used at 350 rpm and 1.5 N/cm torque.

In the 30 K-file group (n = 10 teeth), root fillings were removed by using Gates-Glidden burs, sizes 2 and 3 (Dentsply Maillefer) in the cervical and middle thirds of the canals and with K-files size 30 (Dentsply Maillefer) up to the working length and Hedström files (Dentsply Maillefer) size 35, 40, and 45 by using the step-back technique.

In the 40 K-file group, reinstrumentation was performed with K-files size 40 (Dentsply Maillefer) up to the working length.

In the 50 K-file group, reinstrumentation was performed with K-files size 50 (Dentsply Maillefer) up to the working length.

For the Reciproc and ProDesign R instruments, reciprocating motion was used, and the files were introduced until resistance was felt and then used with 3 in-and-out pecking motions with light apical pressure. After reaching the working length, a brushing motion against the canal walls was used for both reciprocating and rotary files until no visual evidence of residual filling materials could be seen with the operating microscope and the canal walls were smooth.

An aliquot of 0.5 mL orange oil solvent (Citrol; Biodinâmica, Ibiporã, PR, Brazil) was put into the pulp chamber for 2 minutes to soften the gutta-percha at the cervical level before beginning with root-filling removal, and the same irrigation protocol was performed each time after the use of an instrument. The solvent was not used in the subsequent steps of instrumentation.

Micro-CT Scanning Procedures

Each tooth was scanned 4 times: after the root canal filling and after the use of each instrument during the root canal retreatment. The teeth were placed in silicone molds to allow the sample to be scanned in the same position after each step and were mounted on a custom attachment in a micro-CT device. The same scanning parameters were used for all specimens. For reconstructions, the parameters

used were exactly the same for each tooth after each scanning procedure. After binarization, the region of interest was determined as the circumferential area of the root canal. The measures of volume were performed manually in CTan software, and the end of the root apex was used as the landmark to determine the root canal areas analyzed. For each sample, the volume of filling material was calculated at 4 levels: apical 1, between 1.0 and 3.0 mm; apical 2, between 3.0 and 5.0 mm; middle third, between 5.0 and 7.0 mm; and cervical third, between 7.0 mm and up to the cementoenamel junction. The volumes were recorded, and the percentage of remnant filling material after each procedure was expressed in terms of percentage of the initial root-filling material volume.

Statistical Analysis

Preliminary analysis of data normality was performed with the Shapiro-Wilk test, showing that the data were not normally distributed. Statistical analysis was performed with nonparametric tests. The Kruskal-Wallis test was used to compare removal of the filling material between the groups at the different levels, the Friedman test was used to compare the percentage reduction in filling material after each procedure, the Dunn test was used for post hoc analysis, and the Wilcoxon test was used to analyze the percentage reduction in material volume for intragroup comparison. The level of significance was set at $P < .05$.

Results

Residual filling material was found in all groups after retreatment procedures. Three specimens presented complete removal of filling material: 1 in the Mtwo group, 1 in the Logic 50/.01 group B, and 1 in the 40 K-file group. Table 1 shows the median, minimum, and maximum percentage values of remaining material at the different root canal levels.

No significant difference was observed when comparing the removal of filling material by Reciproc and ProDesign R, by Mtwo and ProDesign Logic 40/.05, and by ProDesign Logic 50/.01 in the Logic 50/.01 group A and the Logic 50/.01 group B ($P > .05$) (Fig. 1).

The use of Mtwo and ProDesign Logic 40/.05 rotary files did not significantly enhance filling material removal after use of the reciprocating files at all root canal levels ($P > .05$).

The filling material remaining after the use of the ProDesign Logic 50/.01 file was significantly lower compared with the material remaining after Reciproc was used in apical 2 and ProDesign R in apical 1 and apical 2 ($P < .05$).

Apical 1 and apical 2 levels presented a larger amount of remaining filling material in comparison with the middle and cervical levels, irrespective of the group analyzed.

Discussion

The aim of root canal retreatment is to remove as much filling material as possible in an attempt to eliminate bacterial remnants and improve the activity of irrigation solutions and intracanal medicaments on root canal dentin.

In this study, the authors used several retreatment procedures, including hand files, rotary files, and reciprocating instruments. Although the instruments were efficient in removing a large amount of gutta-percha, none of the techniques were able to completely remove the filling material from the root canal walls, which is in agreement with the literature (4–13, 15, 20, 22).

Recently, micro-CT has been used to evaluate the remaining filling material (4, 7, 9, 11, 12, 20, 22–25). Micro-CT imaging was chosen for this study because it is a nondestructive technique, enables three-dimensional assessment of the canal filling material before and after instrumentation, and provides precise quantitative evaluation of residual material, expressed in mm^3 (7, 11). Micro-CT analysis showed that all groups had remnants of filling material on root canal walls. Studies have shown that rotary (7, 14, 25–27) or reciprocating files (8, 11) remove more filling material, whereas some studies have reported hand files to be more effective (13, 20, 28). The present study indicated no significant difference between the use of reciprocating and rotary files compared with hand files, corroborating the findings of previous studies (5, 29). The hypothesis of the same efficacy of instruments with different CM-wire, M-wire, and NiTi alloys was confirmed. In this study, Reciproc, which is made from M-wire, had a similar performance in removing filling material compared with the ProDesign R CM-wire files. The Reciproc group showed slightly less remnant filling material compared with the ProDesign R group, but with no statistical difference. The Mtwo NiTi files and ProDesign Logic 40/.05 CM-wire files also showed no statistical difference in removing filling material, demonstrating that although CM-wire files are more flexible than M-wire and NiTi files, they showed the same ability to remove filling material during retreatment procedures.

A great advantage of using engine-driven instruments is that less time is required for filling material removal in retreatments (7–9, 13, 14, 22, 28). Furthermore, these instruments are safe and reduce both operator's and patient's fatigue (6, 9). In this investigation, Gates-Glidden burs were used in the 30 K-file group, and hand files were used in the 30 K-file, 40 K-file, and 50 K-file groups. Although these instruments were effective in removing filling material, the use of Gates-Glidden burs in a previously enlarged canal may be hazardous and often results in overextension of the preparation, weakening and thereby leading to the risk of vertical root fracture or perforation of the root canal. When re-treating curved root canals, ledges, perforations, and

TABLE 1. Median, Maximum, and Minimum Values of Percentage of Remaining Filling Material at Different Root Canal Levels

Group	Apical 1	Apical 2	Middle	Cervical
Reciproc R25	18.42 (1.04–77.82)^{aA}	20.70 (0.25–80.00)^{aA}	1.99 (0.0–59.12)^{aA}	0.0 (0.0–15.01)^{aA}
Mtwo 40/.04	2.48 (0.0–48.70)^{aA}	2.53 (0.0–19.88)^{aAB}	0.71 (0.0–12.06)^{aA}	0.0 (0.0–4.39)^{aA}
ProDesign Logic 50/.01	1.48 (0.0–44.21)^{aA}	2.20 (0.0–16.76)^{aB}	0.24 (0.0–12.06)^{aA}	0.0 (0.0–4.39)^{aA}
ProDesign R	33.55 (0.0–77.62)^{aA}	16.83 (0.0–41.35)^{abA}	2.10 (0.0–59.54)^{aA}	0.20 (0.0–31.66)^{aA}
ProDesign Logic 40/.05	4.51 (0.0–62.41)^{aAB}	0.0 (0.0–38.02)^{aAB}	0.0 (0.0–25.04)^{aA}	0.0 (0.0–16.05)^{aA}
ProDesign Logic 50/.01	0.84 (0.0–36.82)^{aB}	0.0 (0.0–36.94)^{abB}	0.0 (0.0–24.41)^{aA}	0.0 (0.0–15.96)^{aA}
Hand file 30 K	32.84 (0.0–81.99)^{aA}	0.0 (0.0–47.72)^{bA}	0.0 (0.0–81.99)^{aA}	0.0 (0.0–1.95)^{aA}
Hand file 40 K	5.58 (0.0–57.95)^{aA}	0.0 (0.0–45.48)^{aA}	0.0 (0.0–34.61)^{aA}	0.0 (0.0–1.95)^{aA}
Hand file 50 K	5.29 (0.0–57.82)^{aA}	0.0 (0.0–41.82)^{bA}	0.0 (0.0–33.21)^{aA}	0.0 (0.0–1.95)^{aA}

Different superscript lower case letters in each column indicate statistical differences between groups ($P < .05$). Different superscript upper case letters in each column indicate statistical differences in the same group after different procedures ($P < .05$).

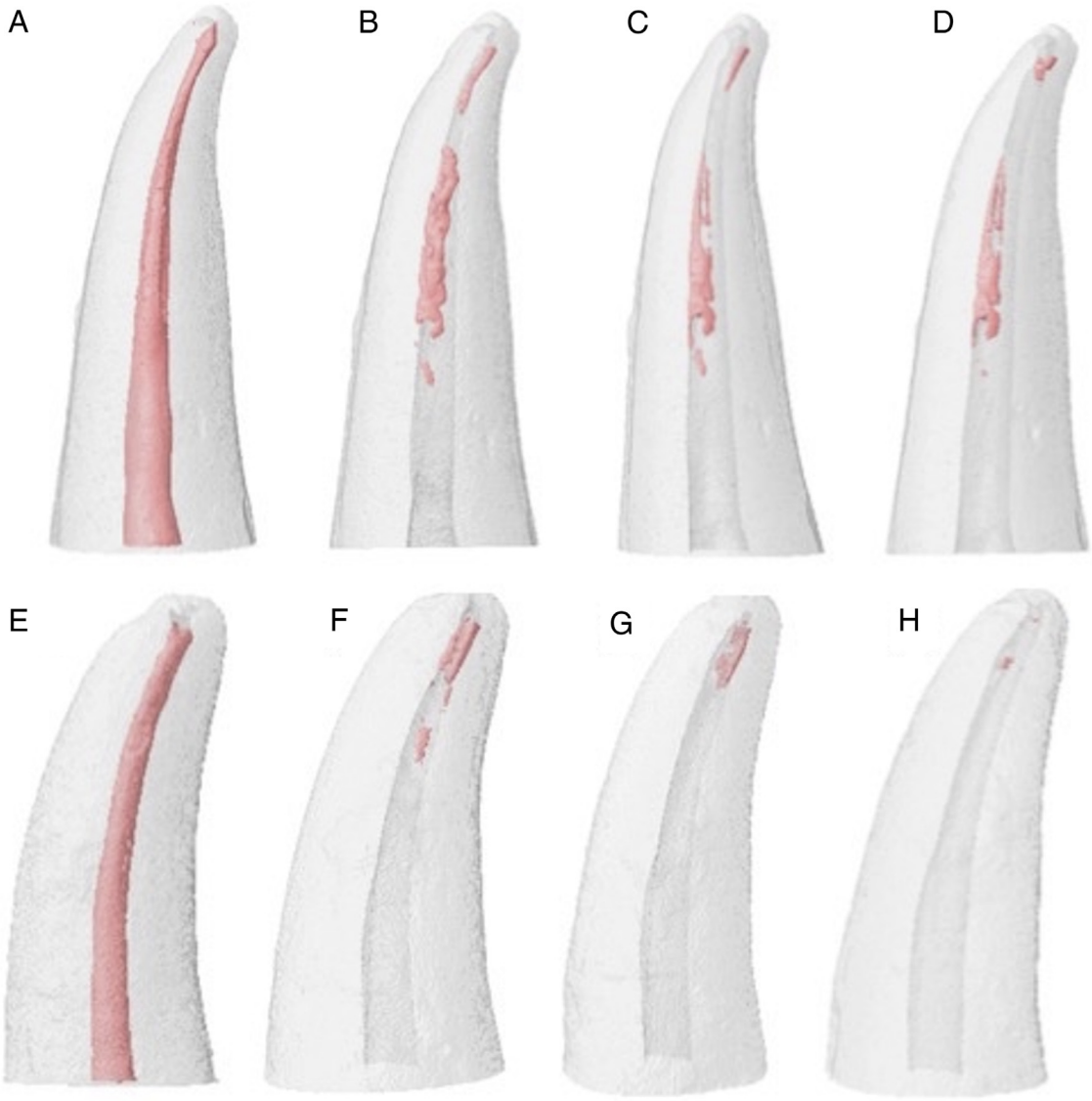

Figure 1. Micro-CT reconstructions of representative samples before and after each retreatment procedure. (*A* and *E*) Preoperative images, (*B*) Reciproc, (*C*) Mtwo, (*D* and *H*) ProDesign Logic 50/.01, (*F*) ProDesign R, and (*G*) ProDesign Logic 40/.05.

straightening of the inner side of the curve may occur because of the inflexibility of hand files (30).

Root canal anatomy is an important aspect to consider in nonsurgical retreatments. The majority of studies evaluating filling material removal have used straight roots to simplify specimen standardization (6, 8, 10–13). In the present study, maxillary lateral incisors with apical curvatures were used because this anatomic variation is frequently found in this group of teeth (31). Canal curvatures represent a challenging clinical situation in retreatment because alterations in root canal shape and instrument breakage may occur during reinstrumentation (30, 32). To overcome this difficulty, reciprocating and rotary instruments have been recommended because they are shown to be safe in maintaining the original canal shape in retreatment procedures when curvatures were present (9). The authors speculated that the CM-wire alloy used in the composition of some instruments used in this study may have contributed to the re-preparation of curved canals because of their characteristics such as fatigue resistance and flexibility.

In nonsurgical retreatment, the apical third is the critical zone in root canal re-preparation (30). Studies have demonstrated that the remnant filling material is more frequently found in this area (4, 7, 24, 32), which is in agreement with the present study. To achieve better cleaning up to the working length when performing reinstrumentation, procedures such as the clinical use of passive ultrasonic activation with NaOCl or solvent and the use of laser irradiation have been indicated (4, 9, 11, 24).

Because residual filling material is frequently observed, additional procedures have been used after initial reinstrumentation to improve filling removal. The combination of initial penetration with rotary instruments followed by the use of hand files for removing gutta-percha residues may be indicated because hand files provide superior tactile sense (7, 15). The use of Self-Adjusting Files also seems to improve removal of residual filling material after the use of rotary files, resulting in more effectively cleaned canals (23). In the present study, 3 specimens presented complete removal of filling material, probably because of the use of 2 additional instruments after the initial file. Under the

experimental conditions of this study, the results demonstrated that the use of rotary systems, especially the ProDesign Logic 50/.01 file, improved the removal of filling material after the use of reciprocating instruments, suggesting that a hybrid technique associating these types of instruments is valuable in the retreatment of root canals. The hybridization of different techniques for removing filling material has shown favorable results, as demonstrated by Yuruker et al (15).

There is no consensus in literature with regard to the size to which it would be necessary to enlarge the root canal during retreatment (30). Studies have demonstrated that to obtain better apical cleaning, it is necessary to enlarge the diameter of the initial preparation with larger-sized instruments (6, 7, 11, 25). Rodig et al (7) instrumented the root canals to a final size 40 and concluded that this procedure promoted adequate enlargement, permitting conservation of tooth structure and prevention of procedural mishaps in curved canals. In addition, Alves et al (25) achieved up to 100% of filling material removal in a large number of samples after using Reciproc 40, compared with the use of Reciproc 25. In a previous study (11), a significant reduction in the amount of filling material was achieved by reinstrumenting the apical third 2 sizes beyond the initial preparation size, with final size 50. Zuolo et al (8) enlarged the root canal of maxillary central incisors to a final size 50 and observed better removal of filling material with Reciproc R50 when compared with hand and rotary files. However, Reciproc R50 presents a large taper 0.05, and it could lead to excessive removal of dentin. The ProDesign Logic 50/.01 instrument used in this investigation significantly reduced the amount of filling material in apical third compared with reciprocating files and seemed adequate for instrumenting and removing filling material in the apical portion without weakening the tooth structure. Moreover, this instrument was shown to be safe, because no instrument broke during root canal reinstrumentation in this study. Thus, the null hypothesis that ProDesign Logic 50/.01 files improved the removal of filling material in apical portion of the root canal was confirmed.

Conclusions

The combination of reciprocating and rotary files in the retreatment of curved canals, irrespective of the type of alloy of the instruments, was efficient but did not remove root canal filling completely. The use of a ProDesign Logic 50/.01 CM-wire file significantly reduced the residual material at the apical levels compared with the use of reciprocating files.

Acknowledgments

This work was supported by FAPESP (2015/03829-1).
The authors deny any conflicts of interest related to this study.

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