Comparative Study of 6 Rotary Nickel-Titanium Systems and Hand Instrumentation for Root Canal Preparation in Severely Curved Root Canals of Extracted Teeth

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Abstract

Introduction: Some improvements have been developed with new generations of nickel-titanium (NiTi) rotary instruments that led to their successful and extensive application in clinical practice. The purpose of this *in vitro* study was to compare the root canal preparations performed by using GT Series X and Twisted File systems produced by innovative manufacturing process with Revo-S, RaCe, Mtwo, and ProTaper Universal systems manufactured directly from conventional nitinol and with stainless steel K-Flexofile instruments. **Methods:** The mesiobuccal root canals of 140 maxillary first permanent molars that had between 30°–40° curvature angle and 4- to 9-mm curvature radius of the root canal were used. After root canal preparations made by using GT Series X, Twisted File, Revo-S, RaCe, Mtwo, and ProTaper Universal NiTi rotary systems and stainless steel K-Flexofile instruments, transportation occurred in the root canal, and alteration of working length (WL) was assessed by using a modified double-digital radiographic technique. The data were compared by the post hoc Tukey honestly significant difference test. **Results:** NiTi rotary systems caused less canal transportation and alteration of WL than K-Flexofile instruments ($P < .05$). There was no significant difference between NiTi rotary system groups at any levels ($P > .05$) except 2.5 mm from the WL. At this level ProTaper Universal system caused significant canal transportation ($P < .05$). **Conclusions:** GT Series X and Twisted File rotary systems produced with innovative process were concluded to shape the curved canals to result in minimal canal transportation, similar to Revo-S, RaCe, Mtwo, and ProTaper Universal rotary systems manufactured by traditional methods. *(J Endod 2013;39:278–282)*

Key Words

M-wire, root canal instrumentation, rotary instrument, Twisted File

A successful endodontic treatment is believed to depend on thorough cleaning and shaping of root canals (1–3). In morphologic studies of Peters et al (4, 5) and Hubscher et al (6), complexity of root canal anatomy has been put forth explicitly. Variations of canal sections, in-canal irregularities, and associated curvature diversity render procedure failures almost inevitable. Shaping the root canal by preserving curvature is one of the main parameters used for analysis of the methods or instruments developed for root canal preparation (7). Nickel-titanium (NiTi) rotary instruments have been continuously changing in the last 20 years to successfully realize this parameter. One of these alteration fields is the studies focused on the direct chemical structure of the alloy to make NiTi alloy more durable and more effective. Therefore, the M-wire NiTi material, which is suggested to be more flexible than the 55-nitinol and more resistant to cyclic fatigue and with more cutting efficiency, has been produced. The first rotary instrument system generated from this material was GT Series X (Dentsply Tulsa Dental Specialties, Tulsa, OK) (8). Other progress in the production of NiTi rotary instruments is Twisted File (SybronEndo Orange, CA) rotary instrument system produced with plastic deformation via R-phase heat application and bolt contortion. The instruments belonging to this system have been claimed to be more flexible and more resistant to cyclic fatigue, to proceed in the center of the canal, especially in curved canals, and to have minimized canal transportation (9).

In studies investigating the shaping ability of endodontic instruments, double-digital radiographic techniques (10–13) and micro–computed tomography (4, 9, 14, 15) are currently used for assessment of canal transportation. The double-digital radiographic techniques are easy to use, inexpensive, and potentially informative depending on the subject under investigation but lack the capacity to reveal volumetric data (16).

The new materials and methods used in the production of NiTi rotary instruments may contribute to the development of root canal preparation; however, the number of studies investigating these new materials and methods comparatively is limited. The aim of this study was to compare the shaping ability of 6 different NiTi rotary systems and stainless steel K-Flexofile by measuring canal transportation in the mesiobuccal canals of maxillary first molars that had a canal curvature between 30°–40° and root curvature radius between 4–9 mm.

Materials and Methods

The maxillary first permanent molars that had completed apical maturation, continued from the mesiobuccal root canal access to the apical foramen and at a maximum #15 K-Flexofile (Dentsply Maillefer, Ballaigues, Switzerland) instrument pinched in the apical narrowing site, and were extracted because of periodontal or

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prosthetic reasons, were used. After the preparation of the access cavity with Endo Z drills (Dentsply Maillefer), ISO #10 K-file was advanced into the root canal until its tip was observed in the apical foramen. Working length (WL) was determined by subtracting 1 mm from the length at the time the file was first seen.

An experimental setup was prepared to be able to use the radiograph subtracting method before and after the preparation, as described by Iqbal et al (10) and Maggiore (17) for the analysis of the effect of preparation systems on root canal transportation. A turntable was formed, enabling the placing of the teeth in the same position before and after the preparation. A #15 K-Flexofile instrument was placed in the root canal, and the turntable was gradually turned and a series of radiographs were taken until a straight image of the instrument in the root canal was ensured. The tooth was then rotated 90° to reveal the maximum curvature of the root canal (18). The radiographic image at this point was recorded as the final preoperative image. The maximum root curvature angle and the root curvature radius of the instrument in the canal were determined by using the method of Pruett et al (19) with AutoCAD 2007 (Autodesk Inc, San Rafael, CA). A total of 140 maxillary first molars with a root curvature angle of 30°–40° and a root curvature radius of 4–9 mm were included in the study. The analysis of variance and the post hoc Tukey statistical analysis methods were used to allocate the teeth into 7 different groups with 20 in each, similar with respect to the root curvature angle and curvature radius.

Each instrument was used in 4 canals and was then discarded in all groups; however, the instruments that were deformed before reaching this number were discarded. Irrigation was performed with 2 mL 2.5% NaOCl solution after each file. Apical preparation was completed with 30/.06 instruments by using the instrument order instructed by the manufacturer in group 1 (Twisted File), group 2 (GT Series X), group 3 (Revo-S; MicroMega, Besançon, France), group 4 (RaCe; FKG, La Chaux-de-Fonds, Switzerland), and group 5 (Mtwo; VDW, Munich, Germany). Apical preparation was completed with F3 file by using the instrument order instructed by the manufacturer in group 6 (ProTaper Universal; Dentsply Maillefer). In group 7 (K-Flexofile), instrumentation was performed by using the crown-down method with triangular flexible stainless steel K-Flexofile instruments with noncutting tip design. Apical preparation was completed with the ISO 30/.02 instrument.

The prepared samples were placed onto the radiographic imaging setup in the position in which the preoperative images were obtained, and postoperative radiographic imaging of each sample was performed. The final digital radiographs obtained before and after the preparation were downloaded in jpeg format by using the digital radiographic imaging system and carried onto the Adobe Photoshop CS2 software (Adobe Systems Inc, San Jose, CA).

The images were passed through the Paint Daub artistic filter of simple brush type with size 6 and accuracy of 10. The maximum values in the submenu selected through the artistic filter were chosen, and the borders of the image were postered. The distance between the point at which a line was drawn parallel to the longitudinal axis of the coronal third of the canal on the postered final preoperative radiograph (the point at which the canal curvature began) and tip of the canal instrument was divided into 5 equal parts by using the AutoCAD software. Six levels were obtained for measurement. The furthest most point of the instrument corresponding to D0 was named L1, and the point at which the canal curvature began was named L6; the remaining equal parts were named L2, L3, L4, and L5 from the apical to the coronal. The distance of the canal instrument corresponding these levels to the apical foramen was determined in millimeters, and the mean values were calculated for all samples (Table 1).

The postered images were transferred to the AutoCAD software to draw the central axis of the K-Flexofile instrument on the final preoperative image and the last instrument used for preparation of the related group on the postoperative image. Afterwards, a series of horizontal lines joining the outer borders of the instrument were drawn. The central axis of the instrument was obtained by joining the midpoint of each of the horizontal lines. The reflection of the Cartesian system was drawn, and perfect superimposition of the images before and after the preparation was obtained. Thus, the transportation in the described levels could accurately be measured by using the AutoCAD software.

TABLE 1. Means of Distances from D0 Corresponding to Different Levels (n = 140)

Level	Mean (mm)
L1	0
L2	1.1 ± 0.09
L3	2.5 ± 0.96
L4	3.7 ± 0.85
L5	5.0 ± 0.76
L6	7.1 ± 0.89

The distance between the preoperative and postoperative instrument tips at the D0 point was measured by using the previously mentioned setup and the subtracting method. Thus, alteration of WL was also determined.

The maximum, minimum, mean, and standard deviation values of the canal transportation amounts at the levels of each group and WL were calculated. The mean values of these groups were compared by using the analysis of variance and the post hoc Tukey honestly significant difference statistical tests. A P level <.05 was accepted as statistically significant.

Results

Transportation occurred in all samples (Table 2). At the L1 level, K-Flexofile group yielded the significantly highest mean transportation value (0.181 ± 0.077 mm) ($P < .05$), and the others showed lower (Twisted File, 0.084 ± 0.045 mm; GT Series X, 0.094 ± 0.034 mm; Revo-S, 0.107 ± 0.045 mm; RaCe, 0.1 ± 0.045 mm; Mtwo, 0.096 ± 0.063 mm; and ProTaper Universal, 0.118 ± 0.09 mm) ($P > .05$). At the L2 level, K-Flexofile group yielded the significantly highest mean transportation value (0.162 ± 0.07 mm) ($P < .05$), and the others showed lower (Twisted File, 0.087 ± 0.046 mm; GT Series X, 0.087 ± 0.03 mm; Revo-S, 0.093 ± 0.037 mm; RaCe, 0.111 ± 0.053 mm; Mtwo, 0.089 ± 0.056 mm; and ProTaper Universal, 0.105 ± 0.062 mm) ($P > .05$). At the L3 level, ProTaper Universal and K-Flexofile groups showed the significantly highest mean transportation values (0.05 ± 0.004 mm and 0.05 ± 0.006 mm, respectively) ($P < .05$); meanwhile, Twisted File (−0.011 ± 0.005 mm), GT Series X (−0.012 ± 0.004 mm), Revo-S (−0.013 ± 0.004 mm), RaCe (−0.012 ± 0.004 mm), and Mtwo (−0.011 ± 0.007 mm) values recorded lower ($P > .05$). At the L4 and L5 levels, it was found that there was no statistically significant difference between all of the groups (Twisted File, −0.04 ± 0.012 and −0.074 ± 0.058 mm; GT Series X, −0.034 ± 0.02 and −0.08 ± 0.043 mm; Revo-S, −0.046 ± 0.013 and −0.085 ± 0.05 mm; RaCe, −0.044 ± 0.025 and −0.086 ± 0.061 mm; Mtwo, −0.031 ± 0.012 and −0.08 ± 0.064 mm; ProTaper Universal, −0.026 ± 0.016 and −0.069 ± 0.041 mm; and K-Flexofile, −0.057 ± 0.012 and −0.114 ± 0.048, respectively) ($P > .05$). At the L6 level, whereas the K-Flexofile group (−0.136 ± 0.058 mm) led to a statistically significantly higher degree of transportation than the Twisted File group (−0.08 ± 0.053 mm) ($P < .05$), there was no significant difference between the other groups (GT Series X, −0.089 ± 0.043 mm; Revo-S, −0.097 ± 0.046 mm; RaCe, −0.099 ± 0.054 mm; Mtwo, −0.088

TABLE 2. Means and Standard Deviation of Transportation (mm) at All Levels

Group	L1	L2	L3	L4	L5	L6
Twisted File	$0.08465^{a} \pm 0.04567$	$0.0874^{a} \pm 0.0466$	$-0.0110^{a} \pm 0.00538$	$-0.0404^{a} \pm 0.01269$	$-0.074^{a} \pm 0.05875$	$-0.08095^{a} \pm 0.05389$
GT series X	$0.09445^{a} \pm 0.03443$	$0.0878^{a} \pm 0.03042$	$-0.01229^{a} \pm 0.00413$	$-0.0349^{a} \pm 0.02039$	$-0.0801^{a} \pm 0.04375$	$-0.0891^{a,b} \pm 0.04313$
Revo-S	$0.1078^{a} \pm 0.04521$	$0.0935^{a} \pm 0.0371$	$-0.01338^{a} \pm 0.0041$	$-0.0462^{a} \pm 0.013819$	$-0.08515^{a} \pm 0.05014$	$-0.0973^{a,b} \pm 0.04666$
RaCe	$0.10045^{a} \pm 0.0459$	$0.11135^{a} \pm 0.05394$	$-0.01236^{a} \pm 0.00433$	$-0.04475^{a} \pm 0.02537$	$-0.08685^{a} \pm 0.06164$	$-0.09965^{a,b} \pm 0.05494$
Mtwo	$0.09685^{a} \pm 0.06371$	$0.08935^{a} \pm 0.05676$	$-0.01195^{a} \pm 0.0076$	$-0.0311^{a} \pm 0.01255$	$-0.08015^{a} \pm 0.06405$	$-0.08835^{a,b} \pm 0.06085$
ProTaper Universal	$0.1181^{a} \pm 0.09085$	$0.10505^{a} \pm 0.06248$	$0.05010^{b} \pm 0.00488$	$-0.02695^{a} \pm 0.01669$	$-0.0699^{a} \pm 0.0411$	$-0.10455^{a,b} \pm 0.04831$
K-Flexofile	$0.1816^{b} \pm 0.07791$	$0.16215^{b} \pm 0.07032$	$0.05015^{b} \pm 0.00651$	$-0.0579^{a} \pm 0.01266$	$-0.11445^{a} \pm 0.04863$	$-0.13675^{b} \pm 0.05864$

Means with same superscript letters are not statistically significantly different at each level ($P < .05$).

$\pm$ 0.06 mm; and ProTaper Universal, -0.069 ± 0.041 mm) ($P > .05$). However, the Twisted File group showed a similar transportation amount with the other rotary groups ($P > .05$).

Direction of transportation in all the groups at L1 and L2 levels led to positive transportation toward the outer wall of the canal. At the L3 level, although the ProTaper Universal and K-Flexofile groups led to a positive transportation toward the outer wall of the canal, the other groups led to a negative transportation toward the inner wall of the canal. All groups led to a negative transportation toward the inner wall of the canal at other levels.

Whereas some amount of loss of WL occurred as a result of preparation with Twisted File, GT Series X, Revo-S, RaCe, and Mtwo NiTi rotary systems, overinstrumentation was observed in the ProTaper Universal and K-Flexofile groups (Table 3). However, a statistically significant difference was observed only between the K-Flexofile group and other groups in terms of change during the study ($P < .05$).

Discussion

The root canal transportation of NiTi endodontic rotary instruments has been a subject of interest in the endodontic literature. The majority of reports on preserving original canal curvature have focused on NiTi instrument composition or design (5, 8–10, 20–22). The M-wire, which has been suggested to have a different structure from the traditional nitinol, was produced and used in the production of GT series X rotary system (8, 23, 24). In addition, R-phase rotary instrument system was prepared by twisting and placed in the market with the name of Twisted File (8, 25, 26).

The NiTi rotary instruments included in our study were used by considering the instructions of the manufacturer and related studies. Apical preparation of all canals was completed with a #30 instrument to keep the standardization between the systems, because the #30 instrument was present in all the preparation systems compared in this study.

The sharpest point of the curvature in any canal may be at any distance from the apical foramen. Therefore, transportation assessment made from an equal distance from the apical foramen may not give accurate results. To eliminate this, the distance between the point in which the line that was drawn parallel to the long axis of the coronal third of the canal on the final preoperative radiograph left the long axis of the canal (the point at which the root canal curvature began) and the furthest most point of the canal instrument was divided to 5 equal pieces by using the AutoCAD software. Hence, 6 standard levels for measurement were obtained. The end point of the file corresponding to D0 was named L1, and the point at which the root canal curvature began was named L6; the remaining equal parts were named L2, L3, L4, and L5 from the apical to the coronal. Thus, a symmetrical comparison could be made at the critical points of the curvature, whereas in most of the previous studies that used the Maggiore method, the degree of displacement of the canal instrument on the preoperative and postoperative radiographs at 0.5-mm, 1-mm, 2-mm, 3-mm, 4-mm, and 5-mm distances from D0 was considered (11, 12, 18, 27–31).

If transportation occurs during the canal preparation, regaining the original form of the canal is impossible (1). Furthermore, an irregular apical preparation may hinder further canal filling to completely obstruct the canal (11). In the studies of Wu et al (32), although they filled the curved canals with elbow formation by using lateral compaction method, they could place accessory gutta-percha cones in limited amounts. They also reported that the impermeability of root canal filling was negatively affected if apical transportation was wider than 0.3 mm. Transportation reaching this critical level was not encountered in our samples. However, the

TABLE 3. Means and Standard Deviations of Alteration of WL (mm)

Groups	n	Means ± SD
Twisted File[a]	20	−0.129 ± 0.0644
GT series X[a]	20	−0.111 ± 0.0401
Revo-S[a]	20	−0.142 ± 0.0770
RaCe[a]	20	−0.147 ± 0.1098
Mtwo[a]	20	−0.135 ± 0.0281
ProTaper[a]	20	0.254 ± 0.0915
K-Flexofile[b]	20	0.586 ± 0.1780
Total	140	−0.088 ± 0.0333

Means with same superscript letters are not statistically significantly different ($P < .05$).

NiTi rotary instruments used in our study were seen to cause some amount of transportation and alteration of WL. Consistent with our study, in many studies the NiTi rotary instruments were reported to exhibit a good ability of keeping the original form of the root canal; however, they led to slight deviation from the main axis of the root canal (9, 22, 27, 29, 33–35).

In our study, GT Series X and Twisted File NiTi rotary instrument systems, which have different production process, were found to lead to transportation that did not differ from other NiTi rotary instrument systems. In a study evaluating the shaping ability of GT Series X system, this system caused deviation at D0 and at shorter distances than 1 and 3 mm from D0 similar to that of the GT system, which is the first generation (29). In that study, although apical preparation was completed with a 30/.04 instrument, the degree of deviation in the root canal was consistent with our results obtained with 30/.06 apical preparation and was clinically insignificant. In addition, it was shown in our study that GT Series X system led to significantly less transportation compared with manual preparation at levels up to apical 2.5 mm; however, this difference lost its significance at more coronal aspects.

In this study, it was found that Twisted File system led to a lower degree of transportation in critical sites compared with K-Flexofile instruments used with crown-down method; however, it could not be superior to ProTaper Universal system. Gergi et al (9) compared Twisted File instruments, PathFile-ProTaper instrument system, and the stainless steel K-Flexofile instruments in terms of apical transportation after preparation and their course in the canal center and reported that the Twisted File system yielded more superior outcomes than the others. The PathFile-ProTaper system showed better results than the K-Flexofile instruments used with the step-back method in that study. The authors concluded that this was due to the Twisted File instruments being more flexible as a result of being produced through twisting. In that study the final apical preparation was completed with 25/.08 instruments for the Twisted File, F2 (25/.08–.055) for the PathFile-ProTaper, and 25/.02 instruments for the manual method. However, in our study it was completed with 30/.02 for manual method, F3 (30/.09–.05) for the ProTaper Universal, and 30/.06 instruments for the other rotary systems. The difference between the 2 studies may have arisen from larger apical preparation.

This study is one of the first researches evaluating the Revo-S NiTi rotary instrument system in terms of used parameters, thereby evaluating the claim of the manufacturer that designing the instruments of this system (except SC2, reaching apical first) in 3 different diameters of asymmetrical cutting edges provides more flexibility through decreasing the core diameter of the instruments and thus working by fitting to the original canal. However, this system has been shown to lead to similar transportation with other NiTi rotary instruments used in the study.

Our findings differ from the results obtained by Hashem et al (36), who reported that Twisted File rotary system yielded lowest canal transportation than GT Series X and Revo-S rotary systems, and ProTaper rotary systems presented highest value. This might be attributed to the difference of methodology, especially evaluation techniques.

NiTi rotary instruments used in different orders were shown to bring about minimum WL changes in similar amounts in our study. Manual preparation led to a statistically significantly higher degree of WL changes. This finding is consistent with the results of other studies investigating the alteration of WL (34, 37, 38). Thompson and Dummer (37) reported that these changes could occur as a result of flattening that develops during root canal enlargement or the operator's loss of control of the WL.

Conclusions

GT Series X and Twisted File rotary systems produced with innovative process were concluded to shape the curved canals by leading minimal canal transportation, similar to Revo-S, RaCe, Mtwo, and ProTaper Universal rotary systems produced from traditional process. NiTi rotary instruments remained at the center of the root canal more successfully than the K-Flexofile.

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

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