Changes in root canal anatomy using three nickel-titanium rotary system - A cone beam computed tomography analysis

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Abstract

Aim: Cone beam computed tomography (CBCT) was used to evaluate the ability of three NiTi rotary systems to maintain the original root canal anatomy. **Methods:** Sixty mesiobuccal canals of human mandibular first molars were divided into three groups with 20 root canals each. All teeth were scanned by CBCT before instrumentation. The images were captured digitally for further analysis using the Image Tools Software. The images were sectioned in three points, located at 9 mm, 6 mm and 3mm from the apex. In Group 1, the root canals were instrumented with ProTaper Universal™ rotary system; in Group 2, with Twisted File™ rotary system; and in Group 3, with M_{two}™ rotary system. Instrumented teeth were scanned again using CBCT and the images of the uninstrumented canals were compared with images of the instrumented canals. The results were statistically analyzed using the one-way ANOVA test. A level of significance of 0.05 was adopted. **Results:** The means of D1 at distances of 9 mm, 6 mm, and 3 mm from the apex were, respectively: Group 1: 0.88±0.257, 1.00±0.000, and 1.00±0.000; Group 2: 0.79±0.745, 0.65±0.669, and 0.25±0; Group 3: 0.50±0.745, 0.33±0.472, and 0.03±0.104. The means of D2 at distances of 9 mm, 6mm, and 3mm from the apex were respectively: Group 1: 1.00±0.00, 1.00±0.00, and 1.00±0.00; Group 2: 0.41±0.299, 0.30±0.428, and 0.50±0.707; Group 3: 0.58±0.910, 0.85±1.857, and 0.31±0.643. **Conclusions:** The CBCT analysis revealed that the ProTaper Universal™ produced centered preparations and while the Twisted File™ and M_{two}™ rotary systems produced canal deviation.

Keywords: root canal preparation, tomography, emission-computed.

Introduction

Root canal preparation is an important part of endodontic treatment. One of the main objectives in root canal preparation is to develop a shape that tapers from apical to coronal, maintaining the original canal shape[1]. Instruments should remain centered in the root canal throughout the preparation[2]. Nickel-titanium (NiTi) rotary instruments, due to their superelastic behavior, are able to maintain the original canal shape without significant deviation or create irregularities such as zipping, ledges, perforations or danger zones in curved canals. Many types of rotary root canal instruments have been introduced, varying in cross-section, blade, pitch design and taper[3].

The ProTaper™ NiTi rotary system has been upgraded to the ProTaper Universal™ rotary system, which includes shaping, finishing and retreating instruments. It

incorporates a shallow, U-shaped groove at each of its convex triangular sides in cross-section, supposedly to improve flexibility in the larger instruments. The modified design has also been suggested to reduce the subjective feeling of the instrument being "pulled" into the canal or so-called screw-in effect[4-6].

A completely different manufacturing process has been developed by SybronEndo to create a new rotary file for root canal preparation called the Twisted File™ (SybronEndo, Orange, CA, USA). These files have a triangular cross section with constant tapers of .04, .06, .08, .10, and .12. They are available in five tip sizes from 25 to 50. The manufacturer claims that the three new manufacturing processes of these files, namely R-phase heat treatment, twisting of the metal, and special surface conditioning, significantly increase the instrument's resistance to cyclic fatigue and flexibility, even with .06-, .08-, .10-, and .12-tapered instruments, maintaining the original canal center and minimizing canal transportation even in severely curved root canals[1,7,8].

M$_{two}$™ (VDW; Antaeus, Munich, Germany) is a newly developed NiTi rotary system. M$_{two}$ instruments have an S-shaped cross-sectional design, a positive rake angle with 2 cutting edges, no radial lands, progressive blade camber (pitch) in the apical–coronal direction and a noncutting tip[9-11].

In order to investigate the efficiency of instruments and techniques developed for root canal preparation, a number of methods have been used to compare canal shape before and after preparation. Cone beam computed tomography (CBCT) imaging techniques have been evaluated as noninvasive methods for the analysis of canal geometry and efficiency of shaping techniques. Using this technique it is possible to compare the anatomic structure of root canal before and after instrumentation[1,12].

The present study was set out to determine the changes in root canal anatomy using the ProTaper Universal™, Twisted File™ and M$_{two}$™ rotary systems analyzed by CBCT.

Material and methods

Selection and preparation of samples

Sixty mesiobuccal canals of extracted human mandibular first molars (length 20-21 mm) obtained from the tooth bank of the Department of Prosthetics and Oral and Facial Surgery of the Federal University of Pernambuco, Brazil were selected with the approval of the Ethics in Research Committee of the Center of Health Sciences of the University. The mesiobuccal roots had completely formed apices and curved root canals whose curvature ranged from 25° to 30° according to the canal access angle (CAA) technique[13]. The access cavities were prepared, and to determine the working length (WL) a #10 Senseus-Flexofile (Dentsply/Maillefer, Ballaigues, Switzerland) was inserted into the mesiobuccal canal until it was visible at the apical foramen. The WL was calculated to be 1 mm less than the length obtained with this initial file.

Preoperative images

The roots were stored in alginate hydrogel (Jeltrade; Dentsply, Petrópolis, RJ, Brazil) poured in plastic containers to ensure a very close approximation of the preoperative and postoperative images according to a previously described method[14].

After the alginate solidified, all teeth were scanned by CBCT (i-Cat®; Imaging Sciences International, Hatfield, PA, USA) to determine the root canal shape before instrumentation. The exposure time was 26.9 s, operating at 120 kV and 7 mA. The images were sectioned in three points, located respectively at 9 mm (coronal level), 6 mm (middle level) and 3mm (apical level) from the apex. The images were stored in a computer for later comparison.

Root canal preparation

The specimens were randomly divided into three groups with 20 root canals each. All instrumentation was performed according to each manufacturer's instructions. Random distribution of the groups considered the degree of canal curvature, allowing the average curvature, as well as the more severe cases, to be evenly allocated to each group:

Group 1: ProTaper Universal™ Rotary System. The canals were instrumented at a rotational speed of 300 rpm as follows: (a) the SX file was used up to one half of the WL, (b) the S1 file was used up to 4 mm short of the apex, (c) the S1 and S2 files were used to the full WL, and (d) the F1 and F2 files were used to the full WL.

Group 2: Twisted File™ Rotary System. The canals were instrumented at a rotational speed of 300 rpm as follows: (a) the #25.08 file was used up to the coronal third of the root canal, (b) the #25.06 file was used up to 4 mm short of the WL, and (c) the #25.04 and #25.06 files were used up to the full WL.

Group 3: M$_{two}$™ Rotary System. The canals were instrumented at a rotational speed of 300 rpm as follows: the #10.04, #15.05, #20.06, and #25.06 files were used up to the full WL.

The specimens were fastened to a morse (Neboluz, São Paulo, SP, Brazil) to keep them fixed during preparation. After use of each file, the root canals were irrigated with 3 mL of a freshly prepared 1% sodium hypochlorite solution (Roval, Recife, PE, Brazil). Glyde™ (Dentsply Maillefer) was used as a lubricant during instrumentation. A single operator experienced in rotary systems prepared all root canals. Each instrument was changed after five canals. Instruments were examined after every use to record and reject deformed or fractured instruments. An electric motor (Driller Endo-Pro Torque, São Paulo, SP, Brazil) was used.

Postoperative images

After instrumentation, the specimens were scanned under the same conditions as the initial scans and the postoperative images were captured in the same way as mentioned before.

Evaluation of centering ability

Using the Image Tool software (University of Texas Health Science Center, San Antonio, TX, USA) the
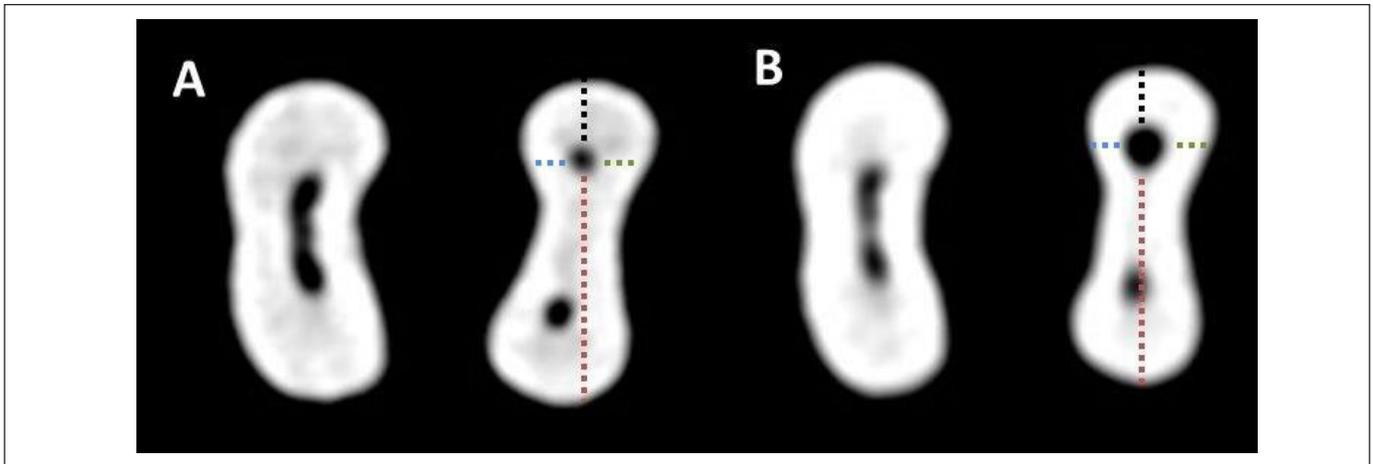
Fig. 1. CBCT scan images showing the centering ability of the ProTaper Universal™ before (A) and after (B) preparation at apical level.
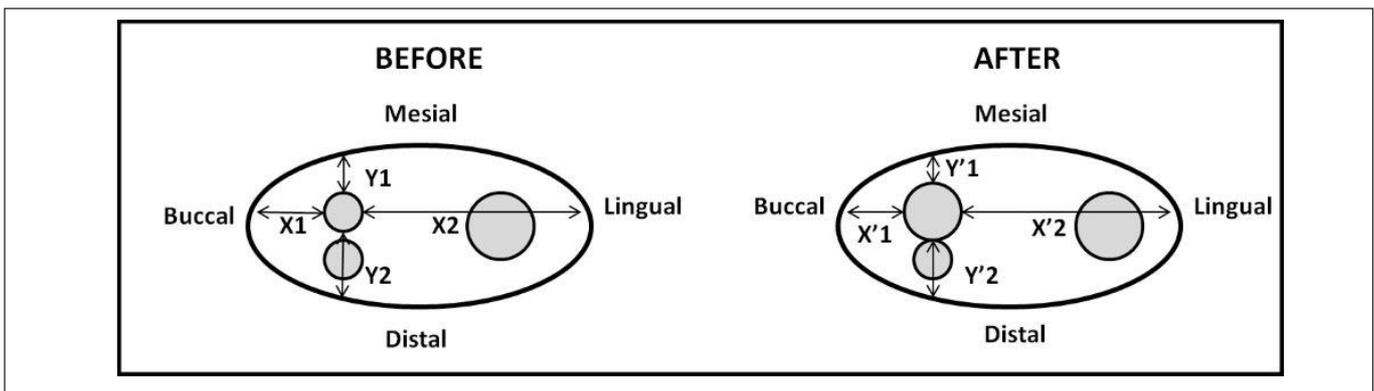

Fig. 2. Schematic presentation of the image used in the evaluation.

preoperative and postoperative images were compared (Figure 1, A and B). Gambill et al.[15] (1996) defined centering ratio as the measurement of the ability of the instrument to stay centered in the canal. This ratio was calculated for each section using the following ratio (Figure 2):

D1: (X1 - X'1)/(X2 - X'2)

D2: (Y1 - Y'1)/(Y2 - Y'2)

Where D1 = the buccolingual measurement and D2 = the mesiodistal measurement. X1 = shortest distance from the buccal aspect of the root to the periphery of the uninstrumented canal. X'1 = shortest distance from the buccal aspect of the root to the periphery of the prepared canal. X2 = shortest distance from the lingual aspect of the root to the periphery of the uninstrumented canal. X'2 = shortest distance from the lingual aspect of the root to the periphery of the prepared canal. Y1 = shortest distance from the mesial aspect of the root to the periphery of the uninstrumented canal. Y'1 = shortest distance from the mesial aspect of the root to the periphery of the prepared canal. Y2 = shortest distance from the distal aspect of the root to the periphery of the uninstrumented canal. Y'2 = shortest distance from the distal aspect of the root to the periphery of the prepared canal. According to this formula, a result of 1 indicates a perfect centering ability; the closer the result is to zero, the worse is the ability of the instrument to remain centered.

Statistical analysis of the data

The categorical data were summarized by means of absolute frequency and relative percentage, and the numerical data by means of the usual descriptive statistics of location and dispersion. The results were statistically analyzed using one-way ANOVA test. A level of significance of 0.05 was adopted, using the Statistical Package for the Social Sciences, version 13 (SPSS, Chicago, IL, USA).

Results

Table 1 and Figure 3 present the main descriptive statistics of the buccolingual measurement (D1) and mesiodistal measurement (D2) according to the rotary system used and the instrumented root segment at distances of 9 mm (coronal), 6 mm (middle) and 3 mm (apical) from the apex.

The means of D1 ranged from 0.03 to 1.00. In group 1, the mean deviation was 0.88 ± 0.257, 1.00 ± 0.000, and 1.00 ± 0.000 at distances of 9 mm (coronal), 6mm (middle) and 3mm (apical) from the apex, respectively. In group 2, the mean deviation was 0.79 ± 0.745, 0.65 ± 0.669, and 0.25 ± 0.425 at distances of 9 mm (coronal), 6 mm (middle) and 3 mm (apical) from the apex, respectively. In group 3, the mean deviation was 0.50 ± 0.745, 0.33 ± 0.472, and 0.03 ± 0.104 at distances of 9 mm (coronal), 6mm (middle)
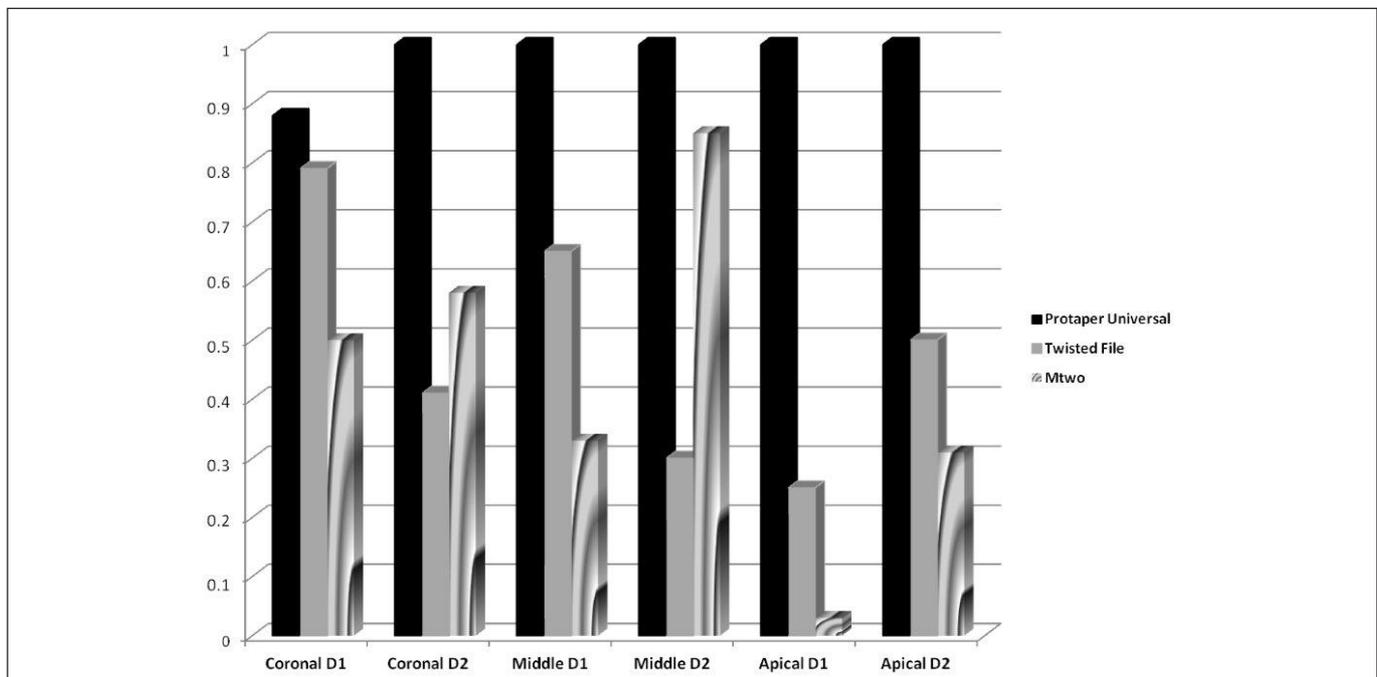
Fig. 3. Mean of the D1 (buccolingual) and D2 (mesiodistal) measurements according to the used instrument and the instrumented root segment.

Table 1. Mean and standard deviation of the buccolingual and mesiodistal measurements according to the instrument used and the root segment instrumented.

| Third | Instrument | | | |
	PTU Mean±SD	TF Mean±SD	M$_{two}$ Mean±SD	p value
Coronal D1	0.88±0.257	0.79±0.745	0.50±0.745	0.171
Coronal D2	1.00±0.000	0.41±0.299	0.58±0.910	0.001
Middle D1	1.00±0.000	0.65±0.669	0.33±0.472	0.012
Middle D2	1.00±0.000	0.30±0.428	0.85±1.857	0.003
Apical D1	1.00±0.000	0.25±0.425	0.03±0.104	<0.001
Apical D2	1.00±0.000	0.50±0.707	0.31 0.643	0.005

PTU: ProTaper Universal; TF: Twisted File; SD: standard deviation; D1: buccolingual measurement; D2: mesiodistal measurement

and 3 mm (apical) from the apex, respectively.

The means of D2 ranged from 0.30 to 1.00. In group 1, the mean deviation was 1.00 ± 0.00, 1.00 ± 0.00, and 1.00 ± 0.00 at distances of 9 mm (coronal), 6 mm (middle), and 3 mm (apical) from the apex, respectively. In group 2, the mean deviation was 0.41 ± 0.299, 0.30 ± 0.428, and 0.50 ± 0.707 at distances of 9 mm (coronal), 6 mm (middle) and 3 mm (apical) from the apex, respectively. In group 3, the mean deviation was 0.58 ± 0.910, 0.85 ± 1.857, and 0.31 ± 0.643 at distances of 9 mm (coronal), 6 mm (middle) and 3 mm (apical) from the apex, respectively.

There were statistically significant differences ($p < 0.05$) among the three groups, except for coronal D1.

Discussion

The introduction of NiTi alloy allowed the manufacture of instruments that were able to prepare curved root canals with safety, less deviations and in less working time, in comparison with stainless steel instruments[3]. New NiTi rotary systems are continuously being marketed, each having subtly different design features, which are claimed to improve flexibility, cutting efficiency, safety and ultimately canal shaping[16,17]. The present study evaluated the ability of three NiTi rotary systems to maintain the original root canal anatomy by using the CBCT. Several methodologies have been used to evaluate the final shape of root canal preparations such as the Serial Sectioning Technique and optical microscopy. However, when using these methods, part of the specimen structure is lost, because there is need to cut the tooth before the postoperative evaluation. The use of simulated root canals in resin blocks, in spite of allowing for a high degree of reproducibility and standardization, does not reflect the clinical behavior of the instruments, because of the different hardness of resin and dentine. Radiographic evaluation[18], however, is not destructive, but allows only a two-dimensional evaluation of the root canal. CBCT has been adapted for dentistry and

compared with medical tomography that leads to increased precision and resolution, as well as reducing the image acquisition time and, as ain consequence, the exposure time to radiation . Another advantage of this method is that there is no destruction of the sample[19].

As reported by Flores et al.[20] (2012), CBCT and specialized software (i-CAT Cone Beam) were successfully used in the present research for measurements before and after instrumentation of root canals and for the calculations of the centering ability of three NiTi rotary systems during cleaning and shaping of the root canals. The present study evaluated the effects of ProTaper Universal™, M$_{two}$™, and TwistedFile™ on root canal anatomy. CBCT analysis showed that the ProTaper Universal™ showed the ability for producing centered preparations and the Twisted File™ and M$_{two}$™ Rotary Systems produced canal deviation. The use of this methodology was based on the study of Sanfelice et al.[14] (2010) which showed it to be reliable, without destructive sectioning of the specimens or loss of the root material during sectioning. Previous studies showed that CBCT used to evaluate root canals prepared with NiTi rotary instruments provided a nondestructive and reproducible method[12,14,21,22]. Data obtained with this technique enable the identification of morphologic changes associated with different biomechanical preparations including canal deviation, dentin removal and final canal preparation. A major advantage of CBCT is the possibility to obtain highly accurate evaluation of root canal shape by the superimposition and measurement of 3D renderings[23].

In the present research, in the group where the M$_{two}$™ rotary system was used, a larger number of deviations was observed. Hin et al.[11] (2013) observed that instrumentation with M$_{two}$ could cause damage to root canal dentin. These results are in disagreement with previous studies[24,25]. Schäfer et al.[26] (2006) also demonstrated the efficiency of cleaning and shaping of this new instrument. Yang et al.[9] (2011) showed that the M$_{two}$™ rotary system maintained the original curvature of the root canal as well as provided a good centering ability. The differences found in this research compared with previous studies[9,24,25,26] may be due to the fact that in this study mesiobuccal roots and curved root canals were used.

The current study showed that the Twisted File™ rotary systems produced morphological changes, such as apical deviation. These results are in disagreement with a previous study[27], which stated that the Twisted File™ rotary system can be used in any clinical case, regardless of the anatomical aspect of the tooth. According to Duran-Sindreu et al.[28] (2012), the Twisted File™ instruments were designed to have improved properties in relation to root canal preparation as compared with other instruments. Stern et al[16] (2012) reported that the Twisted File™ was able of producing centered preparations. Other authors[1,29,30] also demonstrated the ability of the Twisted File™ rotary system to maintain the original root anatomy in curved canals.

The results of the present research showed that the ProTaper Universal™ rotary system produced centered preparations maintaining the original root canal anatomy even in extremely curved canals, as demonstrated in previous

studies[31-34]. These results may be related to the modified cross section design of the ProTaper Universal™ rotary system. The manufacturer reported a decrease of the area in contact with the dentin wall, and that U-shaped grooves had been added at each of the instrument's convex triangular sides to improve flexibility and reduce transportation[21]. Decreasing tapers of the finishing files and increased flexibility of S1 and F1 may have had favorable effects on the performance of the ProTaper Universal™ rotary system. The ProTaper Universal™ instruments showed better performance than the conventional ProTaper™ files evaluated previously, probably because the file tip has been changed from the "modified guiding tip" to the "rounded safe tip". These changes in the instruments may give rise to favorable clinical behavior[35]. On the other hand, Hashem et al.[36] (2012) observed that the ProTaper Universal™ system recorded a significantly lesser centering ratio and higher canal transportation than the twisted File, ProFile GT Series X, and Revo-S systems. Similar results were reported and were attributed to the sharp cutting edges and the multiple tapers along the cutting surface of the files[1].

The use of CBCT revealed that the ProTaper Universal™ had the capacity of producing centered preparations while Twisted File™ and M$_{two}$ rotary systems produced canal deviation.

Acknowledgments

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