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Transportation assessment in simulated curved canals after retreatment with rotary and reciprocating systems

Mariana Santoro Rocha,[1] Brenda Leite Muniz,[1] Marianna Fernandes Carapiá,[1] Felipe Gonçalves Belladonna,[2] Justine Monteiro Monnerat Tinoco,[3] FernandaHecksher,[1] Emmanuel João Nogueira Leal Silva[1]

[1]Department of Endodontics, School of Dentistry, Grande Rio University (UNIGRANRIO), Rio de Janeiro, RJ, Brazil

[2]Department of Endodontics, Federal Fluminense University (UFF), Niterói, RJ, Brazil

[3]Department of Endodontics, Rio de Janeiro State University (UERJ), Rio de Janeiro, RJ, Brazil

• **Conflicts of interest: none declared.**

Abstract

Objective: this study evaluated the ability of rotary (ProTaper-Retreatment and Mtwo-Retreatment) and reciprocating (Reciproc and WaveOne) systems in maintaining the original shape of the canal after root canal retreatment. **Material and Methods:** forty curved resin blocks with simulated root canals were prepared and filled. After that, each block was randomly assigned to 4 groups (n = 10) according to the retreatment system used. Stereomicroscopic images from each block were taken before and after retreatment procedures. Evaluation of canal transportation was obtained for all canal length and for 2 independent canal regions: straight and curved parts. ANOVA followed by Tukey's test was used ($P<0.05$). **Results:** for all canal length ProTaper-Retreatment system showed lowest transportation values followed by Reciproc, MTwo-Retreatment and WaveOne systems ($P <0.01$). At the straight part, ProTaper-Retreatment system produced the lowest canal transportation followed by Reciproc and MTwo-Retreatment systems ($P < 0.05$); at the curved part, ProTaper-Retreatment and Reciproc systems produced the lowest canal transportation followed by MTwo-Retreatment system ($P < 0.05$). The WaveOne system resulted in the highest transportation values at both canal parts ($P < 0.05$). **Conclusion:** overall, ProTaper-Retreatment system produced less canal transportation in both portions of the simulated canals than the others systems tested after retreatment procedures.

Keywords: Canal transportation; Endodontic retreatment; Reciprocating; Rotary; Instrumentation.

Introduction

Nonsurgical endodontic retreatment, periradicular surgery, and extractions are considered to be alternative modalities after conventional root canal treatment fails.[1] Root canal retreatment is considered the first choice due to its most conservative approach.[2] Complete removal of all previous root filling material is thus, of outmost importance in nonsurgical retreatment,[3] once filling remnants may cover areas in which residual infection occurs, increasing the risk of maintaining periradicular inflammation.[4]

Different techniques have been proposed for regaining access to the root canal system through removal of the original filling, including the use of heated instruments, ultrasonic tips, stainless steel hand files and nickel-titanium (NiTi) instruments.[5-8] However, irrespective of the technique used, all of them leave residual fillings along the canal walls.[5-8] Recent studies have shown that reciprocating instruments, such as Reciproc (R) (VDW, Munich, Germany) and WaveOne (WO) (Dentsply Maillefer, Ballaigues, Switzerland), which were initially developed for root canal preparation, can also be used in retreatment procedures.[6-9] Even though there is growing evidence on the safety and benefits of using these systems in retreatment cases[6-9], none of these studies evaluated the shaping ability of these systems during root canal retreatment. Therefore, the aim of the present study was to evaluate the ability of rotary (ProTaper Retreatment [PTR; Dentsply Maillefer] and Mtwo Retreatment [MTR; VDW) compared to reciprocating (R and WO) systems in maintaining the original canal anatomy after root canal retreatment. The null hypothesis tested was that there would be no significant differences in canal transportation among the NiTi systems tested.

Material and Methods

Shaping and Filling Procedures

Forty curved simulated root canals, manufactured in clear resin blocks (Endo Training Blocks ISO 15; Dentsply Maillefer), with a 2% taper, 70° angle of curvature, 10-mm radius of curvature and 17-mm length were used. A stainless steel 10- and 15 K-file (Dentsply Maillefer) scouted the canal up to the working length (WL), creating an initial and standardized glide path. Then, all blocks were prepared with R25 instruments (25/0.08) used at the pre-setting program (RECIPROC ALL) powered by a torque-controlled motor (Silver Reciproc; VDW). The instrument was gradually advanced in the simulated canal using a slow and gentle in-and-out pecking motion with a 3 mm amplitude limit. After each three complete pecking movements, the instrument was removed from the canal and its flutes were cleaned off by insertion into a clean stand with a sponge. The WL was reached after three waves of instrumentation in all blocks.

Between each preparation step, apical patency was confirmed using a size 10 K-file just beyond the WL and the simulated canals were irrigated with 1.0 mL sterile water using a 30-G side-vented needle (Max-i-Probe; Dentsply Rinn, Elgin, IL, USA). Then, the canals were dried with absorbent R25 paper points (VDW).

After canal preparation, each canal was filled with a R25 gutta-percha cone (VDW) and AH Plus sealer (Dentsply De Trey, Konstanz, Germany) using instructions provided by the manufacturer. A heated instrument was used to remove the coronal gutta-percha excess. Then, the blocks were stored at 37ºC for 30 days to allow complete setting of the root canal sealer.

Digital Image Acquisition

The blocks were randomly assigned to 4 groups (n = 10) according to the retreatment system used: PTR, MTR, R and WO. A round silicon base with a rectangular slot was fit to the base of a color stereomicroscope (1005t Opticam stereomicroscope; Opticam, São Paulo, Brazil) coupled to a digital camera (CMOS 10 megapixels; Opticam). This slot matched the exact dimensions of the resin blocks. After canal filling, each specimen was inserted into the slot, and color images were taken and stored in TIFF format. After the retreatment procedures, all blocks were imaged again using the protocol described above.

In order to check the reliability and consistency of the repositioning method, ten resin blocks were used as controls where no preparation was performed. In this group, one color stereoscopic image of each block was taken. After that, the block was removed, replaced back and another image was taken and stored.

Retreatment Procedures

Each retreatment system was used in the following manner:

PTR. PTR instruments were used at 400 rpm with 3 Ncm torque. The following sequence was used: D1 file (30/0.09; 1/3 of the WL), D2 file (25/0.08; 2/3 of the WL) and D3 file (20/0.074; full WL). After that, the retreatment procedure was completed with ProTaper Next (PTN; Dentsply Maillefer) X3 (30/0.07; full WL) and X4 (40/0.06; full WL) instruments used at 300 rpm with 2 Ncm torque.

MTR. MTR instruments were used at 400 rpm with 3 Ncm torque. The following sequence was used: R15/0.05 and R25/0.05 files at full WL. Then, the retreatment procedure was completed with Mtwo (VDW) 30/0.05 (full WL), 35/0.04 (full WL) and 40/0.04 (full WL) files used at 300 rpm with 2 Ncm torque.

R. R25 (25/0.08) files were used as previously described. After that, the retreatment procedure was completed with R40 (40/0.06) instruments up to the WL in the exactly same manner as the R25 file.

WO. The WO Primary (25/0.08) files were used similarly to the R group under WAVEONE ALL pre-setting program. Then, the retreatment procedure was completed with Large (40/0.08) instruments up to the WL in the exactly same manner as the WO Primary file.

A single experienced operator performed all shaping, filling and retreatment procedures. Each system was used in three simulated canals and then discarded. Between the uses of each instrument, the simulated canals were irrigated with 1.0 mL sterile water using a 30-G side-vented needle (Max-i-Probe; Dentsply Rinn, Elgin, IL). After completion of the retreatment procedures, images were taken as described previously.

Image Processing and Analysis

An open source software (FIJI) and its associated plugins were used to perform all image processing, registration, segmentation and extraction of attributes.[10] Image processing and analysis was based on a methodology of a recent published study.[11] Briefly, all images were converted into a 8-bit grayscale and, then, each pair of image (before and after preparation) was registered using the "Rigid Registration" plugin. The initial image was used as the template for the rigid transformation. After that, each canal (before and instrumented) was segmented from the background using an iterative polygon tracing tool. Each line segment was defined by the user following the geometry of the canal and aided by an automatic segmentation algorithm to appropriately define edges. After polygon definition, a simple binarization scheme (0 for background, 255 for the defined polygon) was applied. Then, a skeletonization algorithm was applied to the segmented images. This algorithm uses binary thinning (symmetrical erosion) in order to find the centerlines (skeleton) of objects in the input image[12]. The XY coordinates of each skeleton were exported to a spreadsheet and the difference between each XY coordinate for the baseline and the prepared skeleton images were calculated using the formula:

$$\sqrt[2]{(x_b - x_i)^2 + (y_b - y_i)^2}$$

where x_b and y_b are the coordinates for the initial image of the canal and x_i and y_i are the coordinates for the prepared canal.

Transportation measurements were obtained by converting the obtained values to millimeters (mm) with the aid of a microscope magnification scale. After that, the transportation values were averaged for the whole canal or for two independent regions (straight and curved parts).

Statistical Analysis

Both canals portions generated several deviation values (straight = 21,960 and curved = 33,600), corresponding to each evaluated pixel. Each pixel has been considered as a unit for statistical analysis. Considering the data size, bell-shaped distribution has been assumed, and a Univariate Analysis of Variance (two-way) procedure, with a cut-off significance level of $\alpha = 5\%$, has been selected considering canal portion and preparation systems as independent variables and canal transportation (in mm) as the dependent. Tukey's test was used afterwards for pair-wise comparisons.

Results

The retreatment systems significantly influenced canal transportation (P = 0.000). Considering the overall canal length, PTR system (0.056 ± 0.016) induced significantly lower canal transportation compared to R (0.063 ± 0.024), MTR (0.071 ± 0.013) and WO (0.113 ± 0.041) systems (P <0.01). Canal transportation was more severe at curved canal parts compared to straight parts (P <0.01), as seen in Figure 1. A significant interaction between canal part and preparation systems (P <0.01) indicated different effect patterns for instruments according to the canal level, as follows: at the straight part, PTR system produced the lowest canal transportation followed by R and MTR systems (P < 0.05); at the curved part, PTR and R systems produced the lowest canal transportation followed by MTR system (P < 0.05). The WO system resulted in the highest transportation values at both canal parts (P < 0.05) (Table 1).

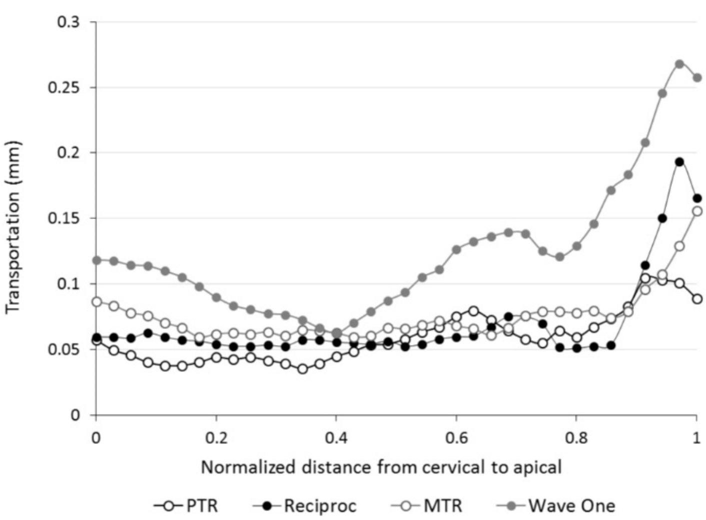

Figure 1. Graphical display of mean transportation values for each retreatment system

Table 1. Mean transportation values (mm) for all canal length and for the straight and curved parts. Different letters in the same row indicate statistical significance

	PTR	R	MTR	WO
All canal length	0.056 ± 0.016[a]	0.063 ± 0.024[b]	0.071 ± 0.013[c]	0.113 ± 0.041[d]
Straight part	0.041 ± 0.004[a]	0.056 ± 0.003[b]	0.068 ± 0.007[c]	0.095 ± 0.017[d]
Curved part	0.065 ± 0.015[a]	0.068 ± 0.030a	0.073 ± 0.016[b]	0.125 ± 0.047c

*± Standard deviation

Discussion

Endodontic non-surgical retreatment remains as the first option after unsuccessful initial root canal treatment.[2-13] During the removal of gutta-percha and sealer from filled canals procedural errors such as canal transportation may occur, which could lead to retreatment failure.[8] Although the literature has already shown evidence of effective action of rotary or reciprocating instruments during retreatment cases[5-9], there is a lack of studies on canal transportation after root canal retreatment with new instruments designed specifically for retreatment purposes compared to reciprocating systems. Therefore, the present study aimed to evaluate the ability of two rotary retreatment systems (PTR and MTR) and two reciprocating systems (R and WO) in maintaining the original canal anatomy.

In the present study, the tested null hypothesis was rejected, as differences were observed among the tested systems. Considering the overall canal length, PTR system induced significantly lower canal transportation followed by R, MTR and WO systems (P <0.01). At the curved part, no differences were observed between PTR and R systems. Both systems produced the lowest canal transportation followed by MTR and WO systems. These results may be explained by several factors such as the preparation technique, the cross-sectional design, different tapers of the instruments, type of material (NiTi alloy) and the employed kinematics. The PTR system starts with its two greater tip and taper files (30/0.09 and 25/0.08) working only at two-thirds of the WL. Then, a slightly decreased tip and taper file (20/0.074) was used at the full WL, whilst PTN instruments X3 (30/0.07) and X4 (40/0.06) enlarged the apical third. These files are made of M-wire NiTi alloy, a more flexible alloy which possess less straightening tendency.

The R system also showed good results without any differences in the curved canal part compared to PTR system. In contrast, the WO system resulted in the highest transportation values at both canal parts. Although R and WO instruments have similarities, such as the M-wire NiTi alloy and the reciprocating motion, differences observed in the present study may be explained by their different cross-sectional designs: the R instrument has a double-cutting edge S-shaped geometry, whereas the WO file has a modified, convex, triangular cross-section with radial lands at the tip and a convex triangular cross-section at middle and coronal portions. Moreover, the R instrument has a smaller cross-sectional area when compared to WO file, which influences the bending resistance of the instrument, making it more flexible and, thus, decreasing its tendency to straighten in curved canals.[14] Also, the greater depth of flutes in the R instruments favour the filling material removal[15] with less in-and-out motions.

In this study, simulated curved canals in clear resin blocks have been used. As previously shown, these blocks have the advantage of standardizing canal conditions, which is extremely relevant during the evaluation of the shaping ability of different NiTi systems.[11] However, this method presents some limitations, such as the difference in the micro-hardness between root dentine and resin, and the possible side effects produced by heat generation during canal preparation, which may soften the resin leading to binding of the cutting blades of the instruments.[16,17]

Regarding the evaluation method, color stereomicroscopic images from each block were taken exactly at the same position before and after retreatment procedures, and all image processing and data analysis were performed with an open-source program (FIJI). This *in vitro* methodology has been used as a comprehensive and objective nondestructive assessment of changes in canal path. Although the bidimensional approach may represent a limitation of this method, it is important to emphasize that current three-dimensional-based techniques used to evaluate canal transportation have not yet provided fully quantitative volumetric data, resulting in the evaluation of limited slices and manual selection of gravity center points.[8,18]

Conclusion

Under the conditions of the current study, it can be concluded that PTR system produced overall less canal transportation in both parts of the simulated canals than R, MTR and WO after retreatment procedures.

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Mini Curriculum and Author's Contribution

1. Mariana Santoro Rocha – DDS. Contribution: bibliographical research, experimental procedures, manuscript writing.
2. Brenda Leite Muniz – DDS. Contribution: bibliographical research, experimental procedures, manuscript writing.
3. Marianna Fernandes Carapiá – DDS. Contribution: bibliographical research, experimental procedures, manuscript writing.
4. Felipe Gonçalves Belladonna – DDS and MSc. Contribution: manuscript writing, manuscript review, image editing, bibliographical research.
5. Justine Monteiro Monnerat Tinoco - DDS and MSc. Contribution: manuscript writing, manuscript review, statistical analysis, bibliographical research.
6. Fernanda Hecksher - DDS and MSc. Contribution: manuscript writing, manuscript review, bibliographical research.
7. Emmanuel João Nogueira Leal Silva – DDS and PhD. Contribution: manuscript writing, manuscript review, statistical analysis, image editing, work supervisor and paper submission.

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Corresponding Author

Emmanuel João Nogueira Leal Silva

E-mail: nogueiraemmanuel@hotmail.com