Root Canal Shaping Effect of Instruments with Offset Mass of Rotation in the Mandibular First Molar: A Micro–computed Tomographic Study

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Abstract

Introduction: The aim of this study was to evaluate the root canal shaping effect of 2 nickel-titanium rotary instruments with offset mass of rotation compared with an instrument with a conventional centered mass of rotation. **Methods:** Thirty-six extracted human mandibular first molars with 2 independent mesial canals and 1 oval distal canal were selected and divided equally into 3 groups for instrumentation with ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland), Revo-S (RS; Micro-Mega, Besançon, France), and ProTaper Universal (PTU, Dentsply Maillefer) systems (n = 12). For apical preparation, PTN X2 (#25/0.06), RS SU (#25/0.06), and PTU F2 (#25/0.08) were used in the mesial canals and PTN X3 (#30/0.07), RS AS30 (#30/0.06), and PTU F3 (#30/0.09) were used in the distal canals. Specimens were scanned before and after instrumentation using a SkyScan 1272 scanner (Bruker micro-CT, Kontich, Belgium) at 10-μm isotropic resolution. Changes in the canal area, volume, structure model index (SMI), and untouched canal area were evaluated. Canal transportation and centering ratio were measured at 1, 3, 5, and 7 mm from the apical foramen. Data were statistically analyzed using 1-way analysis of variance with the Tukey post hoc test. **Results:** The PTN and RS systems showed significantly less transportation and better centering ability compared with the PTU system at 1 mm from the apical foramen (P < .05). All instrumentation increased the canal area, volume, and SMI values without significant differences among the 3 groups (P > .05). **Conclusions:** Regardless of the differences in the cross-sectional design, alloy type, and taper variation, instruments with offset mass of rotation showed better root canal shaping ability compared with an instrument with a centered mass of rotation. *(J Endod 2018;44:822–827)*

Key Words

Micro–computed tomography, offset mass of rotation, ProTaper Next, Revo-S, shaping effect

> **Significance**
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> This study compared the root canal shaping effect of nickel-titanium rotary instruments with offset mass of rotation compared with an instrument with a conventional centered mass of rotation. Instruments with offset mass of rotation showed better root canal shaping ability.

Even though the introduction of nickel-titanium (NiTi) rotary files greatly improved root canal preparation efficiency (1), canal instrumentation is still challenging, and procedural errors may occur during canal preparation (2). To minimize the engagement between the file and dentin, any undesirable taper lock, and the torque on any given file, NiTi rotary systems with an offset mass of rotation and a unique asymmetric cross-sectional design have been introduced; the resultant action of this is a swaggering motion (3). ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) and Revo-S (RS; Micro-Mega, Besançon, France) belong to this type of system, with differences in the alloy type, cross-sectional design, and tapering. The PTN system is manufactured from the M-Wire alloy with a rectangular cross section and variable tapering (4), whereas the RS system is made of a conventional NiTi alloy with a triangular cross section and constant tapering (5). Previous studies investigated the transportation and centering ability of the PTN and RS systems in the mesial canals of mandibular molars using micro–computed tomographic (micro-CT) (6) and cone-beam computed tomographic methods (7). To date, more studies are needed to compare the shaping effect of these file systems. Therefore, the aim of this study was to evaluate the root canal shaping effect of these 2 NiTi rotary instruments with an offset mass of rotation compared with an instrument with a conventional centered mass of rotation.

Materials and Methods

The study was approved by the Ethics Committee of the University of Dental Medicine, Mandalay, Myanmar (#20150202). Thirty-six extracted mandibular first molars with a slight apical binding for a #10 K-file in the 2 independent mesial canals (15°–30° curvature) and a #15 K-file in 1 single oval distal canal (5°–20° curvature) were selected (8). The specimens were scanned

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before and after root canal instrumentation with the same setting using a SkyScan 1272 scanner (Bruker micro-CT, Kontich, Belgium) with a 10-μm isotropic resolution, 125 μA, 80 kV, a 1-mm aluminum filter, and a 0.4° rotation step with 180° rotation.

Root Canal Preparation

For the instruments with offset mass of rotation, the PTN and RS systems were chosen, and as an instrument with a conventional centered mass of rotation, the ProTaper Universal (PTU) system (Dentsply Maillefer) was used. In all groups, root canal preparation was performed according to manufacturers' instructions by an experienced operator. The working length was established at 1 mm short of the apical foramen using a #10 K-file. For each rotary file, the dedicated program from the X-Smart Plus motor (Dentsply Maillefer) was used.

The PTN Group. The glide path was established by a ProGlider file (Dentsply Maillefer) with 300 rpm and 2 Ncm (9). PTN files were used in the following sequence: X1 (#17/0.04) and X2 (#25/0.06) in the mesial canals and X1, X2, and X3 (#30/0.07) in the distal canals.

The RS Group. The glide path was established by G-files (Micro-Mega), G1 (#12/0.03) and G2 (#17/0.03) with 400 rpm and 1.2 Ncm (10). An Endoflare file (Micro-Mega) (#25/0.12) was used for coronal 2–3 mm flaring with 600 rpm and 3 Ncm. In the mesial canals, SC1 (#25/0.06) was used to two thirds of the working length, and SC2 (#25/0.04) and SU (#25/0.06) were used to the working length. In the distal canals, the same sequence was followed for AS30 (#30/0.06).

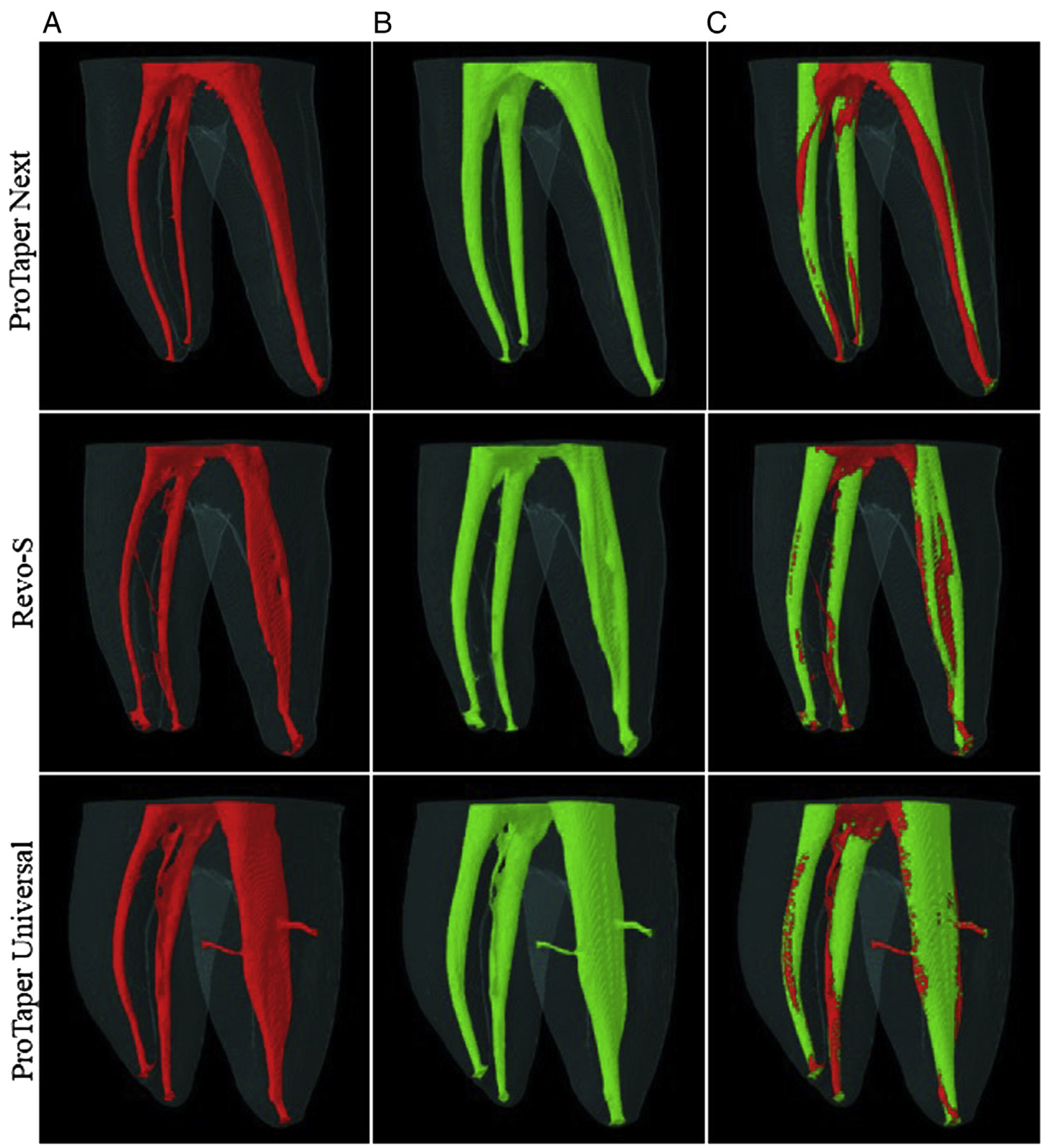

Figure 1. Color-coded 3-dimensional models of the root canal system of the mandibular first molars. (*A*) Preoperative models (*red color*). (*B*) Postoperative models (*green color*). (*C*) Superimposed models. The *red area* in (*C*) represents the untouched canal area.

The PTU Group. The glide path was established by 3 PathFiles (PF, Dentsply Maillefer), PF1 (#13/0.02), PF2 (#16/0.02), and PF3 (#19/0.02) with 300 rpm and 2 Ncm. The sequence of SX, S1, S2, F1 (#20/0.07), and F2 (#25/0.08) was used in the mesial canals, and F3 (#30/0.09) was added in the distal canals.

In all groups, the new set of files was used for each specimen. The mesial canals were prepared to size #25 (X2, SU, and F2), and the distal canals were prepared to size #30 (X3, AS30, and F3). During preparation, canals were flooded with 2.5% sodium hypochlorite (NaOCl) solution. After each file withdrawal, canals were irrigated with 2 mL 2.5% NaOCl using a 30-G needle at 1 mm short of the working length, recapitulated with a #10 K-file, and reirrigated with 2 mL 2.5% NaOCl. Finally, the canals were irrigated with 10 mL 2.5% NaOCl.

Evaluation of micro-CT Scanning

The raw data sets were reconstructed using NRecon software v1.6.1 (Bruker micro-CT). Reconstructed pre- and postinstrumented data sets were coregistered by DataViewer software v1.5.1 (Bruker micro-CT). CTAn software v1.14.4 (Bruker micro-CT) was used to measure the preoperative and postoperative canal areas, volumes, and structure model index (SMI) values. The proper threshold value was determined in the density histogram with the global thresholding method. Original grayscale images and segmented images were compared to obtain the accurate result. The changes in area, volume, and SMI were calculated by subtracting the preoperative value from the postoperative value. Changes were expressed in percentages. Using CTvol software v2.2.3 (Bruker micro-CT), color-coded 3-dimensional models were also created to check the consistency of image processing (Fig. 1*A–C*). The untouched canal area was calculated using ImageJ software v1.50 b (Fiji version; National Institutes of Health, Bethesda, MD) (11). The volume of interest was set up from the pulp chamber floor to the root apex. From 2-dimensional slides, transportation and the centering ratio were evaluated at 1, 3, 5, and 7 mm from the apical foramen (Fig. 2*A–C*) (12).

Statistical Analysis

Data were expressed as means and standard deviations. The Kolmogorov-Smirnov test was used to check the normal distribution of data. The means were analyzed by 1-way analysis of variance with the Tukey post hoc test at a 95% level of confidence to find any significance among the groups.

Results

At 1 mm from the apical foramen, the PTN and RS groups showed significantly less transportation and better centering ability than the PTU group ($P < .05$). However, no significant differences were noted at other levels from the apical foramen in the mesial canals and at all levels from the apical foramen in the distal canals among the instrument groups ($P > .05$). Before root canal instrumentation, there was no significant difference among the 3 groups regarding canal area, volume, and SMI value ($P > .05$) (Tables 1 and 2). After preparation, all systems increased the area, volume, and SMI in each canal. The PTN and RS groups with less taper showed comparable amounts of changes of canal area, volume, and SMI and an untouched area for the PTU group with a greater taper in each canal ($P > .05$). With all systems, the distal canal showed a significantly lower percentage change in area and volume and a higher percentage of untouched areas compared with both the mesial canals ($P < .05$).

Discussion

The present study evaluated the shaping effect on root canal geometry of the mandibular first molar of the 2 file systems with offset masses of rotation compared with 1 conventional file system with a centered mass of rotation using micro-CT analysis. In the present study, both systems with offset mass of rotation showed significantly less transportation and better centering ability than the conventional file system with a centered mass of rotation.

Generally, the shaping effect of NiTi rotary files depends on a complex relationship of canal anatomy, alloy type, design of instrument, and instrumentation technique (13). One study showed that the PTN system produced significantly less transportation than the PTU and WaveOne (Dentsply Maillefer) systems (14), which can be partly explained by the smaller apical taper of the PTN X2 (size #25/0.06) compared with the PTU F2 and WaveOne primary files (both tips are size #25/0.08). This reason may also be applicable to the present result because the larger tapered instrument showed less flexibility and produced more transportation (15, 16). A supplementary experiment for the present study also showed that the F2 file with a larger apical taper of 0.08 showed a larger cross-sectional area at all levels than the X2 and SU files with a smaller apical taper of 0.06 (data not shown). Therefore, this taper difference of the instrument systems might be 1 of the reasons for the differences in the transportation and centering ratio among groups.

Instruments with offset mass of rotations have a different design from those with a centered mass of rotation. These instruments have a unique asymmetric cross-sectional design and a resultant action of

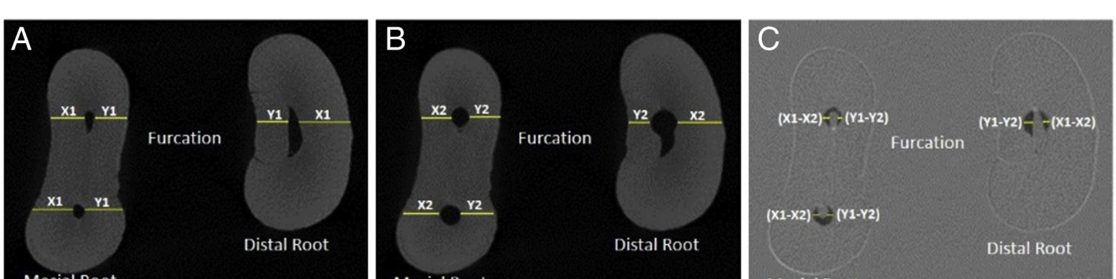

Figure 2. (*A*) Preoperative image. (*B*) Postoperative image. (*C*) Superimposed image. Transportation was calculated by (X1 − X2) − (Y1 − Y2), and a result of 0 indicates no transportation. A negative result indicates transportation toward the furcation region, whereas a positive result indicates transportation away from the furcation region. The centering ratio was calculated by (X1 − X2)/(Y1 − Y2) or (Y1 − Y2)/(X1 − X2). The numerator was the smaller one of the 2 numbers, (X1 − X2) or (Y1 − Y2) if these numbers were unequal. A result of 1 indicates a perfect centering ability. A result closer to 0 shows the poorest centering ability.

TABLE 1. Preoperative and Postoperative Canal Area (mm^2), Volume (mm^3), Structure Model Index (SMI) and Their Changes (%) , and Untouched Canal Area (%) (Each n = 12)

	Mesiobuccal canal			Mesiolingual canal			Distal canal		
	PTN	PTU	RS	PTN	PTU	RS	PTN	PTU	RS
Area									
Preoperative	26.47 ± 3.40	25.43 ± 4.77	25.24 ± 5.49	22.45 ± 5.31	23.14 ± 4.84	23.68 ± 6.03	59.34 ± 11.58	59.37 ± 11.86	54.92 ± 13.09
Postoperative	32.76 ± 3.28	32.00 ± 4.77	31.48 ± 5.23	28.08 ± 3.87	29.24 ± 5.13	28.72 ± 4.60	62.15 ± 11.41	61.17 ± 12.12	57.17 ± 13.90
Changes (%)	24.65 ± 12.45[a]	27.17 ± 12.52[a]	26.51 ± 13.61[a]	28.20 ± 18.25[a]	27.57 ± 13.75[a]	24.50 ± 18.47[a]	5.03 ± 4.51[b]	3.12 ± 2.82[b]	4.12 ± 4.48[b]
Untouched area (%)	26.89 ± 15.16[a]	25.15 ± 12.45[a]	26.39 ± 13.40[a]	23.30 ± 9.53[a]	26.99 ± 13.64[a]	24.86 ± 13.66[a]	54.74 ± 10.15[b]	53.54 ± 17.69[b]	53.86 ± 8.68[b]
Volume									
Preoperative	2.45 ± 0.54	2.50 ± 0.71	2.36 ± 0.76	2.06 ± 0.78	2.08 ± 0.44	2.06 ± 0.71	8.20 ± 2.48	8.09 ± 1.79	8.15 ± 2.91
Postoperative	4.56 ± 0.67	4.89 ± 0.84	4.43 ± 0.85	3.79 ± 0.60	4.29 ± 0.96	3.94 ± 0.82	10.76 ± 2.28	10.96 ± 2.79	10.41 ± 3.26
Changes (%)	95.38 ± 55.82[a]	104.79 ± 42.15[a]	97.47 ± 44.40[a]	104.70 ± 65.95[a]	109.91 ± 41.27[a]	104.43 ± 60.21[a]	35.97 ± 20.86[b]	35.65 ± 16.77[b]	31.14 ± 20.93[b]
SMI									
Preoperative	2.16 ± 0.23	2.37 ± 0.34	2.26 ± 0.36	2.17 ± 0.24	2.39 ± 0.54	2.19 ± 0.36	1.48 ± 0.31	1.70 ± 0.48	1.68 ± 0.42
Postoperative	2.55 ± 0.32	2.80 ± 0.19	2.79 ± 0.23	2.59 ± 0.21	2.76 ± 0.31	2.72 ± 0.29	1.79 ± 0.28	1.99 ± 0.32	2.04 ± 0.35
Changes (%)	18.38 ± 11.40[a]	19.80 ± 13.70[a]	25.34 ± 17.67[a]	20.26 ± 8.83[a]	18.72 ± 16.41[a]	26.04 ± 18.88[a]	24.04 ± 22.56[a]	25.81 ± 42.90[a]	24.27 ± 19.92[a]

PTN, ProTaper Next; PTU, ProTaper Universal; RS, Revo-S.

Values are mean ± standard deviation. Different superscript letters show significant differences between groups with the Tukey multiple comparison test at $P < .05$.

TABLE 2. Canal Transportation (mm) and Centering Ratio Values by ProTaper Next (PTN), ProTaper Universal (PTU), and Revo-S (RS) Nickel-titanium Rotary Systems (Each n = 12)

	Mesiobuccal canal			Mesiolingual canal			Distal canal		
Apical level	PTN	PTU	RS	PTN	PTU	RS	PTN	PTU	RS
1 mm									
Transportation	0.04 ± 0.03[a]	0.12 ± 0.09[b]	0.04 ± 0.03[a]	0.04 ± 0.03[a]	0.13 ± 0.10[b]	0.04 ± 0.03[a]	0.04 ± 0.03	0.05 ± 0.06	0.05 ± 0.03
Centering ratio	0.59 ± 0.28[a]	0.29 ± 0.17[b]	0.60 ± 0.20[a]	0.59 ± 0.25[a]	0.32 ± 0.17[b]	0.65 ± 0.25[a]	0.68 ± 0.24	0.52 ± 0.32	0.52 ± 0.29
3 mm									
Transportation	0.07 ± 0.06	0.09 ± 0.08	0.06 ± 0.05	0.06 ± 0.04	0.08 ± 0.07	0.06 ± 0.05	0.05 ± 0.05	0.06 ± 0.05	0.04 ± 0.03
Centering ratio	0.56 ± 0.28	0.40 ± 0.27	0.58 ± 0.26	0.55 ± 0.24	0.48 ± 0.13	0.51 ± 0.19	0.66 ± 0.20	0.70 ± 0.21	0.68 ± 0.21
5 mm									
Transportation	−0.08 ± 0.08	−0.15 ± 0.08	−0.09 ± 0.08	−0.13 ± 0.11	−0.19 ± 0.17	−0.08 ± 0.05	−0.13 ± 0.07	−0.13 ± 0.09	−0.08 ± 0.05
Centering ratio	0.57 ± 0.28	0.39 ± 0.25	0.58 ± 0.25	0.44 ± 0.22	0.36 ± 0.29	0.59 ± 0.24	0.51 ± 0.22	0.60 ± 0.20	0.58 ± 0.23
7 mm									
Transportation	−0.20 ± 0.08	−0.27 ± 0.14	−0.18 ± 0.10	−0.20 ± 0.14	−0.20 ± 0.14	−0.18 ± 0.13	−0.16 ± 0.05	−0.08 ± 0.14	−0.13 ± 0.09
Centering ratio	0.28 ± 0.14	0.20 ± 0.16	0.37 ± 0.21	0.38 ± 0.26	0.31 ± 0.23	0.40 ± 0.17	0.45 ± 0.11	0.55 ± 0.22	0.51 ± 0.27

Values are mean ± standard deviation. Different superscript letters show significant differences between groups with the Tukey multiple comparison at $P < .05$.

a swaggering motion during instrumentation (3, 4). This motion may be 1 of the possible reasons for decreasing the screwing effect and may cause less transportation (13). It has been speculated that the asymmetric cross-sectional geometry could facilitate canal penetration by a snakelike movement, leading to less stress on the instrument and resulting in less transportation of dentin (17). Therefore, this motion difference between the instrument systems might be another reason to explain the differences in the transportation and centering ratio among groups.

The number of files used to prepare the canals might influence the transportation and centering ratio outcomes. In this investigation, to enlarge the mesial canals to size #25, 5 files (SX, S1, S2, F1, and F2) in the PTU group, 2 files (X1 and X2) in the PTN group, and 3 files (SC1, SC2, and SU) in the RS group were used. The lesser number of files used in the PTN and RS groups might be 1 of the possible reasons to explain the less transportation and better centering ratio results compared with the PTU group.

In general, instruments with the M-Wire alloy are more flexible than instruments with the conventional NiTi alloy (18). However, 2 studies reported no difference between the F2 file of the PTU system and the WaveOne Primary file in transportation and centering ability regardless of alloy types (14, 19). It has also been shown that there is no difference between Vortex files (Dentsply Tulsa Dental Specialties, Tulsa, OK) with M-Wire and EndoSequence files (Brasseler, Savannah, GA) with conventional NiTi alloys in transportation and centering ability of NiTi files (20). One study also found that the 2 file systems with a swaggering motion, the X2 file of the PTN system and the OneShape file (#25/0.06) (Micro-Mega) with different alloy types (M-Wire vs conventional NiTi alloy), had no significant difference in transportation at all levels (21). Based on these reports, the M-Wire alloy seems to have more flexibility than the conventional NiTi alloy; however, it does not always seem to have better centering ability in the canal. Similarly, in the present study, PTN with the M-Wire alloy and RS with the conventional NiTi alloy revealed similar transportation and centering ability, even though these systems are different in alloy type and cross-sectional design.

The postoperative canal area, volume, and SMI were increased in all canals in the present study without significant differences among systems. In general, when the instruments have the same tip sizes and tapers, the amount of dentin removal will be similar, and when the instruments have greater taper with the same tip size, the amount of dentin removal will be more (17, 21). However, in the present study, the X2 file of the PTN system and the SU file of the RS system possessing a 0.06 apical taper and a tip size of #25 removed similar amounts of dentin compared with the F2 file of the PTU system with a 0.08 apical taper and the same tip size in the mesial canals. Likewise, the X3 file of the PTN system with a 0.07 apical taper and the AS30 file of the RS system with a 0.06 apical taper also removed similar amounts of dentin compared with the F3 file of the PTU system with a 0.09 apical taper in the distal canals. These results for dentin removal may be explained by the motion of the instruments. PTN and RS files with the offset center of rotation might have a larger envelope of motion compared with the conventional centered mass of rotation, providing a clinical advantage in preparing the canal to achieve the same size as a larger and stiffer file with a symmetric axis of rotation (4). Therefore, apical 0.06 and 0.07 tapers with an offset center of rotation can remove similar amounts of dentin compared with other instruments having 0.08 and 0.09 apical tapers with conventional centered masses of rotation.

In this study, all file systems left an untouched canal area in each canal, which is comparable with previous studies (14, 22). It was observed that the PTN system exhibited similar performance in terms of the untouched canal area compared with other file systems without the swaggering motion (14). In a previous study, PTN was even associated with a significantly higher percentage of untouched area than the ProTaper Gold (Dentsply Maillefer) and PTU systems, probably because of the reduced contact area in the canal wall (23). In the present study, the PTN and RS systems also left a similar untouched canal area compared with the PTU system, which is in agreement with previous studies.

Moreover, in the present study, the distal canal was shown to be less effective in various aspects of shaping by the 3 file systems, showing significantly less percentage changes in area and volume with more untouched surface area. This might be because of the preexisting oval shape of the distal canal (24). Based on these findings, NiTi rotary instruments with an offset mass of rotation seemed to have a beneficial effect on the amount of dentin removal but not on untouched areas in small as well as large canals.

Glide path preparation is the first and 1 of the most important steps in canal preparation for safety and prevention of the canal aberration (25–27). PathFiles, ProGlider files, and G-files are the suggested NiTi rotary instruments for glide path preparation for the PTU, PTN, and RS systems, respectively (5, 9, 28), and these combinations were used in the present study. There are some studies (29, 30) in which ProGlider/PTN instrumentation revealed fewer canal aberrations compared with instrumentation with PathFiles/PTN, K-file/PTN, or PTN only. The kind of glide path preparation instruments used did not exert any influence on the canal volume and area changes (29).

One of the additional limitations of this study would be that the specimens used in this study possessed only moderately curved canals. However, specimens with severely curved canals lacking S-shape curvature in proximal and clinical view radiographs are quite rare and difficult to collect, standardize, and divide evenly between 3 groups. Further studies with the specimens having severely curved canals are required to more accurately evaluate the performance of these file systems.

Under the conditions of this study, the PTN and RS systems with offset masses of rotation seemed to have less canal transportation and better centering ability compared with the PTU system with a conventional centered mass of rotation. The resultant swaggering motion of the PTN and RS systems might have a beneficial effect on dentin removal but not on untouched canal areas. Further study will be needed on other behaviors of instrumentation, including debris extrusion, comparing these 2 systems with offset masses of rotation and different cross-sectional geometry.

Acknowledgments

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

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