Quantitative Transportation Assessment in Simulated Curved Canals Prepared with an Adaptive Movement System

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Abstract

Introduction: The aim of this study was to evaluate the ability of the Twisted File Adaptive (TF Adaptive; SybronEndo, Orange, CA) system in maintaining the original profile of root canal anatomy. The ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) and Twisted File (TF) (SybronEndo) systems were used as reference techniques for comparison. **Methods:** Thirty simulated curved root canals manufactured in clear resin blocks were randomly assigned to 3 groups ($n = 10$) according to the instrumentation system: TF in rotary motion, TF in TF Adaptive motion, and ProTaper Universal. Color stereomicroscopic images from each block were taken exactly at the same position before and after instrumentation. All image processing and data analysis were performed with an open-source program (Fiji). Evaluation of canal transportation was obtained for 2 independent canal regions: straight and curved levels. Univariate analysis of variance and Tukey Honestly Significant Difference were used, and a cutoff for significance was set at alpha = 5%. **Results:** Instrumentation systems significantly influenced canal transportation ($P = .000$). A significant interaction between instrumentation system and root canal level ($P = .000$) was also found as follows: at the straight part, TF and TF Adaptive systems produced similar canal transportation, which was significantly lower than for the ProTaper Universal system; at the curved part, TF resulted in the lowest canal transportation followed by TF Adaptive and ProTaper Universal systems. Canal transportation was higher at the curved canal parts ($P = .00$). **Conclusions:** The TF in rotary motion produced overall less canal transportation in the curved portion when compared with the others tested systems. The ProTaper Universal system showed the highest canal transportation. *(J Endod 2015;41:1125–1129)*

Key Words

Canal transportation, root canal instrumentation, R-phase, Twisted File, Twisted File Adaptive

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Canal shaping remains one of the challenging aspects of endodontic treatment because mishaps such as ledges, zips, perforations, and canal transportation can occur, particularly when preparing curved canals (1). The use of nickel-titanium (NiTi) instruments has enhanced the overall shaping quality and reduced the frequency of procedural errors (2, 3). In short, NiTi files have raised new perspectives for mechanical canal preparation, such as less debris extrusion, better centering ability, and reduced learning curve.

Recently, the Twisted File Adaptive system (TF Adaptive; SybronEndo, Orange, CA) has been introduced onto the market. In theory, this system claims to maximize the advantages of reciprocation movement while minimizing its disadvantages. The TF Adaptive system uses a patented unique motion technology, which automatically adapts the movement according to the instrumentation stress input to the file. According to the manufacturer, when the TF Adaptive instrument is lightly stressed in the canal, the motor performs conventional clockwise movement, allowing better cutting efficiency and removal of debris. In contrast, during increased torsional stress, the movement automatically changes into a reciprocation mode. Moreover, TF Adaptive files have 3 unique design features: R-phase heat treatment, twisting of the metal, and special surface conditioning (4). Although this dynamic movement and file design look promising, little knowledge exists regarding the TF Adaptive shaping ability (5).

To evaluate the shaping ability of different NiTi systems, the use of simulated curved canals in resin blocks have been largely used (6, 7). Although widespread, different methodological approaches have been proposed for the measurement of canal transportation in the simulated canal blocks model, resulting in the fact that, to the present date, there is no established golden standard method to evaluate morphologic changes in simulated canals. However, a common aspect between methodologies is the evaluation approach based on the establishment of evaluation points, usually randomly preselected by the operator. The direct and deliberated influence of the operator on the selection of points might be a source of bias. Thus, an automatic measurement approach able to reliably assess the entire extension of the simulated canal without direct operator interference would be remarkably welcome and appealing.

The present study was designed to assess the ability of the TF Adaptive system in maintaining the original profile of canal anatomy in simulated curved canals of clear resin blocks. An innovative approach to evaluate the canal transportation is introduced and discussed using a skeletonization algorithm to calculate the canal transportation by automatic coregistration of the pre- and postinstrumentation images. ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) and Twisted File (TF) (SybronEndo) systems were used as reference techniques for comparison. The null hypothesis tested was that there are no significant differences in canal transportation among the tested NiTi systems.

Materials and Methods

Digital Image Acquisition

Thirty simulated curved root canals in clear resin blocks with a 2% taper, 10-mm radius of curvature, 70° angle of curvature, and 17-mm length (Endo Training Blocks ISO 15, Dentsply Maillefer) were randomly assigned into 3 groups according to the instrumentation system (n = 10): TF group, TF Adaptive group, and ProTaper Universal group. Before any instrumentation procedure, a round silicon base with a rectangular slot fitting the microscope base was positioned under a color stereomicroscope (1005t Opticam stereomicroscope; Opticam, São Paulo, Brazil) connected to a digital camera (CMOS 10 megapixels, Opticam). The rectangular slot matched the exact dimensions of the simulated canal blocks. Each specimen was then inserted into the slot, and images were taken and stored in TIFF format. After the instrumentation procedures, all blocks were imaged again following the same protocol.

Ten blocks were used as a control group in which no instrumentation was performed at all. In this group, 1 color stereoscopic image of the block was taken first, removed, and replaced back to take another image of the same noninstrumented canal.

Instrumentation

Initially, for all groups, stainless steel size 10- and 15 K-file instruments (Dentsply Maillefer) were used to scout the canal up to the working length (WL), creating an initial and standardized glide path.

TF Group. TF instruments were used in rotary motion at 300 rpm with 2 Ncm torque (VDW Silver, Munich, Germany). The following sequence was used: SM1 (20/0.04, full WL) and SM2 (25/0.06, full WL).

TF Adaptive Group. TF instruments were used under TF Adaptive motion (Elements Adaptive motor, SybronEndo). The following sequence was used: SM1 (20/0.04, full WL) and SM2 (25/0.06, full WL).

ProTaper Universal Group. ProTaper Universal instruments were used at 300 rpm with 2 Ncm torque (VDW Silver). The following sequence was used: SX (1/2 of the WL), S1, S2, F1 (20/0.07), and F2 (25/0.08) files at the full WL.

A single operator performed all instrumentation, and only new instruments were used. Apical patency was confirmed between each preparation step by the use of a size 10 K-file just beyond the WL, and canals were irrigated with 1.0 mL sterile water using a 30-G side-vented needle (Max-i-Probe; Dentsply Rinn, Elgin, IL) placed to a depth just short of binding. After final irrigation with 1.0 mL sterile water, post-instrumentation images were performed as described earlier.

Image Processing and Analysis

All image processing, registration, segmentation, and extraction of attributes were performed within the Fiji (Fiji is Just ImageJ) open-source software interface or 1 of its associated plug-ins (8). The images were first converted into 8-bit gray scale, and after that each pair of image (baseline and after instrumentation) was registered using the "Rigid Registration" plug-in (9) (Fig. 1*A* and *B*). The baseline image was used as the template for the rigid transformation. A coregistered image from the pre- and postinstrumentation canals is shown in Figure 1*C*.

After that, each canal (baseline 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 attributed (Fig. 1*D* and 1*E*). A skeletonization algorithm was then applied to the segmented images. This algorithm uses binary thinning (symmetric erosion) for finding the centerlines (skeleton) of objects in the input image (10). An example of the final centerline of each baseline and instrumented canals is depicted in Figure 1*F* and *G*. The XY coordinates of each skeleton were saved in a spreadsheet, and the distance (in pixels) between each XY coordinate found for the baseline and the instrumented skeleton images were calculated using the following formula:

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

where x_b and y_b are the coordinates for the baseline canal and x_i and y_i are the coordinates for the instrumented canal. The obtained values were further converted to millimeters by applying the used microscope magnification scale. These values were considered as measurements of canal transportation, which were then averaged for the whole canal or for 2 independent regions (straight and curved levels), as seen in Figure 1*H*.

Statistical Analysis

At the straight canal level, a total number of 23,250 dots referring to canal transportation were registered, whereas 25,200 dots at the curved parts were analyzed. Each dot has been considered as a unit for statistical analysis. Because of the considerable data size, a bell-shaped distribution was assumed, and, thus, a univariate 2-way analysis of variance procedure was selected. Instrumentation systems and root canal levels were selected as independent variables and canal transportation (mm) as the dependent variable. Tukey Honestly Significant Difference (HSD) was used for pair-wise comparisons, and the Student t test was used to compare means for straight and curved canal parts. Alpha-type error was selected at 5%.

Results

The control group showed no canal transportation, confirming the reliability and consistency of the current method. As seen in Table 1, instrumentation systems significantly influenced canal transportation (P = .000). Compared with the straight part of the root canal, transportation was higher at the curved canal portion (0.036 ± 0.036 and 0.072 ± 0.058, respectively) (P = .000). For both canal levels, the TF system induced the lowest mean of canal transportation followed by TF Adaptive and ProTaper Universal systems. However, a significant interaction between instrumentation system and root canal level was also found. At the straight portion, TF and TF Adaptive systems produced similar canal transportation (P > .05), which was significantly lower than the ProTaper Universal system (P = .000); at the curved part, the TF system resulted in the lowest canal transportation followed by the TF Adaptive and ProTaper Universal systems (P = .000).

Discussion

Overall, the TF system used in rotary motion showed lower canal transportation in the curved canal level than the other tested systems. Therefore, the null hypothesis was rejected. Previous studies showed that the TF Adaptive system induces lower canal transportation and better centering ability when compared with reciprocating systems (11, 12). However, this is the first time that the centering ability of the TF was compared using rotary and adaptive movements, allowing the isolation of 1 variable: movement kinematic. Rotary motion showed improved performance compared with this new combined rotary/reciprocating motion in simulated root canals, remarkably in the canal curvature.

The ProTaper Universal system showed the highest canal transportation in both straight and curved portions, which is in line with previous