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Computed tomography evaluation of rotary systems on the root canal transportation and centering ability

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Abstract: The endodontic preparation of curved and narrow root canals is challenging, with a tendency for the prepared canal to deviate away from its natural axis. The aim of this study was to evaluate, by cone-beam computed tomography, the transportation and centering ability of curved mesiobuccal canals in maxillary molars after biomechanical preparation with different nickel-titanium (NiTi) rotary systems. Forty teeth with angles of curvature ranging from 20° to 40° and radii between 5.0 mm and 10.0 mm were selected and assigned into four groups (n = 10), according to the biomechanical preparative system used: Hero 642 (HR), Liberator (LB), ProTaper (PT), and Twisted File (TF). The specimens were inserted into an acrylic device and scanned with computed tomography prior to, and following, instrumentation at 3, 6 and 9 mm from the root apex. The canal degree of transportation and centering ability were calculated and analyzed using one-way ANOVA and Tukey's tests ($\alpha = 0.05$). The results demonstrated no significant difference ($p > 0.05$) in shaping ability among the rotary systems. The mean canal transportation was: -0.049 ± 0.083 mm (HR); -0.004 ± 0.044 mm (LB); -0.003 ± 0.064 mm (PT); -0.021 ± 0.064 mm (TF). The mean canal centering ability was: -0.093 ± 0.147 mm (HR); -0.001 ± 0.100 mm (LB); -0.002 ± 0.134 mm (PT); -0.033 ± 0.133 mm (TF). Also, there was no significant difference among the root segments ($p > 0.05$). It was concluded that the Hero 642, Liberator, ProTaper, and Twisted File rotary systems could be safely used in curved canal instrumentation, resulting in satisfactory preservation of the original canal shape.

Keywords: Endodontics; Cone-Beam Computed Tomography; Dental Instruments.

Introduction

The aim of endodontic treatment is to clean and shape root canals adequately so that canal disinfection and filling are optimized. According to Schilder,[1] root canal preparation should present a flare shape from apical to coronal, preserving the apical foramen and not alter the original canal curvature. However, endodontic preparation in curved and narrow root canals is more challenging, with a tendency for the prepared canal to deviate away from its natural axis.[2]

In the last few decades the development of rotary nickel-titanium (NiTi) systems has significantly improved the quality of canal shaping and allowed for root canal preparation with continued rotation on narrow and/or curved root canals.[3] The success of NiTi systems is related to the design, flexibility, and elastic memory.[3,4,5] Moreover, NiTi instruments allow for greater conical canal preparation with less work time and more centered shaping of the canal in its original axis, producing rounder preparations and reducing procedural errors.[4,6,7]

Several studies have demonstrated successful results with continuous rotation full-sequence NiTi systems such as ProTaper,[8,9] Hero 642,[10] Liberator[5] and Twisted File.[1,11] However, differences between the design and manufacturing procedures associated with these systems may result in variability in the final shape of the instrumented root canal. According to the Twisted File and ProTaper manufacturers, the use of greater tapers in combination with a "crown-down" preparation technique is intended to facilitate cleaning and shaping by shortening working time with the use of fewer instruments.[6,12] In contrast, the Hero and Liberator systems allow for protocols that guarantee an enlargement in the apical diameter, even in curved root canals.[13]

Considering the clinical advantages of biomechanical preparation with rotary systems, it is necessary to investigate the shaping effectiveness of NiTi file systems and understand how the respective design features impact performance. Different methods can be used to evaluate the root canal shaping, though more recently, the use of computed tomography (CT) has been suggested for this purpose because it is a nondestructive and very precise method that even allows measuring the amount of root dentin removed by endodontic instruments.[10] Therefore, the aim of this study was to evaluate, by volumetric cone beam computed tomography (CBCT), the degree of transportation and centering ability of curved mesiobuccal canals in maxillary molars after biomechanical preparation with different rotary nickel-titanium systems: Hero 642 (HR), Liberator (LB), Twisted File (TF), and ProTaper (PT).

Methodology

This study was approved by the Ethics Committee of *Universidade de Ribeirão Preto* – UNAERP, SP, Brazil (protocol #097/2009).

Specimen and root canal preparation

Forty extracted human maxillary first molars were selected on the basis of having similar degrees of mesiobuccal canal curvature (20°-40°) and radii (5-10 mm), measured according to Schneider[14] and Pruett *et al.*[15]

Crowns were sectioned at the enamel-dentine junction in order to standardize root canal length (17 mm). Teeth were accessed by using an Endo-Access bur (Dentsply, Maillefer, Ballaigues, Switzerland) under air/water irrigation, and the root canal irrigated with 2.5% NaCL. Working length (WL) was established by inserting a 10 K-file (Dentsply, Maillefer, Ballaigues, Switzerlan) to the root canal terminus and subtracting 1 mm from this measurement (WL = 16 mm).

Specimens were randomly divided into four groups (n = 10) according to the rotary system used: Twisted File (SybroEndo, Orange, USA), Hero (MicroMega, Besançon, France), Liberator (Miltex Inc., York, USA), and ProTaper (Dentsply Maillefer, Ballaigues, Switzerland).

A single operator performed the root canal instrumentation according to the manufacturers' instructions. In all groups, apical enlargement was performed with an instrument up to a file size of 20 K introduced at full WL. K-file manipulation included a three-quarter turn clockwise followed by a similar counter-clockwise movement and withdrawal. Upon removal, the instruments were cleaned. In the HR and LB groups, initially the coronal and middle third were shaped with EndoFlare (Micro-Mega, Besaçon, France) at 5 mm of the WL. Shaping continued to the full WL with HR and LB size 20 taper 0.02, followed by 25, 30, 35 and 40. In the PT group, the shaping procedure commenced at S1 (at 7 mm of WL) and SX (at 5 mm of WL) in order to prepare the coronal and middle third, respectively. The apical third was prepared with S1, S2, F1, and followed by F2 at full WL. In the TF group, the shaping procedure commenced with TF size 25 taper 0.08 to prepare the coronal third. TF size 25 taper 0.06 was used until 2 mm short of WL. Shaping continued to the full WL with TF size 25 taper 0.04, followed by 0.06 and 0.08. The irrigation was performed with 3 mL of 2.5% NaCL after each instrument. X-Smart torque control motor (Dentsply Maillefer, Ballaigues, Switzerland) was used to operate all files at 300 rpm and 2.4 Ncm. Each instrument was used to prepare 5 canals, corresponding with a single use.

Image analysis

The specimens were positioned in an acrylic resin holder and scanned before and after instrumentation by using an i-CAT cone beam 3-D scanner (Dental Imaging System, Salt Lake City, USA). Exposure parameters were 120 kV and 8 mA. The field of view was 17 cm in diameter and 13 cm in height. Images slices were taken at 3, 6, and 9 mm short of the apical foramen, corresponding to the apical, middle, and coronal thirds, respectively.

The images were analyzed using CorelDraw X3 software (Corel Corporation, Ottawa, Canada), where the central axis prior to, and following, root canal instrumentation was marked with the convergence of four dotted lines drawn in the vestibular-palatine direction (with a gap of 45º between them). For canal transportation and centering ability analysis, nine different measures were made: d1, d2, d3, m1, m2, m3, D1, D2, and D3. The d1, d2, and d3 values correspond to the difference between the distances of the distal periphery prior to, and following, root canal instrumentation. Similarly, the m1, m2, and m3 values correspond to the difference between the distances of the mesial periphery prior to, and following, root canal instrumentation. D1, D2, and D3 correspond to the final diameter after root canal instrumentation. The image analysis and measurement procedure are represented in Figure 1.

Canal transportation

Canal transportation corresponded to the shortest distances from the central axis of the canal to the periphery before and after instrumentation, and was measured in mesial and distal directions. Canal transportation (CT) was calculated according to the formula of Loizides *et al*.:[6] CT = MT – DT, where MT represents the mesial transportation distance and DT represents the distal transportation distance. MT was determined by the mean of the m1, m2, and m3 values. Similarly, DT was determined by the mean of the d1, d2, and d3 values. In relation to the transportation direction, a negative value represents transportation occurring in the direction facing the furcation (*i.e.*, distal direction), whereas positive values represent transportation lateral to the curvature (*i.e.*, mesial direction), and a "0" value indicates no canal transportation.

Centering ability

Centering ability corresponded to the ability of the instrumented molars to stay centered in the original canal axis. Centering (CA) was calculated for each section according to the formula of Loizides *et al*.:[6] CA = (m total - d total) / CD, where CD (canal diameter) was determined by the mean of D1, D2, and D3.

Statistical analysis

Data resulting from canal transportation and centering ability were submitted to one-way ANOVA and Tukey's tests. Statistical analysis was performed with Statistical Package for the Social Science (SPSS) 17.0 (SPSS Inc., Chicago, USA).

Results

Canal transportation

The canal transportation (mm) mean and standard deviation among the three tested levels in each group are displayed in Table 1.

There was no significant difference between the four systems concerning canal curvature changes after instrumentation at all root section levels. Comparing the transportation percentage, 114 (95%) canal deviations occurred in 120 of the measurements performed, with only 6 (5%) not presenting any deviation. The PT presented with more specimens with no deviation, followed by HR and TF. All four groups had less transported canals toward the outside of the curve (mesial), and most canals were transported toward the inside of the curve (distal) on the apical 3 mm sections. The HR group had the highest degree of distal transportation while the PT/LB groups had the lowest. Table 2 describes the canal transportation direction among the studied groups.

Table 1. Mean of canal transportation (mm) and standard deviation among the groups and root section levels.

Root section levels	HR Hero 642	LB Liberator	PT ProTaper	TF Twisted File	*p**
3 mm	-0.103 ± 0.102	-0.034 ± 0.035	-0.019 ± 0.085	-0.047 ± 0.078	0.114
6 mm	-0.031 ± 0.072	0.004 ± 0.044	-0.013 ± 0.051	-0.023 ± 0.049	0.526
9 mm	-0.014 ± 0.039	0.018 ± 0.037	0.025 ± 0.044	0.007 ± 0.057	0.243

*ANOVA ($p < 0.05$). (*) Positive values indicate mesial direction of transportation. Negative values indicate distal direction of transportation.

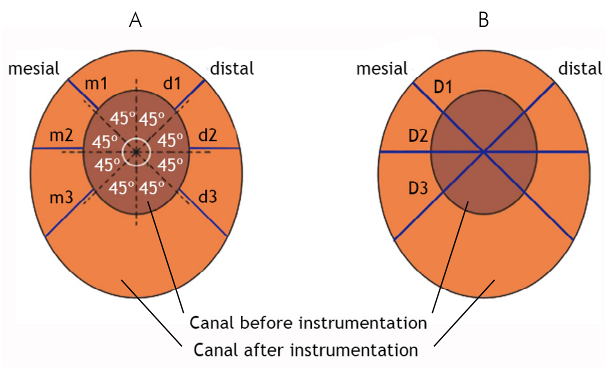

Figure 1. Schematic of the super-positioned root canals, before and after instrumentation, with central axis and respective peripheral distances. (A) Difference between the distances of the distal portion d1, d2 and d3; difference between the distances of the mesial portion m1, m2 and m3. (B) Final diameter of the root canal after instrumentation D1, D2 and D3.

Table 2. Canal transportation direction among groups.

Group	Mesial	Distal	No deviation
HR-Hero 642	8	20	2
LB-Liberator	14	16	0
PT-ProTaper	11	16	3
TF-Twisted File	10	19	1

Centering ratio

The centering ability (mm) mean and standard deviation among the three tested levels in each group are displayed in Table 3. The results revealed no significant difference between the four systems concerning centering ability after instrumentation at all root section levels.

Discussion

Considering the development of different devices and instrumentation techniques to perform root canal preparation, several methods have been proposed to evaluate the shaping ability of instrumented canals with the aim of preserving the apical foramen and original canal curvature.[5,8,13,16,17,18,19] Satisfactory results have been obtained with the root serial section technique,[16] radiographic platform,[18] and root resin canal simulation.[17] However, more accurate information can be achieved with micro-computed tomography (micro-CT)[6,13] and computed tomography (CT),[1,7,8,20] which allows for the quantitative and qualitative evaluation of root canals in 3 dimensions.[9] Therefore, in the present study, the root canal transportation and centering ability of four different NiTi rotary systems were evaluated with CT.

Table 3. Mean of centering ability (mm) and standard deviation among the groups and root section levels.

Root section levels	HR Hero 642	LB Liberator	PT ProTaper	TF Twisted File	*p**
3 mm	-0.165 ± 0.156	-0.064 ± 0.069	-0,045 ± 0.135	-0.065 ± 0.135	0.169
6 mm	-0.066 ± 0.158	0.013 ± 0.097	-0.031 ± 0.131	-0.055 ± 0.117	0.527
9 mm	-0.046 ± 0.105	0.050 ± 0.103	0.069 ± 0.116	0.021 ± 0.139	0.151

*ANOVA ($p < 0.05$). (*) Positive values indicate mesial direction of transportation. Negative values indicate distal direction of transportation.

Previous reports already clarify that canal transportation can be considered a procedural error resulting in lower efficiency of preparation techniques due to inadequate root canal cleaning and the persistency of periapical lesions.[21] In this sense, Wu *et al.*[22] reported that apical transportation of more than 0.3 mm could negatively affect the sealability of filling material. In the present study the shaping ability of all groups was similar, considering the apical transportation and centering ability values in which none of the rotary systems used reached apical transportation greater than 0.2 mm. These results corroborate with previous reports that show minimal rates of apical deviation of narrow and curved canals instrumented with NiTi rotary systems.[1,5,8]

Although in the present study there was no statistical difference between the NiTi systems used, the data analysis shows a centralization tendency and lower transportation values for PT and TF. These results are probably related to the minimal interaction of these instruments in the apical region, whereby the anatomical diameter was established with a size 20 file and the final diameter related to a size 25 file. It is important to consider that this final diameter determination of PT and TF is based on orientation provided by the respective manufacturers. Similar results and conclusions were achieved by Versiani *et al.*,[8] which reported favorable centering ability and canal transportation results even with a final file with a size 30 diameter.

Similarly, satisfactory canal transportation and centering ability results of a TF system compared to different grinded NiTi files were previously reported.[1,7,11] The shaping ability of these instruments could be related to the difference in manufacturing method, which consists of twisting the metal and special surface conditioning to provide increased flexibility and fracture resistance[23] Gergi *et al.*[7] and Marzouk and Ghoneim[2] also reported that using 0.08 taper of TF to full WL did not result in any severe aberrations in the apical portion. Therefore, according to Marzouk and Ghoneim,[2] the improved results of canal transportation with TF compared to single file reciprocating systems may be due to using lower tapered files prior to using a 0.08 tapered file.

A previous study also reported an improved centering ratio with Hero 642 compared to stainless K-files.[24] Also, satisfactory results were observed when the original curvature deviation with Hero 642 instrumented canals was compared to other NiTi rotary systems.[10] These results corroborate the present study as satisfactory centering ability results were observed with the Hero 642 system among all root canal segments.

Another relevant parameter to be analyzed is related to the deviation directions according to the root canal segments and instrument type/kinematics.[9,25] In the present study, we observed a greater incidence of distal deviations (inside of the curve) on all systems used. This result differs from previous studies that indicate that the apical segment usually has more canal transportation toward the outside of the curve.[19,22,25] As in the present study, an average deviation from the direction of the different thirds was used, and hence our results probably reflect the higher incidence of deviation inside of the curve that occurs in the cervical and middle segments, as previously reported by Stavileci *et al.*[9]

An important difference between the NiTi systems used in the present study is related to the number of the files used. ProTaper and Twisted File systems use a small number of files in an attempt to simplify the root canal instrumentation, whereas Hero and Liberator systems allow the use of a larger number of instruments. Since the anatomic diameter at 1 mm from the apex of the mesiobuccal root is around 0.22 mm and 0.43 mm in mesial-distal and buccal-lingual directions, respectively,[22] Hero and Liberator systems provide further enlargement in the third apical dentine removal, which is greater in this region compared to the final instrument of the ProTaper and Twisted File. Although Hero and Liberator instrumentation results in a larger apical diameter, the transportation values obtained with these instruments were similar to those obtained with the ProTaper and Twisted File systems. Corroborating these results, Pasternak-Júnior *et al.*[20] observed that the final instrument #45 did not cause deviation when compared to instrument #35. The tendency to centralization, and consequently the low transport values, obtained in this study with the Hero and

Liberator systems are probably related to the use of. 02 taper instruments in the apical segment, and even with larger diameters provide safety in the preparation of curved root canals due to the flexibility of these instruments.[20]

Despite the similar centering ability between the four rotary systems tested in this study, the use of a size #40 final instrument in Hero and Liberator systems suggests that the removal of dentin in the cervical segment was around 100-150 µm. Contrary to this, the ProTaper and Twisted File systems probably made less contact with the dentin walls in the apical region, as the final instrument was a #25 size file. The removal of the apical dentin during biomechanical preparation plays an important role in the cleaning and disinfection of the root canal system. According to Berber *et al.*,[26] the microorganisms inside the root canal are able to penetrate the dentinal tubules at around 200 micrometers. Regarding the impact of instrumentation cleaning, Fornari *et al.*[27] observed that the larger the final diameter, the greater the percentage of touched walls, which leads to increased cleaning of the root canal. Aside from this, the enlargement of the apical segment favors the effectiveness of substances used during both the root canal irrigation as medications in certain periapical pathological conditions.[26,27]

In light of the recent efforts to simplify the biomechanical preparation techniques, the effect of rotary instruments at the apical segment should be considered for the proper cleaning, shaping, and disinfection of root canals. Thus, in systems like the Twisted File and ProTaper, which favor the preparation of cervical and middle segments through the use of instruments with greater taper, additional smaller taper files could be considered to complement this technique and enlarge the apical region.

Conclusion

Within the experimental conditions and results of the present study, it could be concluded that Hero 642, Liberator, ProTaper, and Twisted File systems can be safely used in curved canals instrumentation at full working length with satisfactory preservation of the original canal shape.

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