Efficacy of ProTaper NEXT Compared with Reciproc in Removing Obturation Material from Severely Curved Root Canals: A Micro–Computed Tomography Study

Giselle Nevares, PhD, * *Diana S. de Albuquerque, PhD,* * *Laila G. Freire, PhD,*† *Kaline Romeiro, MSc,* * *Howard M. Fogel, MSc,*‡ *Marcelo dos Santos, PhD,*§ *and Rodrigo S. Cunha, PhD*‡

Abstract

Introduction: The aim of this study was to compare the remaining root canal obturation, volume of dentin removed, and apical transportation after retreatment of severely curved root canals by using Reciproc (REC) or ProTaper NEXT (PTN) systems. **Methods:** Twenty-eight mesial canals of mandibular molars were instrumented and then obturated with gutta-percha and sealer and allocated into 2 balanced groups (n = 14), the REC group (R25 file) and the PTN group (X3 and X2 files). Micro–computed tomography analysis was performed to assess the percentage of residual obturation material, the amount of dentin removed, and apical transportation. The effective time for the removal of obturation and procedural errors were recorded. **Results:** Obturation was effectively removed from the root canal in the REC and PTN groups ($P \leq .001$), and the percentages of remaining obturation material were similar between both groups (84.8% PTN vs 86.5% REC) ($P > .05$). The amount of dentin removed (3.17 $\pm$ 2.64 mm^3 PTN versus 3.50 $\pm$ 2.82 mm^3 REC), apical transportation (at 1 mm: 0.096 $\pm$ 0.189 mm PTN versus 0.093 $\pm$ 0.186 mm REC; at 3 mm: 0.059 $\pm$ 0.069 mm PTN versus 0.082 $\pm$ 0.080 mm REC; at 5 mm: 0.097 $\pm$ 0.093 mm PTN versus 0.133 $\pm$ 0.138 mm REC), and the working time (269.69 $\pm$ 19.25 seconds PTN versus 268.62 $\pm$ 16.37 seconds REC) were also similar in both groups ($P > .05$). One file fractured in the REC group. **Conclusions:** Both systems were equally effective in the removal of obturation from severely curved canals and can be used for retreatment. Neither system could completely remove the obturation material; therefore, additional techniques are needed to improve cleaning of the root canal. *(J Endod 2016;42:803–808)*

Key Words

Apical transportation, gutta-percha removal, retreatment, root canal obturation material

Despite the high success rates of the endodontic treatment (1), procedural errors and operative challenges can lead to treatment failure (2). Endodontic retreatment is the primary therapeutic option in these cases and initially involves removal of the obturation material (3). Several techniques for the removal of the root canal gutta-percha and/or sealer have been tested, such as the use of manual, rotary, and reciprocating instruments and laser irradiation. However, none of the techniques evaluated to date could completely remove remnants of gutta-percha and/or sealer from the root canal (4–6).

Rotary and reciprocating nickel-titanium instruments initially created for shaping the root canal have been tested for retreatment (7). The Reciproc (REC) system (VDW, Munich, Germany) was designed for the complete preparation of the root canal by using a single file in reciprocating motion. The files have an S-shaped cross section and achieved laboratory and clinical effectiveness in retreatment (8, 9). The ProTaper NEXT (PTN) files (Dentsply Tulsa Dental Specialties, Tulsa, OK) have a rectangular cross section, and the center of mass and/or the center of rotation are offset. Through conventional rotatory motion, the device generates a mechanical wave similar to a sinusoidal wave, making its movement asymmetrical (10). The PTN file showed similar cutting ability of severely curved root canals compared with REC file (11). However, the ability of the PTN system to remove obturation material has not yet been evaluated.

Instrumentation during retreatment procedures can lead to changes in dentin volume and transportation of root canals. Transportation can result in ledging, zipping, and perforation, particularly in the apical third, and weakens the tooth structure (12). Excessive dentin removal should be prevented to avoid weakening the root and increasing the risk of vertical root fracture and/or perforation.

Therefore, the present study aimed to compare remaining root canal obturation, volume of dentin removed, and apical transportation after retreatment of severely curved root canals by using REC and PTN systems. The effective time needed for the removal of obturation material and procedural errors were recorded as well. The null hypotheses tested were the lack of significant differences in the effectiveness of the REC and PTN systems for the parameters evaluated.

From the *Department of Operative Dentistry and Endodontics, Dental College of Pernambuco, University of Pernambuco, Camaragibe, Pernambuco, Brazil; †School of Dentistry, University of São Paulo, São Paulo, São Paulo, Brazil; ‡Division of Endodontics, College of Dentistry, University of Manitoba, Winnipeg, Manitoba, Canada; and §Division of Endodontics, Restorative Dentistry, School of Dentistry, University of São Paulo, São Paulo, São Paulo, Brazil.

Address requests for reprints to Dr Giselle Nevares, Avenida Gal Newton Cavalcanti, 1650, Tabatinga, 54753-901 Camaragibe, PE, Brazil. E-mail address: gnevares@yahoo.com

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Materials and Methods

Sample Size Calculation

The total sample size for this study was calculated on the basis of a previous research study that also used micro–computed tomography (micro-CT) scans to evaluate the removal of root canal obturation material by using rotary systems (13). The Student *t* test for independent samples (Minitab Statistical Software 16.1; Minitab Inc, State College, PA; URL: www.minitab.com) with a Δ of 7.6, ratio of 1.00, α of 5%, and a power of 80% indicated that the minimum sample size required was 12 per group.

Sample Selection

The study was reviewed and approved by the Research Ethics Committee of the University of Pernambuco, Camaragibe, state of Pernambuco, Brazil (protocol CAAE 31651014.3.0000.5207). The same operator conducted the protocols followed in the study. The mesial roots of 189 first and second molars were examined by using a stereomicroscope (×4 magnification). The reasons for extraction were not related to this study. Only intact teeth with lengths >17 mm and fully formed apexes were selected. After radiographic examination, teeth with previously treated canals, pulp calcification, or internal resorption were excluded from this study. To compare the techniques in the same root, only roots with 2 separate mesial canals were selected. The curvature angles and radius were chosen on the basis of the initial radiographs by using Image J software version 1.46r (National Institutes of Health, Bethesda, MD). The mean angle of curvature was 35.5° (standard deviation, 6.86° and coefficient of variation, 19.32%) (14). The mean radius of curvature was 5.3 mm (standard deviation, 1.73 mm and coefficient of variation, 32.64%) (15).

Sample Preparation

The crowns were sectioned by using a diamond disk to achieve an overall length of 17 mm. Endodontic access was performed and glide path was established by using a #10 file. Working length (WL) was established at 1 mm short of the apical foramen. All canals were instrumented by using the WaveOne Small file (21/.06) (Dentsply Tulsa Dental Specialties). The pulp chamber was initially irrigated with 2 mL 2.5% sodium hypochlorite (NaOCl). The file was then introduced into the root canal until resistance was felt, and 3 forward and backward movements were performed with slight apical pressure. The file was removed from the canal and cleaned with a sponge, and the canal was irrigated. These steps were repeated until the file reached WL and the tip of the irrigation needle penetrated 2 mm short of WL. The smear layer was removed by using 2 mL 17% EDTA and agitated with a sonic device (EndoActivator; Dentsply Tulsa Dental Specialties). This was followed by a final flush of NaOCl and agitated again. Obturation was performed by using a modified hybrid Tagger's technique (16). The tip of a tapered gutta-percha point (Wave One Small) was coated with sealer (AH Plus; Dentsply Tulsa Dental Specialties) and adjusted into the root canal. An engine plugger was placed 4–5 mm into the canal for thermomechanical compaction. The teeth were radiographed buccolingually and mesiodistally to assess the quality of the obturation, and the crowns were sealed with temporary filling material (Cavit; 3M ESPE, St Paul, MN) and stored at 37°C at 100% humidity for 30 days. There were 2 experimental groups, REC and PTN. Pairs of mesiobuccal and mesiolingual canals were balanced and randomly distributed between the groups (www.random.org) (n = 14), and both systems were tested in the same root.

Micro-CT Scanning

Teeth were scanned after obturation (preoperative scan) by using a SkyScan 1176 micro-CT scanner (Bruker-microCT, Kontich, Belgium), which allows for scanning of high-density objects (6) with an isotropic voxel size of 17.42 μm and a 0.1-mm copper filter. Other parameters included x-ray voltage of 90 kV, 258 μA, 360° rotation, and 0.5° rotation step. The images were reconstructed with NRecon v.1.6.9 software (Bruker-microCT) by using the modified Feldkamp cone-beam reconstruction algorithm. The original grayscale images were processed for noise reduction with a fine-tuning function: gaussian filter (smoothing = 3), beam hardening correction of 19%, post-alignment of 1.0 to compensate possible misalignment during acquisition, and ring artifact correction of 10.

Removal of Obturation Material

In the REC group, obturation was removed by using an R25 file (25/.08) following the same protocol used in the instrumentation of the canals. In the PTN group, X3 files (30/.07) were used in the cervical and middle thirds and X2 files (25/.06) in the apical third. These files were used at 500 rpm and 3 Ncm of torque in a continuous rotary motion. After 3 forward and backward movements at a 3-mm range, the file was removed from the canal and cleaned with a sponge. These movements were repeated until the WL was reached. In both groups, the removal of obturation was considered complete when obturation material was no longer visualized between the cutting blades, and the canals exhibited smooth walls. For each sample, the total time needed for the instruments to operate in the canal to remove the obturation material and reach the WL was counted in seconds. Time taken to irrigate, change, and clean instruments was excluded. Each set of files was used on a single canal, and the irrigation protocol was similar to that used in the initial instrumentation, with a total volume of 20 mL irrigant in each canal. A postoperative scan was performed to allow evaluation of the remaining obturation material.

Residual Obturation Material and Amount of Dentin Removal

The resulting images from preoperative and postoperative scans were geometrically aligned by using the 3-dimensional (3D) registration function of DataViewer v.1.5.1 software (Bruker microCT). The volume of interest for each specimen, extending from the furcation region to the apex of the mesial root, was set by integration of the regions of interest in all cross sections. Comparisons between the original and the segmented scans were performed to ensure accuracy of the segmentation. Volumetric analysis was performed, and 3D models were constructed (Fig. 1). Preoperative and postoperative volumes of root obturation material and dentin in the mesiobuccal and mesiolingual canals were measured in cubic millimeters for the entire canal and its thirds (cervical, middle, and apical).

Apical Canal Transportation

Apical canal transportation was measured on axial sections at 1, 3, and 5 mm from the anatomic apex (Fig. 2). Transportation was calculated in millimeters with the software Image J by using a modification of the formula $|(X1 - X2) - (Y1 - Y2)|$ (17). A result of 0 from the canal transportation formula would indicate no canal transportation. X1 is the shortest distance between the mesial edge of the root and the obturated canal, X2 is the shortest distance between the mesial edge of the root and the re-treated canal, Y1 is the shortest distance between the distal edge of the root and the obturated canal, and Y2 is the shortest distance between the distal edge of the root and the re-treated canal (Fig. 3). Preoperative and postoperative measurements were compared to reveal the

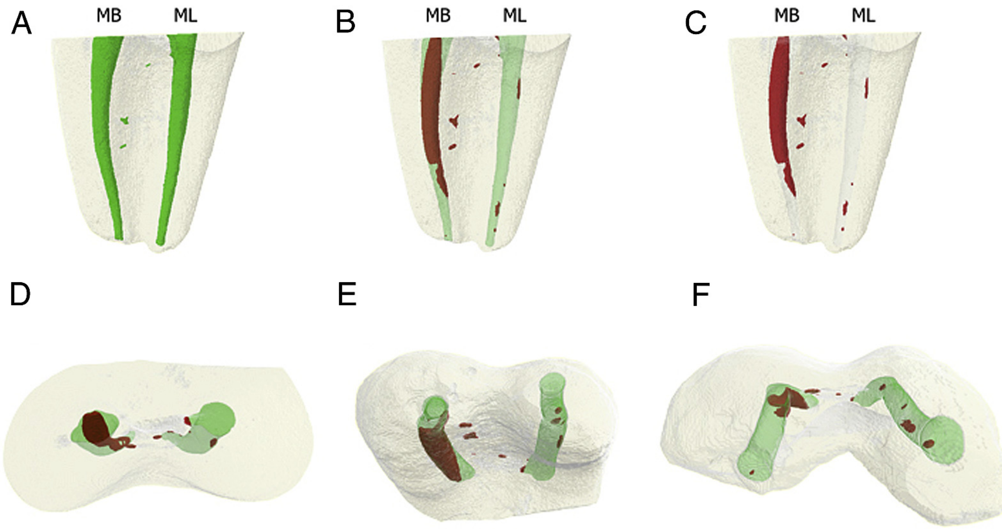

Figure 1. 3D reconstruction images: (*A*) obturation material (*green*); (*B*) superimposed images; (*C*) remaining obturation material after PTN (MB, mesiobuccal canal) and REC files (ML, mesiolingual canal) (*red*); (*D–F*) indicate different angles.

presence or absence of deviations in canal anatomy (Fig. 2). An operator blinded to the study results performed these measurements twice at different times. The concordance correlation coefficient was calculated by using a 95% confidence interval.

Statistical Analysis

For comparisons of the mean times needed for the removal of obturation, the percentage of obturation material and dentin removed, and apical transportation, the following tests were used: paired *t* test and a *t* test with equal variances in cases of normality between the variables and the Wilcoxon test for paired data in cases of rejection of the hypothesis of normality. The hypothesis of normality and the equality of variance were evaluated by using the Shapiro-Wilk test and Levene F test, respectively. The margin of error used in the decision of the statistical tests was 5.0%.

Results

A pilot study tested a protocol by using the X1 file (17/.04) for the removal of obturation material from the apical third. However, because of the high incidence of distortion and fracture of this instrument, the X1 file was excluded from the protocol of the present study. One file fractured in the REC group approximately 5 mm from the tip. This specimen was discarded, and the sample size was reduced to 26 canals ($n = 13$).

The initial volume of the canal obturation material in the total, cervical, middle, and apical thirds was similar between the samples (Table 1) ($P > .05$). The time required (in seconds) for obturation material removal was similar between the PTN (269.69 ± 19.25) and REC (268.62 ± 16.37) groups ($P > .05$).

The percentage of obturation material removal was similar between the PTN and REC groups in the overall analysis and in the analysis of the cervical, middle, and apical thirds ($P > .05$) (Table 1). Although both techniques reduced the initial volume (in cubic millimeters) of obturation material ($P \leq .001$), remaining material was left behind in both groups.

No significant difference in dentin removal (in cubic millimeters) was observed between REC and PTN systems in total (3.17 ± 2.64 PTN versus 3.50 ± 2.82 REC), cervical (0.814 ± 0.613 PTN versus 1.276 ± 0.807 REC), middle (0.865 ± 0.560 PTN versus 0.948 ± 0.577 REC), and apical (0.752 ± 0.466 PTN versus 0.662 ± 0.722 REC) thirds ($P > .05$).

There was concordance between the 2 measurements (in millimeters) obtained in the evaluation of apical transportation (≥0.957 in the PTN group and ≥0.929 in the REC group), and the intervals ranged between 0.957 and 0.991. No statistically significant difference was found between the mean measurements obtained at the 1-, 3-, and 5-mm levels when comparing the 2 systems studied ($P > .05$) (Table 1).

Discussion

The roots selected for the present study had 2 canals that were separate and distinct from the pulp chamber to the apex. This was the same as the study by Junaid et al (18). The distribution of the groups with respect to angle and radius of canal curvature was well-balanced, and curvature was classified as severe, as in previous studies (11, 19). The mesiobuccal canals of mandibular molars tend to have a more pronounced curvature than the mesiolingual canals (20). Therefore, both anatomies were equally distributed between the groups to minimize the number of variables. Furthermore, the initial obturation volumes were similar between the groups ($P > .05$) (Table 1). Other studies that evaluated the performance of the REC system for the removal of obturation material (5, 8, 21) used vertically split roots for quantification with imaging software. Although this methodology is well-established, tooth structure and/or obturation material may be lost during splitting of the teeth. The methodology used in the present study (micro-CT images) allowed observation of root canals in a 2-dimensional and 3D manner by using preoperative and postoperative evaluations without the need to destroy the specimens (22). For all the analyses, only the main canal was considered because this is the primary target of nickel-titanium endodontic instruments.

Although neither of the 2 systems evaluated (REC and PTN) were developed for retreatment, there is a trend to use instruments designed for root canal shaping for this purpose as well (23). Effective obturation and dentin removal are directly associated with the instrument used (24). In the current study, the PTN and REC groups showed similar results for the removal of obturation material. Therefore, the null hypothesis tested for this parameter was accepted ($P > .05$). Few studies have evaluated the efficacy of the REC system in removing

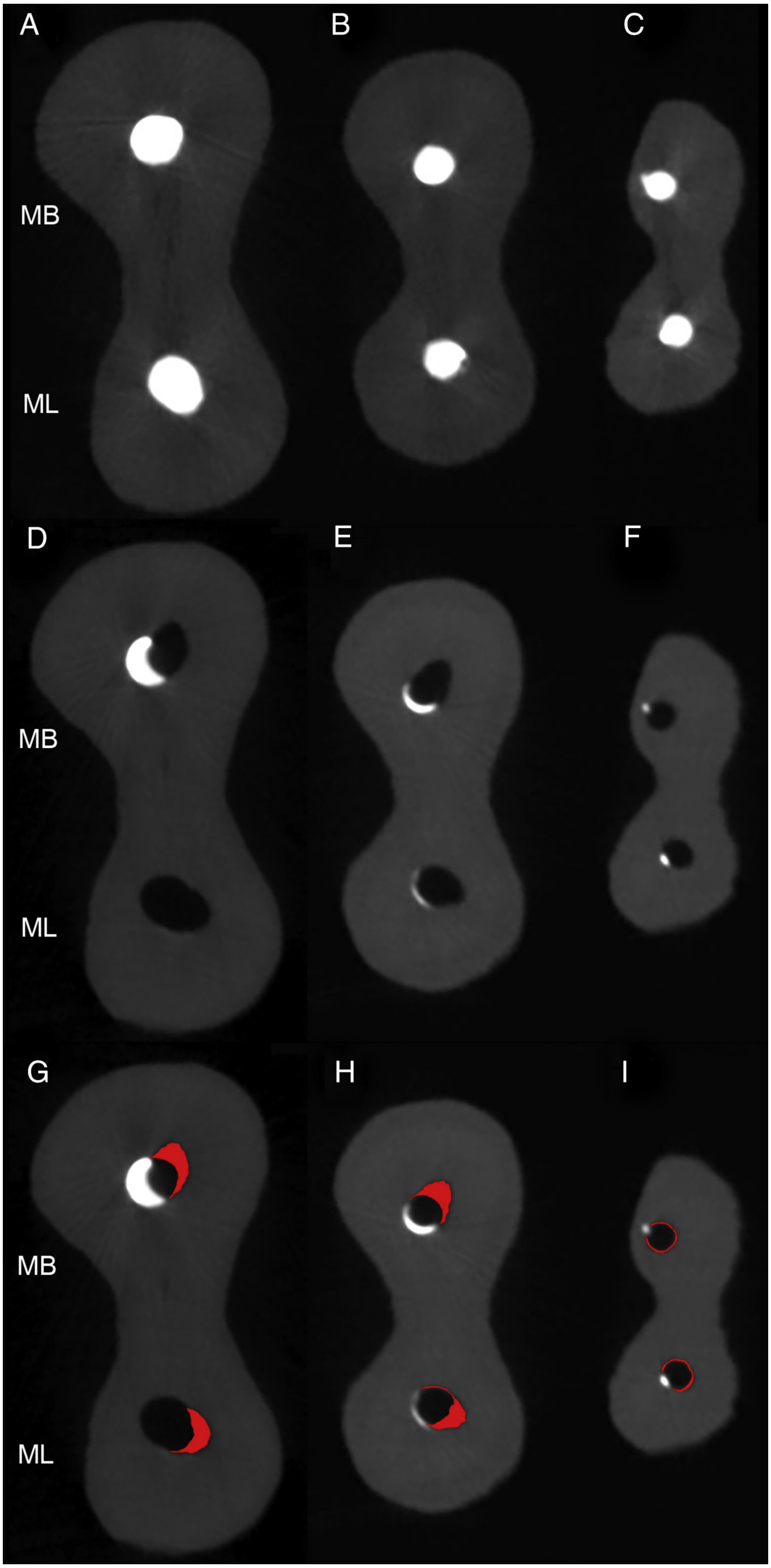

Figure 2. Cross sections of micro-CT scan images. Obturation at (*A*) 5 mm, (*B*) 3 mm, and (*C*) 1 mm level from the apical foramen. After removal of obturation material at respective cross sections (*D–F*). (*G–I*) Transported area (*red*) at respective cross sections.

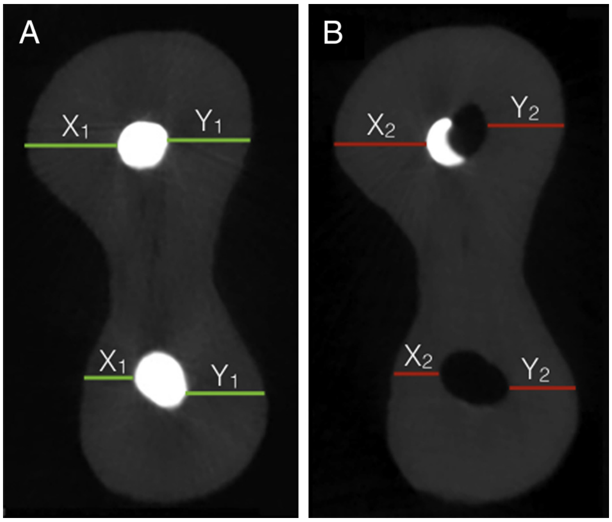

Figure 3. Micro-CT scan images with markings showing points of measurement before (*A*, *green*) and after (*B*, *red*) removal of obturation material.

obturation, and the results have been promising because of its similar (5, 13, 21) or better performance (8) when compared with rotary instruments developed for retreatment. According to the manufacturers, the R25 file features a constant taper (8%) in the first 3 mm (D1-D3) that decreases to D16, and the X2 file has a 6% taper in the first 3 mm, followed by an increasing and decreasing percentage tapered design varying between 4% and 7%. It might be expected that the greater taper at the tip of the R25 file may promote greater removal of obturation compared with the PTN system. However, this result was not observed in the current study. The PTN file with an asymmetric motion describes a bigger envelope of motion compared with a similarly sized file with centralized mass and rotation axis (10). Capar et al (11) confirmed these findings, indicating that the R25 and X2 files have similar shaping ability. In addition, in contrast to the PTN system, the cutting effectiveness of the REC system has been associated with its cross section but not with the reciprocating motion (25).

Remaining obturation material was found in all samples. This is in agreement with other retreatment studies that showed that none of the techniques evaluated could completely remove remnants of gutta-percha/cement from the root canal (6). To date, only 2 studies have evaluated the performance of the REC system in the removal of obturation material by using micro-CT images (4, 26). In the present study, the average total amounts of remaining obturation material in both groups (13%–15%) were higher compared with the studies of Fruchi et al (4) (6%) and Rödig et al (26) (8%). Several variables may have contributed to this discrepancy. Fruchi et al obturated canals by using the single-cone technique, whereas Rödig et al used lateral condensation. In the present study, the canals were obturated by using a thermoplasticized technique. The average total amounts of remaining obturation material in the current study were similar to a recent retreatment study that used micro-CT scan (13%–16%) (6), which also used warm obturation technique. Ma et al (27) concluded that there was less obturation material remaining after retreatment when canals had been obturated by using lateral condensation compared with a thermoplasticized technique. Canals obturated by using lateral condensation technique did not present a homogeneous obturation mass but tended to have sealer pooled between the gutta-percha cones (28). In addition, the thermoplasticized gutta-percha technique obturates anatomic irregularities, reduces voids, and results in a superior obturation quality compared with the single-cone technique (29). Mesial root canals of mandibular molars have a high incidence of irregularities (30). Obturation of this irregular geometry may have made the removal procedure more challenging. Fruchi et al (4) used solvent to facilitate the removal of gutta-percha. Solvent was not used in the current study to eliminate the chemical melting of gutta-percha and the adherence of a thin layer of this material to the canal walls (27). In addition, softened gutta-percha may be pushed into irregularities, hindering the cleaning process (31). Furthermore, Rödig et al (26) used the R25 file followed by R40 file (40/.06) in WL, and this may have contributed to the higher percentage of gutta-percha removal. In both groups, the removal of the obturation material was more effective in the cervical third, and no statistically significant difference was observed between the REC and PTN groups in any of the root canal regions examined ($P > .05$).

TABLE 1. Mean Initial Volumes of Obturation Material (mm^3), Mean Percentages of Obturation Material Removed, and Mean Apical Canal Transportation in Each Section (mm)

	PTN	REC	*P* value
Initial obturation (mm^3) (n = 13)			
Cervical	2.304 ± 0.636	2.328 ± 0.759	.849
Middle	1.289 ± 0.304	1.456 ± 0.473	.102
Apical	0.339 ± 0.135	0.387 ± 0.187	.267
Total	3.930 ± 0.850	3.970 ± 1.130	.918
Obturation removal (%) (n = 13)			
Cervical	88.197 ± 10.335	93.676 ± 6.806	.056
Middle	79.205 ± 17.552	84.258 ± 17.978	.409
Apical	82.282 ± 17.067	71.071 ± 25.703	.143
Total	84.820 ± 10.810	86.580 ± 12.350	.602
Apical transportation (level) (n = 13)			
1 mm	0.096 ± 0.189	0.093 ± 0.186	1.000
3 mm	0.059 ± 0.069	0.082 ± 0.080	.625
5 mm	0.097 ± 0.093	0.133 ± 0.138	.519

Data shown as mean ± standard deviation.

Instrumentation during retreatment procedures can lead to changes in dentin volume and transportation of root canals that can only be observed by using 3D technology (32). Excessive dentin removal should be prevented to avoid further root weakening with the consequent risk of vertical root fracture and/or perforation (33). The results of the present study indicate that the tested null hypothesis was accepted with respect to dentin removal. It can be inferred that the 2 systems tested had similar shaping ability, considering that both systems removed dentin from the root canals ($P < .05$) and the volume was similar between the groups ($P > .05$). The total amount of dentin removed in the present study was lower than that observed by Rödig et al (26), who found 5.0 mm^3 of dentin removal by using the REC system in specimens with a WL of 17 mm. The greater dentin removal observed by these authors was probably due to the larger file size used in their study. Although not a determining factor for system choice in the removal of obturation material, the time needed for this procedure was recorded. Despite the differences in the number of files used, the effective time needed for the procedure was similar between the groups. Therefore, the null hypothesis was accepted for this parameter ($P > .05$). This finding is in agreement with the study of Rödig et al, where the effective time needed by single-file REC was similar to that of the multiple-file ProTaper Retreatment System (Dentsply Tulsa Dental Specialties).

Endodontic instruments have a tendency to diverge from the long axis of root canal during preparation (32). This tendency increases with increasing canal curvature. Root canal transportation increases the risk of ledging, zipping, and perforation, particularly in the apical third, and weakens the tooth structure (34). In the present study, apical transportation was assessed at 1, 3, and 5 mm from the apical foramen. The null hypothesis was accepted for this parameter because there was no significant difference between the groups ($P > .05$). The REC and PTN systems stayed centered in the apical third of root canal and safely preserved the original canal anatomy.

It can be concluded that REC and PTN systems had similar performances in the retreatment of severely curved root canals. The present study indicated that PTN system could be used for the removal of gutta-percha from the root canal. There was no significant difference between the 2 systems with regard to remaining root obturation material, volume of dentin removed, or apical transportation. Considering that neither system could completely remove the obturation material, additional techniques should be used to improve cleaning of root canal.

Acknowledgments

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

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