Geometric Analysis of Root Canals Prepared by Four Rotary NiTi Shaping Systems

Ahmed Abdel Rahman Hashem, BDS, MSc, PhD,[*] *Angie Galal Ghoneim, BDS, MSc, PhD,*[†] *Reem Ahmed Lutfy, BDS, MSc, PhD,*[†] *Manar Yehia Foda, BDS, MSc, PhD,*[†] *and Gihan Abdel Fatah Omar, BDS, MSc, PhD*[‡]

Abstract

Introduction: A great number of nickel-titanium (NiTi) rotary systems with noncutting tips, different cross-sections, superior resistance to torsional fracture, varying tapers, and manufacturing method have been introduced to the market. The purpose of this study was to evaluate and compare the effect of 4 rotary NiTi preparation systems, Revo-S (RS; Micro-Mega, Besancon Cedex, France), Twisted file (TF; SybronEndo, Amersfoort, The Netherlands), ProFile GT Series X (GTX; Dentsply, Tulsa Dental Specialties, Tulsa, OK), and ProTaper (PT; Dentsply Maillefer, Ballaigues, Switzerland), on volumetric changes and transportation of curved root canals. **Methods:** Forty mesiobuccal canals of mandibular molars with an angle of curvature ranging from 25° to 40° were divided according to the instrument used in canal preparation into 4 groups of 10 samples each: group RS, group TF, group GTX, and group PT. Canals were scanned using an i-CAT CBCT scanner (Imaging Science International, Hatfield, PA) before and after preparation to evaluate the volumetric changes. Root canal transportation and centering ratio were evaluated at 1.3, 2.6, 5.2, and 7.8 mm from the apex. The significance level was set at $P \leq .05$. **Results:** The PT system removed a significantly higher amount of dentin than the other systems ($P = .025$). At the 1.3-mm level, there was no significant difference in canal transportation and centering ratio among the groups. However, at the other levels, TF maintained the original canal curvature recording significantly the least degree of canal transportation as well as the highest mean centering ratio. **Conclusions:** The TF system showed superior shaping ability in curved canals. Revo-S and GTX were better than ProTaper regarding both canal transportation and centering ability. *(J Endod 2012;38:996–1000)*

Key Words

Computed tomography, canal transportation, root canal volume, twisted file, Revo-S, GTX, ProTaper, nickel-titanium instruments

Canal shaping remains to be one of the critical aspects of endodontic treatment because a number of mishaps such as ledges, zips, perforations, and root canal transportation can occur, particularly when preparing curved canals (1). The introduction of nickel-titanium (NiTi) rotary instruments has represented a major breakthrough in root canal preparation by permitting easier and faster instrumentation while maintaining the original canal shape with considerably less iatrogenic errors (2–4). However, it has been shown that the design features and method of manufacturing might significantly affect the clinical performance of NiTi rotary instruments (5–7). Hence, a constant search for better performance in terms of the quantity of material removed from the root wall concurrent with faithful adherence to the original shape of the root canal is progressing through introducing new methods of manufacturing NiTi rotary instruments (2, 5).

Recently, new generations of NiTi rotary instruments with higher flexibility and greater cutting efficiency have been introduced (2). The Twisted File (TF; SybronEndo, Amersfoort, The Netherlands) represents one of the most advanced endodontic NiTi rotary files in the market. It has 3 unique design features: the R-phase heat treatment, twisting of the metal, and special surface conditioning. These features significantly increase the instrument's resistance to fracture (8, 9) and provide greater flexibility (10).

The ProFile GT Series X (GTX; Dentsply, Tulsa Dental Specialties, Tulsa, OK), the new generation of ProFile GT, is characterized by innovative M-wire NiTi technology, more open blade angles, variable-width lands, and a 1-mm maximum shank diameter (11). The variable-width lands are claimed to minimize taper lock in the canal and produce larger chip space between the cutting flutes, accordingly increasing the cutting efficiency without transportation.

Revo-S (RS; Micro-Mega, Besancon Cedex, France), another NiTi rotary system, was developed with a distinctive asymmetric cross-section intended to decrease the stress on the instrument (12). The manufacturer claims that this particular instrument geometry facilitates canal penetration and the upward removal of debris. To date, the effect of these new NiTi rotary systems on root canal geometry has not been compared. Therefore, the aim of the present study was to evaluate and compare the effect of using different NiTi rotary systems (ie, Revo-S, TF, GTX, and ProTaper [PT; Dentsply Maillefer, Ballaigues, Switzerland]) on the volume of removed dentin, canal transportation, and canal centering ability in extracted human teeth using cone-beam computed tomography (CBCT) scanning.

From the Departments of *Endodontics and ‡Oral Radiology, Future University, Cairo, Egypt; and †Department of Endodontics, Cairo University, Cairo, Egypt.
Address requests for reprints to Dr Ahmed Abdel Rahman Hashem, Department of Endodontics, Faculty of Oral and Dental Medicine, Future University, Fifth District, Cairo, Egypt. E-mail address: endohashem@gmail.com
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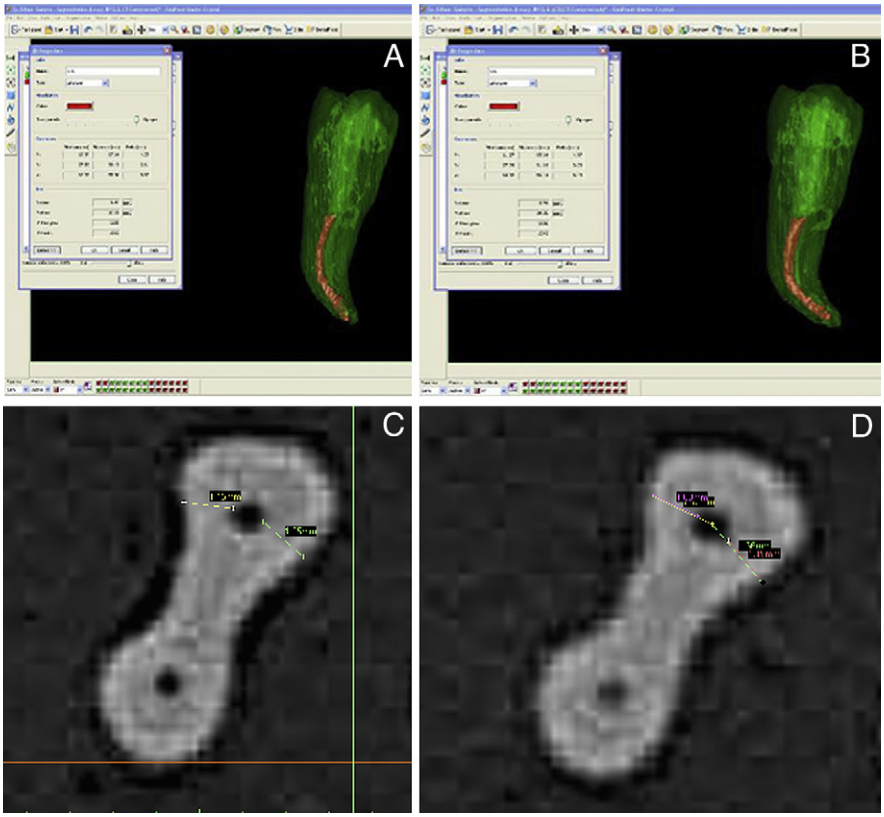

Figure 1. Volumetric changes measurements (*A*) before instrumentation and (*B*) after instrumentation. Canal transportation measurements (*C*) before instrumentation and (*D*) after instrumentation.

Materials and Methods

Selection and Specimen Preparation

Forty extracted human mandibular first molars with an average length of 20 to 21 mm, curved mesial roots, 2 separate mesial canals, and apical foramina were selected. Teeth were accessed using an Endo-Access bur (Dentsply Maillefer), and the meisobuccal canals were localized and explored with a size 10 K-file (Dentsply Maillefer). Mesiobuccal canal curvatures were assessed according to Schneider's technique (13). Only canals with curvature (25°-40°) were included in the study. Distal roots with the respective part of the crown were sectioned at the furcation level and discarded. The determination of the working length was performed at magnification ×8 using a surgical microscope (Opmi-Pico; Karl Zeiss, Jena, Germany) by inserting a #10 K-file to the root canal terminus and subtracting 1 mm from this measurement. Specimens were coded and randomly divided into 4 equal experimental groups (n = 10) according to the rotary NiTi file system used in canal instrumentation: the RS group, the TF group, the GTX group, and the PT group.

Root canal instrumentation was performed by a single operator in strict accordance with the manufacturers' recommendations for each system. All files were operated by a 1:16 gear reduction handpiece powered by an electric torque control motor (Dentaport; J Morita, Tokyo, Japan). Each canal was prepared to the working length in a crown-down sequence, and the final apical preparation was set to size 30 in each group. Between each file size, copious irrigation with 2 mL 5.25% NaOCl was performed using a 27-G needle (Stropko NiTi Needle, SybronEndo), and patency was maintained using a size #10 K-file. Each instrument was discarded after use in 5 canals.

Image Analysis

The roots were positioned in a custom-made specimen holder in which they were aligned perpendicularly to the beam and scanned before and after instrumentation using the i-CAT CBCT scanner (Imaging Science International, Hatfield, PA). Exposure parameters were 120 kV and 3 to 7 mA. The field of view had an 8-cm diameter and was 8 cm high. Slices were 640 × 640 pixels, and the pixel size was 0.13 mm. The acquired data were viewed, and measurements were performed by the software SimPlant View 12.03 for Intel X86 Platform V 12.0.3.14, operating system windows XP SP3 (1992-2008 Materialise Dental n.v., Technologielann 15, 3001 Leuven, Belgium). The mesiobuccal canal was traced, and the total volume was measured (Fig. 1*A* and *B*). Four cross-section planes at levels 1.3, 2.6, 5.2, and 7.8 mm from the apical end of the root were viewed through the explorer mode. The shortest distance from the canal wall to the external root surface was measured in the mesial and distal directions for the mesiobuccal root canal. The distance was measured on the reconstructed 2-dimensional image without reduction by using the measure length tool (Fig. 1*C* and *D*). Measurements were recorded before and after instrumentation to calculate the following: (1) the volume of removed dentin determined in mm^3 for each root canal by subtracting the uninstrumented canal volume from the instrumented canal volume, (2) the degree of canal transportation at each level according to the following formula (14): $(x_1\text{-}x_2) - (y_1\text{-}y_2)$, and (3) the canal centering ratio at each level according to the following ratio (14): $(x_1\text{-}x_2)/(y_1\text{-}y_2)$ or $(y_1\text{-}y_2)/(x_1\text{-}x_2)$, where x_1 is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal, x_2 is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, y_1 is the shortest distance from the distal

TABLE 1. Statistical Analysis of the Mean Values for the Volume of Removed Dentin (mm^3) for the Tested Groups

Group	Mean SD	*P* value
RS	$2.06^b \pm 0.73$	.025*
TF	$2.10^b \pm 1.48$	
GTX	$3.03^b \pm 1.93$	
PT	$4.67^a \pm 1.96$	

Means with different letters are statistically significantly different according to the Mann-Whitney *U* test.

*Significant at $P \leq .05$.

edge of the root to the distal edge of the uninstrumented canal, and y_2 is the shortest distance from the distal edge of the root to the distal edge of the instrumented canal.

Statistical Analysis

Data were presented as means and standard deviation values. One-way analysis of variance was used for comparisons of the centering ratio and canal transportation in the studied groups. The Tukey post hoc test was used for pair-wise comparisons between the groups when the analysis of variance test was significant. The Kruskal-Wallis test was used for comparison between volume changes in the studied groups. The Mann-Whitney *U* test was used for pair-wise comparison between the groups when the Kruskal-Wallis test was significant. The significance level was set at $P \leq .05$.

Results

The mean and standard deviation values for the volume of the removed dentin, the canal transportation, and the centering ratio at the studied levels for the experimental groups are presented in Tables 1 and 2.

Volume of Removed Dentin

The PT group recorded the significantly highest mean volume of removed dentin (4.67 ± 1.96 mm^3). On the other hand, the RS, TF, and GTX groups yielded the significantly lowest mean volume changes (2.06 ± 0.73, 2.1 ± 1.48, and 3.03 ± 1.93 mm^3, respectively) with no significant difference among them.

Canal Transportation

At the 1.3-mm level, there was no statistically significant difference in canal transportation among the groups ($P > .05$). However, at the 2.6-mm level, the TF group recorded the least transportation among all groups (0.059 ± 0.02 mm). The RS group then followed with a significantly higher transportation mean of 0.114 ± 0.025 mm. Meanwhile, the GTX and PT groups yielded the significantly highest mean transportation values (0.141 ± 0.035 mm and 0.162 ± 0.019 mm, respectively) with no significance between them. At the 5.2-mm level, the GTX and TF groups showed the significantly lowest mean transportation values (0.051 ± 0.015 mm and 0.69 ± 0.02 mm). At the 7.8-mm level, the TF, GTX, and RS groups recorded the significantly lowest mean transportation values (0.137 ± 0.044 mm, 0.159 ± 0.04 mm, and 0.162 ± 0.032 mm, respectively) with no significance among them. On the other hand, the PT group yielded the significantly highest mean transportation value (0.25 ± 0.035 mm).

Centering Ratio

At the 1.3-mm level, there was no statistically significant difference in the canal centering ratio among the groups ($P > .05$). However, at the 2.6-mm level, the TF group recorded the significantly highest mean centering ratio (0.91 ± 0.15), whereas the PT group yielded the significantly lowest mean centering ratio (0.55 ± 0.15). At the 5.2-mm level, the TF group showed the significantly highest centering ratio (0.82 ± 0.13), whereas the RS group recorded the significantly lowest centering ratio (0.52 ± 0.12). At the 7.8-mm level, the TF and RS groups recorded the significantly highest mean centering ratio (0.76 ± 0.11 and 0.70 ± 0.17, respectively) with no significant difference between them, whereas the PT group yielded the significantly lowest mean centering ratio (0.50 ± 0.10).

Discussion

The advantages of NiTi instruments in root canal preparation are well documented; however, their cutting ability is a complex interrelationship of different parameters such as the cross-sectional design, chip-removal capacity, helical and rake angles, metallurgical properties, and surface treatment of the instrument (5, 15). The Revo-S, TF, GTX, and ProTaper are recently introduced file systems that are distinctly different in their geometric design and manufacturing method. Hence, the purpose of this study was to compare the effect of these new NiTi rotary instruments on canal transportation, the centering ratio, and the volume of removed dentin using CBCT scanning. Noninvasive CBCT scanning was used because it provides an accurate, reproducible, 3-dimensional evaluation of changes in both dentin thickness and root canal volume before and after preparation without the destruction of specimens (14, 16, 17).

An extracted teeth model was used because testing file systems under realistic circumstances in natural dentin is considered more beneficial than in standardized artificial canals (18). Crowns were maintained to simulate clinical conditions in which the interference of cervical dentin projections would create tensions on the files during canal instrumentation (19). Four levels (ie, 1.3, 2.6, 5.2, and 7.8 mm from the root apex) were chosen representing the apical and middle thirds of root canal in which curvatures, highly susceptible to iatrogenic mishaps, usually exist.

In the present study, ProTaper recorded the significantly highest mean volume of removed dentin compared with the other tested rotary

TABLE 2. Statistical Analysis of Mean Transportation (mm) and the Centering Ratio Values for Tested Groups

Level	Assessment	RS	TF	GTX	PT	*P* value
1.3 mm	Transportation	$.044 \pm .015$	$.025 \pm .010$	$.046 \pm .019$	$.033 \pm .009$	.387
	Centering ratio	$.65 \pm .15$	$.75 \pm .07$	$.72 \pm .15$	$.68 \pm .13$	.339
2.6 mm	Transportation	$.114^b \pm .025$	$.059^c \pm .020$	$.141^a \pm .035$	$.162^a \pm .019$	<.001*
	Centering ratio	$.71^b \pm .09$	$.91^a \pm .15$	$.74^b \pm .14$	$.55^c \pm .15$	<.001*
5.2 mm	Transportation	$.104^b \pm .030$	$.069^c \pm .020$	$.051^c \pm .015$	$.164^a \pm .033$	<.001*
	Centering ratio	$.52^c \pm .12$	$.82^a \pm .13$	$.66^b \pm .11$	$.64^b \pm .15$	.002*
7.8 mm	Transportation	$.162^b \pm .032$	$.137^b \pm .044$	$.159^b \pm .040$	$.250^a \pm .035$	<.001*
	Centering ratio	$.70^a \pm .17$	$.76^a \pm .11$	$.61^b \pm .09$	$.50^c \pm .10$	.001*

Means with different letters are statistically significantly different according to the Tukey test.

*Significant at $P \leq .05$.

instruments. This is in agreement with previous studies on extracted teeth (20–22). This might be attributed to the sharp cutting edges of the convex triangular cross-sectional design of ProTaper instruments coupled with the flute design with its progressive tapers sequence along the shaft compared with the constant taper embraced by the other tested instruments. ProTaper recorded significantly more tooth structure removal than TF as previously reported (23). On the other hand, GTX showed more dentin removal than TF and Revo-S but with no statistical significance. The current results could not be compared with other reports because, to our knowledge, no previous published data are available comparing these 3 systems.

In this study, all tested rotary systems resulted in canal transportation at all examined levels, a finding that is consistent with other studies (18, 19, 24). At 1.3 mm, the 4 groups showed no statistically significant difference among them in both canal transportation and the centering ratio. This might be because of the noncutting tip design they all possess, which functions only as a guide to allow easy penetration with minimal apical pressure (25), and the standardized master apical file size (23). At the other studied levels, TF recorded the significantly lowest mean canal transportation as well as the highest mean centering ratio among the tested groups. This result is consistent with another study (26) and might be attributed to the new manufacturing method (ie, R-phase heat treatment, twisting of the metal, and the surface deoxidation [8–10]) resulting in increased phase transformation temperatures and increased flexibility of TF files compared with the other NiTi instruments manufactured by grinding (27).

Revo-S recorded significantly less transportation than ProTaper at all of the studied canal levels. It was not even significant from TF at 7.8 mm regarding canal transportation and the centering ratio. This could be related to the asymmetric cross-sectional geometry of the SC1 and SU instruments intended to facilitate canal penetration by a snake-like movement and upward removal of debris, hence leading to uniform removal of dentin and less stress on the instrument as claimed by the manufacturer.

GTX, a modified version of the Profile system, recorded a significantly higher centering ratio than Revo-S at 5.2 mm. The centering ability of the Profile system has been previously reported (25) and has been suggested to be caused by the radial lands on the cutting edges of the file that attenuated the effect of the instrument on the outside of the root canal curve, thus keeping the file concentric within the natural canal. Although GTX recorded significantly higher mean canal transportation than Revo-S and TF at 2.6 mm, it was not significant from TF at 5.2 mm and 7.8 mm and even recorded significantly less transportation than Revo-S at 5.2 mm. This might be attributed to the innovative M-wire NiTi technology (11). Furthermore, the unique feature of variable-width lands was reported to minimize the taper lock in the canal and to produce larger chip space between cutting flutes allowing for rapid cutting without transportation (11). McSpaddan (28) has speculated that radial lands help to distribute the pressure of the blades evenly around the curvature, thus allowing more circumferentially uniform cutting to occur compared with the actively cutting files without lands. However, Peters et al (29) concluded that variations in canal anatomy before preparation had more influence on the postoperative canal geometry than the rotary system itself.

The ProTaper system recorded a significantly less centering ratio and higher canal transportation than the other groups at 2.6, 5.2, and 7.8 mm. Similar results were reported and were attributed to the sharp cutting edges and the multiple tapers along the cutting surface of the files (26), especially the large increase in taper size from 0.04 to 0.07 (S2 to F1) (30). In addition, the apical enlargement performed until F3 for standardization might have an impact on the results because NiTi files with tapers greater than 0.04 were previously suggested not be used for apical enlargement of curved canals or else transportation would result (25, 31).

Conclusion

Within the parameters of this study, it could be concluded that all tested rotary systems produced canal transportation at the apical and midregions of the canal. The innovated method of manufacturing the TF system resulted in superior shaping ability in curved canals, with the instruments remaining more centered and producing less canal transportation than the other systems. On the other hand, Revo-S and GTX exhibited superior performance than ProTaper in both canal transportation and centering.

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

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