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Canal transportation and centring ability of RaCe rotary instruments

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Abstract

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Aim Evaluate, through computerized tomography, canal transportation and centring ability of RaCe rotary instruments after preparation of mesiobuccal root canals in maxillary molar teeth.

Methodology Twenty-seven teeth were submitted to three cone beam tomographic analyses, one preoperatively, and two after preparation with file size 35, .02 taper and size 50, .02 taper. Canal transportation and centring ability were measured with reference to the distance between the noninstrumented portion of the root canals and the mesial and distal periphery of the root, compared with images obtained after the preparation with size 35 and 50 instruments.

Results Canal transportation after preparation with the size 35 file was 0.030 ± 0.253 mm and after the size 50 file was 0.057 ± 0.317 mm. The centring ratio values after preparation with the size 35 file was 0.42 ± 0.32 and after the size 50 file was 0.54 ± 0.29, with no significant statistical difference between the groups.

Conclusions RaCe instruments allowed the preparation of curved root canals with preparation diameters larger than those normally used with minimal canal transportation and adequate centring ability.

Keywords: canal transportation, computed tomography, nickel–titanium, RaCe instruments, rotary instrumentation.

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Introduction

Root canal preparation with nickel–titanium (NiTi) instruments has been a resource available to dental professionals since Walia *et al.* (1988) demonstrated that these instruments are more flexible, possess shape memory and are more resistant to torsion than those made of stainless steel. Several rotary systems have been introduced in recent years and research has demonstrated, through the analysis of various parameters, that their advantages over the manual method include a lower incidence of the formation of deviations, better canal shaping and reduced preparation time (Young *et al.* 2007).

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However, considering curved root canals, and also, the use of stainless-steel instruments, the limit of flexibility must be respected to avoid deviations in their original direction. Several theories of root canal instrumentation techniques have established that the utilization of size 25 file in the apical region fulfils all pre-requisites for root canal cleaning and shaping (Buchanan 2000, Pécora & Capelli 2006). Nevertheless, other studies have demonstrated that apical preparations with FlexoFile files with diameters larger than 30 significantly reduce the number of microorganisms and increase the antiseptic effects of irrigants (Shuping *et al.* 2000, Khademi *et al.* 2006). Wu & Wesselink (1995) recommended the enlargement of root canals up to diameter size 40 to remove larger amounts of debris and promote a better cleaning of the apical third, through the removal of a larger portion of contaminated dentine. However, it can be observed that in these studies there was no concern regarding the determination of the anatomical diameter, a procedure that should be carried out after pre-flaring the cervical and middle thirds of the root canal (Wu *et al.* 2002, Vanni *et al.* 2005). The elimination of interferences in these regions allow a more accurate assessment of the real anatomical diameter of the apical constriction and more reliable determination of the preparation diameter, as well as, the appropriate cleaning of the root apical portion (Siqueira-Júnior 2005, Pécora & Capelli 2006).

Current literature supports that the biomechanical preparation of curved root canals should be carried out with large taper NiTi rotary instruments and minimum apical preparation diameter (ISO size 20, 25 or 30), allowing for the compaction of the filling material with a smaller chance of extrusion (Young *et al.* 2007). In spite of advantages in the filling phase, biologically the objectives may not be achieved, because the apical preparation of infected root canals is a critical point and should aim at maximum disinfection control, hence the existing literature also supports the philosophy of the preparation of larger apical size with moderate taper (Shuping *et al.* 2000, Falk & Sedgley 2005).

However, safety limits for NiTi rotary instruments because of possible morphological changes of root canals have not yet been demonstrated. Apart from Card *et al.* (2002), who used Lightspeed instruments up to diameter 65 in mesial root canals of mandibular molars, reports on preparations of mesiobuccal root canals of maxillary molars with the use of current NiTi rotary systems have not yet appeared in the literature.

The most recent methodologies for deviation analyses are computerized tomography (CT) and computerized microtomography (μCT). Tomography has been widely used as a tool to evaluate the final shape of the root canal. It provides a three-dimensional reproduction of the tooth, which results in better quality examinations in relation with other techniques. As CT and μCT are noninvasive techniques, they permit the visualization of root canals before, during and after biomechanical preparation (Bergmans *et al.* 2001, 2003, Gluskin *et al.* 2001, Peters *et al.* 2001, Hübscher *et al.* 2003).

The objective of this study was to evaluate, *ex vivo*, canal transportation and centring ability of mesiobuccal maxillary molar root canals after their biomechanical preparation with rotary instruments of different apical diameters (35 and 50), through cone beam CT.

Material and methods

Thirty extracted human maxillary first molars with complete root formation and apical foramina whereby it was possible to introduce a size 15 FlexoFile (Dentsply Maillefer, Ballaigues, Switzerland) were selected. The degree of curvature and radius were determined from periapical radiographs, according to Schneider (1971) and Pruett *et al.* (1997), respectively. All teeth were shortened to a length of 18 mm, and had curvatures between 32° and 49° and a radius between 5.5 and 9.9 mm.

For each tooth, 3 mm of the palatal and distobuccal roots were separated using a bur and handpiece. The apices of the mesiobuccal roots were then inserted in a rectangular colourless paraffin base ($100 \times 80 \times 3.5$ mm) mounted on a glass plate with the same dimensions, until all apices could be visualized into three arrays of 10 teeth each.

Afterwards, the glass plate was wrapped with a stainless-steel band. Autopolymerized resin (Dencor, Classic Artigos Odontológicos, São Paulo, Brazil) was then poured to fill the whole space until the roots were covered, except for the apical portion that was inserted in the paraffin base. After the polymerization, the paraffin and the glass plate were removed and kept in a closed container with 100% humidity (Versiani *et al.* 2008). Figure 1 shows a schematic drawing of the procedure.

The specimens were fitted into a Fox scale (Bio Art Equipamentos Odontológicos, São Carlos, Brazil) and adapted to a Cone Beam I – Cat tomograph (Imaging Sciences International, Hatfield, PA, USA). The images were captured in a small field of view (6 cm) with 40 s of exposure time and resolution of 0.2 voxels (maximum resolution), and pixel size of 0.20 mm, totalizing 599 cuts in the axial and frontal directions. Xoran-Cat software was used (Imaging Sciences International) for image reconstruction.

Twenty-seven of the 30 specimens were selected to comply with the tomography performance field. Three topograms were selected for each assessed specimen. The first corresponded to the area located 3 mm (apical third), the second 6 mm (middle third) and the third 9 mm (cervical third) from the root apex. The control group comprised tomographic images of the mesiobuccal roots, which were measured mesiodistally, from the most mesial to the most distal zone, on the topogram surfaces before root canal instrumentation and after preparation with instruments 35 and 50.

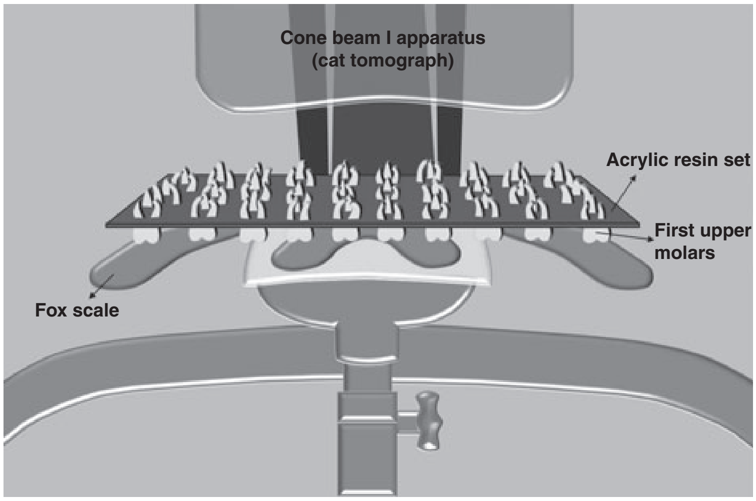

Figure 1 Test sample fitted into a Fox scale with two lateral fittings on each side for its correct positioning adapted to a Cone Beam I - Cat tomography (a, b).

Biomechanical preparation of the root canals was carried out by an experienced operator with NiTi RaCe rotary instruments (FKG, Le Chaux-of-Fonds, Switzerland) placed in a contra-angle handpiece, driven by an Endo-Mate TC electric motor (NSK, Europe, Frankfurt, Germany). First, the working length (WL) was established with a size 15 file (Dentsply Maillefer). The sequence of RaCe instruments used in this study are shown in Table 1. The instruments were replaced by new ones after every eight canals. The irrigating solution used was 1% sodium hypochlorite (Dermus Manipulação, Florianópolis, Brazil); 2 mL of which were deposited with syringe and NaviTips (Ultradent Products Inc, South Jordan, UT, USA) in the interval between each instrument.

The first preparation stage of the root canals was achieved with size 35, .02 taper instruments at WL. The test samples were then submitted to tomography examination following the same protocol described above. After this procedure, the root canals were prepared up to a Race size 50, .02 taper instrument, when another tomography examination was carried out.

Table 1 Sequence of instruments as used in this study with rpm, Torque and penetration depth for each instrument used in this study

Instruments	rpm	Torque (Ncm)	Penetration depth (mm)
Pre-RaCe 40.10	500	1.5	10
Pre-RaCe 35.08	500	1.5	12
RaCe 30.06	350	1	14
RaCe 25.04	350	0.5	16
RaCe 25.02	350	0.5	17
RaCe 30.02	350	0.5	17
RaCe 35.02	350	0.5	17
RaCe 40.02	350	1	17
RaCe 45.02	350	1	17
RaCe 50.02	350	1	17

After capturing the cone beam tomograph in pdf format with Adobe Acrobat 7.0 software (Adobe Systems Inc, San José, CA, USA), the images were edited with CS3 Photoshop software (Adobe Systems Inc) and recorded in JPEG format.

Evaluation of canal transportation

To compare the degree of canal transportation, a technique developed by Gambill *et al.* (1996) was used. Canal transportation corresponds to the deviation of the axis (in millimetres) after instrumentation, compared with the control group. The values were obtained from the measurement of the shortest distance of the noninstrumented portion of the root canal and the mesial and distal aspects of the root, compared with the same measurements obtained from the root canal images after preparation with instruments 35 and 50. The measurement of the real distance of the points of interest for obtainment of canal transportation was carried out with 'Distance' tool of the UTHSCSA Image Tool 3.0 software for Windows (University of Texas Science Center, San Antonio, TX, USA). The following formula was used for the calculation of transportation:

$$(M1 - M2) - (D1 - D2)$$

The following formula was then used for the preparation with instrument 50.

$$(M1 - M3) - (D1 - D3)$$

The measurements correspond to the shortest distance between the mesial aspect of the root and the mesial portion of the noninstrumented canal (M1), the root mesial aspect and the mesial portion of the instrumented canal after preparation with file size 35 (M2) and after file size 50 (M3), as well as to the distal aspect of the root and the distal portion of the noninstrumented root canal (D1), the root distal aspect and the distal portion of the canal instrumented after file sizes 35 (D2) and 50 (D3) (Fig. 2). The direction of transportation was assessed from the results obtained for the canal transportation of each specimen. A negative result indicated transportation toward the distal portion, a positive result toward the mesial portion, and null, the absence of transportation.

Evaluation of centring ability

According to Gambill *et al.* (1996), the mean centring ratio indicates the ability of the instrument to stay centred in the canal. This ratio was calculated for each section using the following ratio:

$$M1 - M2/D1 - D2 \text{ or } D1 - D2/M1 - M2$$

The example described above establishes the centring ratio between the initial tomography cut and after the use of instrument 35. The centring ratio after the use of instrument 50 was performed according to the following formula:

$$M1 - M3/D1 - D3 \text{ or } D1 - D3/M1 - M3$$

The formula was chosen according to the numbered value that should always be the lowest of the results obtained through the difference. A result of 1 (one) indicated perfect centralization capacity and the closer the result to zero the worse the ability of the instrument to keep itself in the canal central axis. The results were submitted to statistical analysis. Data were submitted to preliminary tests to verifying the normality of the distribution. As the tested sample presented normal distribution, parametric statistical tests were applied, with the aid of the GraphPad InStat software (GraphPad Software Inc, San Diego, CA, USA), together with the Variance Analysis to verify the existence of statistically significant differences between the averages, and with the complementary Tukey test to verify the difference amongst the groups, with a significance level of 5%.

Results

The average curvature angle of the specimens varied between 38.7° ± 5.5°, whilst the variation of the average curvature radius was 8.08 ± 1.3 mm. The sample was considered homogeneous according to the one sample *t*-test ($P > 0.0001$).

The values for average canal transportation after the use of file 35 in the apical, middle and cervical thirds were −0.038 ± 0.215, 0.057 ± 0.243 and 0.072 ± 0.301 mm, respectively. After the use of instrument

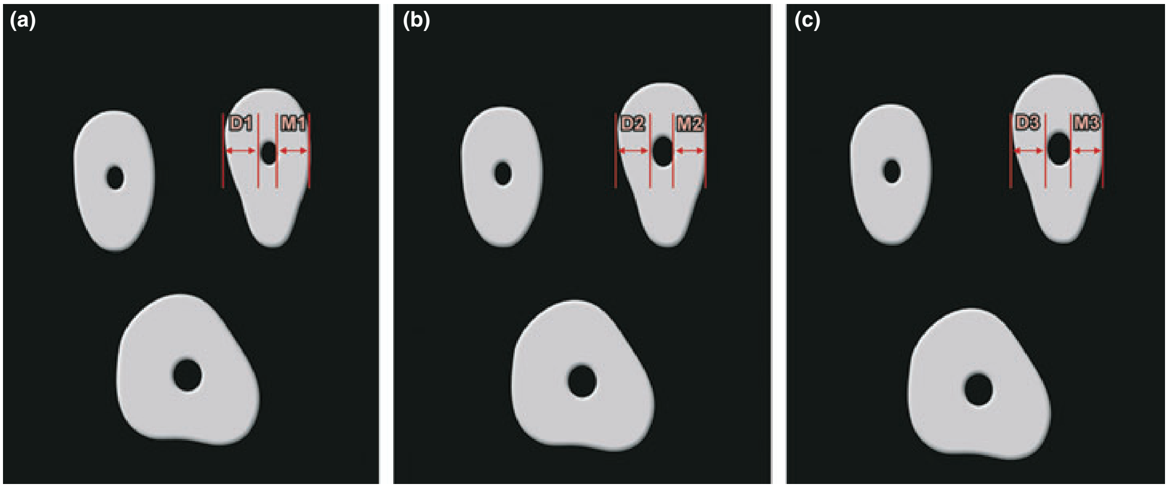

Figure 2 Topograms of the middle third, where D and M correspond to the shortest distance between the root mesial and distal aspect, respectively, in relation to the noninstrumented root canal (a), after instrument 35 (b) and after instrument 50 (c).

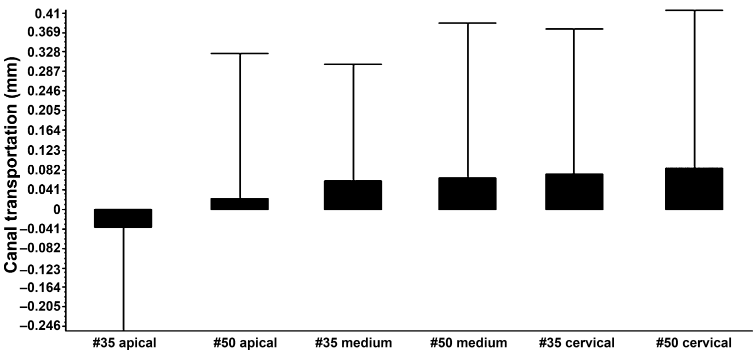

Figure 3 Average of canal transportation (in millimetres) after the use of instruments 35 and 50 in the apical, middle and cervical thirds of the root canals.

50, the index was 0.021 ± 0.303 in the third apical, 0.065 ± 0.320 in the middle third and 0.085 ± 0.328 in the cervical third, with no statistically significant difference between the groups ($P > 0.05$). The total canal transportation after the use of instrument 35 was 0.030 ± 0.253 mm and after the use of instrument 50 was 0.057 ± 0.317 mm, with no statistical difference between the groups ($P > 0.05$). The results are shown in Fig. 3.

It was observed that after the use of instrument 35 the average centring ratio values were 0.45 ± 0.32, 0.43 ± 0.39 and 0.39 ± 0.25 for the apical, middle and cervical thirds, respectively. After the use of instrument 50, the values were 0.64 ± 0.24 in the apical third, 0.45 ± 0.35 in the middle third and 0.54 ± 0.28 in the cervical third, with no statistically significant difference between the thirds ($P > 0.05$). The total mean centring ratio after the use of instrument 35 was 0.42 ± 0.32 and after instrument 50 was 0.54 ± 0.29, with no statistical difference between the groups ($P > 0.05$). The results of the centring ratio average are shown in Fig. 4.

The results demonstrate that the increase in the file diameter did not influence the capacity of the instrument to remain centralized inside the root canals.

Discussion

The introduction of NiTi alloy allowed the manufacture of instruments that were capable of preparing curved root canals with safety, less deviations and in less working time, in comparison with instruments made of stainless steel (Young *et al.* 2007).

Several methodologies have been used to evaluate the final shape of root canal preparations such as the Serial Sectioning Technique (Bramante *et al.* 1987) and optical microscopy (Jung *et al.* 2005). However, when using these methods, part of the specimen structure is lost, because there is a need to cut the tooth before the postoperative evaluation. The use of simulated root canals in resin blocks (Thompson & Dummer 1997), in spite of allowing for a high degree of reproducibility and standardization, does not reflect the clinical behaviour of the instruments, because of the difference in hardness between the resin and dentine. Radiographic evaluation (Sydney *et al.* 1991), however, is not destructive, but only allows for two-dimensional evaluation of the root canal.

Recently, cone beam volumetric tomography has been adapted for dentistry and compared with medical tomography that leads to increased precision and

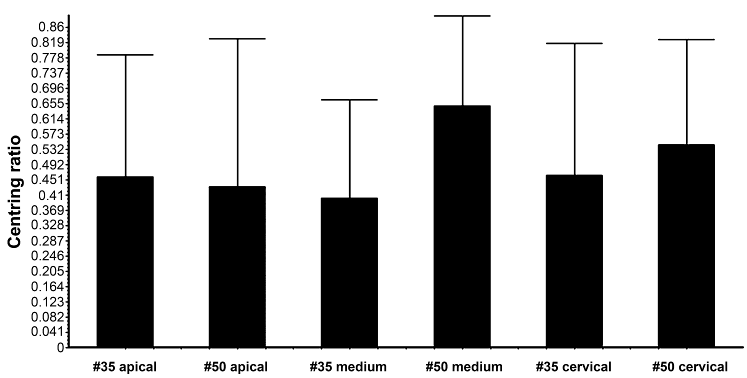

Figure 4 Centring ratio after the use of instruments 35 and 50 in the apical, middle and cervical thirds of the root canals.

resolution, as well as reducing the image acquisition time and, as a consequence, the time of exposure to radiation. Another advantage of this method is that there is no destruction of the sample (Arnheiter *et al.* 2006).

The selection of teeth with a similar root canal angle and radius of curvature was important and were found to be statistically homogeneous. The angles and radius selected were considered severe, as more deviations occur in teeth with these characteristics (Schneider 1971, Lopes *et al.* 1998).

Preparations to the WL were carried out with the instrument with a size 35 instrument, and then sequentially up to a size 50 instrument. The results demonstrated there was no statistically significant difference between the thirds of the canals analysed with regard to the average of canal transportation, which indicates safety in the preparation of root canals with rotary instruments with diameters larger than those normally used. However, more specifically in the apical third, the taper of these instruments was .02, i.e. the NiTi instrument flexibility was maintained, a fact that would probably not occur if the taper were larger in the apical portion. Another factor that could contribute to the preparations remaining centralized and maintaining the original direction of the root canals could lie in the design of the active part of the RaCe instruments, with alternating cutting edges and are claimed to prevent the instrument from screwing into the root canal thus reducing intraoperative torque values (Schäfer & Vlassis 2004, Paqué *et al.* 2005).

The direction of transportation in the apical area is mainly related to the external curvature (Tasdemir *et al.* 2005, Merrett *et al.* 2006), although some studies have demonstrated that it can occur in several directions. This indicates that the occurrence of deviations can depend on factors other than the curvature, such as the instrument design, the physical properties of the alloy and the technical instrumentation (Kosa *et al.* 1999, Peters *et al.* 2001). Bergmans *et al.* (2001) reported that at 1 mm from the root apex the direction of transportation was towards the distal portion in maxillary molar mesiovestibular canals, on the internal side of the curvature. In this study, except for the extended apical third with the use of instrument 35 (-0.038 ± 0.215), there was a greater tendency of average transportation to the mesial direction (external side of the curvature) in the other thirds, an occurrence that was also detected in the apical third extended up to instrument 50. The probable reason for the transportation to the inner side of the curvature with the use of size 35 instrument lies in the hypothesis that superelastic instruments follow the canal curvature (Garip & Günday 2001) and depend on factors such as the instrument design, the physical properties of the alloy and the technical instrumentation (Kosa *et al.* 1999, Peters *et al.* 2001).

A limited canal transportation may be related to the good centralization capacity of the instruments in the root canal, mainly in the apical third, which had a better centring ratio compared with the middle and cervical thirds which were influenced by the instruments with a larger taper (.10, .08 and .06). Therefore, besides the previous cervical enlargement and the metallic alloy used, the factors which allowed RaCe instruments to maintain the original direction of curved root canals and remain centralized in their interior were the design and the smallest taper of the instruments used in the apical third (Paqué *et al.* 2005).

In cases where 35–40% of the walls of maxillary molar buccal root canals remain untouched when enlarged up to instrument 40 along the WL (Peters *et al.* 2001), it is advisable to enlarge the root canals up to the preparation diameters frequently utilized, with advantages such as the better cleaning of oval canals or the use in canals where the shape does not allow for the action of the instrument on all walls (Rödig *et al.* 2002, Albrecht *et al.* 2004). It is possible that when the root canals were enlarged up to file size 35 some parts of the walls were not touched. However, when the size 50 instrument was used, more canal walls were prepared, which contributed to better centring. Such enlargement also favours the removal of a larger amount of pulpal remains, dentine and microorganisms, because of the larger volume of irrigating solution that can act in this area (Peters & Barbakow 2000, Khademi *et al.* 2006), thus contributing to a better disinfection of the root canals (Falk & Sedgley 2005, Siqueira-Júnior 2005).

Conclusions

Size 35, .02 taper and 50, .02 taper RaCe instruments allowed the preparation of curved root canals with preparation diameters larger than those normally used and did not influence canal transportation or the ability of the instrument to remain centralized inside the root canals.

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