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Comparison of canal preparation using K3XF, Mtwo and BioRaCe rotary instruments in simulated curved canals

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Key words *curved root canals, root canal deviation, root canal preparation, rotary nickel-titanium instruments*

Aim: This study compared the incidence of deviation along curved canals after preparation with three nickel-titanium (NiTi) rotary systems (K3XF, Mtwo and BioRaCe).

Materials and methods: Curved canals from 60 resin training blocks were filled with ink and divided into three groups according to the instrumentation system. Pre-instrumentation images were acquired by using a stereomicroscope. All canals were prepared up to an instrument size 35/0.04 at the terminus of the canal. Post-instrumentation images were taken using the same conditions and pictures were superimposed. The amount of resin removed was measured at eight different points, beginning at the apical terminus of the canal. Differences in the mesial and distal aspects were measured to evaluate the occurrence of deviation.

Results: Intragroup analysis showed that all instruments promoted some deviation at all levels. There was a significant difference at most of the levels for all groups ($P < 0.05$), except for the 1-mm level of the K3XF ($P = 0.099$) and Mtwo ($P = 0.196$) groups, the 3-mm level of BioRaCe group ($P = 0.071$) and the 7-mm level of the Mtwo ($P = 0.051$) and BioRaCe ($P = 0.257$) groups. Deviation was observed at the distal canal wall at levels 3, 4, 5 and 6 from all groups, at level 2 from both K3XF and Mtwo groups, at level 1 from the K3XF group and at level 7 from the Mtwo group. At the mesial wall, deviation was observed at level 0 from all groups, at level 1 for both Mtwo and BioRaCe groups and at level 7 for both K3XF and BioRaCe groups. Mtwo showed significantly lower deviation at level 1 than K3XF and BioRaCe. At level 2, BioRaCe was significantly better than Mtwo and K3XF and Mtwo performed better than K3XF. No significant differences were observed for the other levels.

Conclusions: All the rotary NiTi systems showed some deviation during the preparation of curved canals. Mtwo showed a significantly better performance at level 1 and BioRaCe at level 2.

Introduction

Over the last two decades, nickel-titanium (NiTi) rotary systems have been widely developed for use during root canal preparation because of their capacity to maintain the original canal shape without creating severe preparation errors, particularly in curved canals. This is related to the fact that NiTi instruments present superelastic behaviour and shape-memory property[1].

Newly developed NiTi instruments are characterised by unique design properties in terms of cross-sectional shape, taper, number and angle of flutes. These new instruments are expected to reduce the

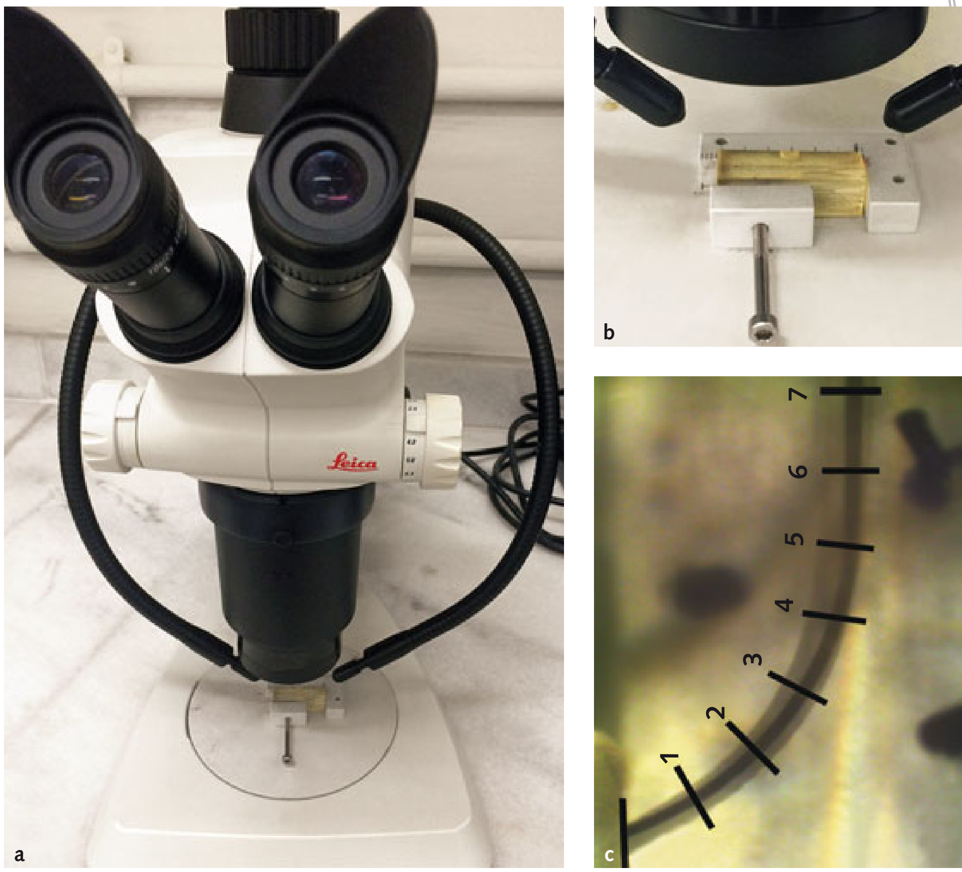

Fig 1 (a and b) The apparatus used to take photographs of the blocks in the stereomicroscope.
(c) Superimposed pre- and post-instrumentation images, showing the performance of instruments at the different levels.

risks of procedural errors during preparation, including ledge, perforation and apical foramen transportation[2]. Moreover, technological developments in metallurgy offer the possibility of enhancing the mechanical properties of NiTi files[3,4]. A new proprietary thermomechanical manufacturing process has been introduced, producing rotary endodontic instruments with increased flexibility and ability to maintain the original canal shape[5].

BioRaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland) and Mtwo (VDW, Munich, Germany) are well-established rotary NiTi instruments[6,7]. More recently, K3XF (SybronEndo, California, USA) has been introduced, which differs from the two other systems regarding the different treatment of the NiTi alloy (heat treatment using R-phase technology). According to the manufacturer, this approach has been reported to provide more flexibility and increased resistance to cyclic fatigue[8,9].

Chemomechanical preparation of curved canals may produce asymmetric dentin removal, with consequent apical transportation. If transportation alters the canal geometry significantly to the point of affecting proper disinfection or filling, it is expected to compromise the prognosis of the treatment of infected curved canals. Canal transportation occurs because the instrument tends to recover its original shape during the preparation of curved canals[9]. Studies reported that some mechanical properties of NiTi instruments, especially flexibility, are important to provide more centred preparations[9-11] and to maintain the original canal curvature even in extremely curved canals[12,13]. So far, no study compared the performance of these three NiTi rotary systems during the preparation of curved root canals.

Therefore, the purpose of this study was to evaluate and compare the incidence of deviation along simulated curved canals in resin blocks after instrumentation with BioRaCe, Mtwo and K3XF. The null hypothesis is that there is no difference in the incidence of deviation in curved canals after instrumentation with the three NiTi rotary systems tested.

Materials and methods

This study used ISO-sized 15, 0.02 tapered Endo Training Blocks (Dentsply Maillefer, Ballaigues, Switzerland). The angle of curvature of the simulated canals was 40 degrees. The canals were filled with Indian ink by using an insulin syringe, in order to facilitate further comparison between pre- and post-instrumentation images. Specimens were randomly assigned to three different groups of 20 blocks each. Each specimen was mounted in a customised stable support apparatus, which consisted of a rectangular slot which was the same size of the block and adapted to the base of a Leica S8 APO stereomicroscope (Leica, Wetzlar, Germany), so that the block could be positioned at 90 degrees to the objective lens (Fig 1). A digital image was captured of each specimen before instrumentation using the software Leica Application Suite 3.6 (Leica), with a magnification of 1.25x and saved as a TIFF file.

All instruments were used up to the working length (WL), which was established at the terminus of the artificial canal (0 limit). Each canal was initially irrigated with 2 ml tap water to remove the excess dye. Negotiation and glide path of all the canals were performed with stainless steel K-file (Dentsply Maillefer), sizes 10 and 15; all were used with circumferential filing motions. All systems used four instruments; each file was used with four pecking motions and apical patency was confirmed with a hand stainless-steel K-file size 10 between each rotary instrument size. Preparation with all systems was completed with the same tip diameter and taper. In the K3XF group, the simulated canals were prepared with the instruments 15/.06, 20/.06, 25/.06 and 35/.04. In the BioRaCe group, canals were prepared with instruments 15/.06, 20/.06, 25/.06 and 35/.04. In the Mtwo group, preparation was carried out with instruments 15/.05, 20/.06, 25/.06 and 35/.04. The instruments were coupled to an endodontic motor (VDW) at the setting suggested by each manufacturer. No lubricant was used during the preparation. Irrigation was performed with tap water; 2 ml after each instrument size and 1 ml after each patency instrument, totalling 15 ml per canal for all groups.

After instrumentation, all specimens were repositioned in the apparatus and photographed as described above. Photoshop software (CS5 Extended, version 12.0.4, Adobe Systems, California, USA) was used to automatically superimpose the images, using the 'Scripts-Load Files into Stack' tool. The figure on top of the stack was placed in 'multiply' view mode, and opacity was adjusted to permit proper visualisation of the two images for measurements. Measurements of the effects of the different instruments on the canal walls were performed according to modifications from previous studies[14-16]. Two evaluators working together and blind to the groups performed all measurements. The amount of resin removed, i.e. the difference between the canal configuration before and after preparation, was determined for both the mesial and distal sides of the canal in 1 mm increments under high magnification and by using the ruler tool of the Photoshop software. The values obtained were corrected on the basis of the 1-mm scale generated by the stereomicroscope image capture system. The first measuring point was at the WL, i.e. the apical terminus of the canal (0 mm), and the last measuring point was 7 mm from the WL. This resulted in eight measuring points for both the mesial and distal sides of the canal, a total of 16 measuring points per acrylic block. All measurements were made at right angles to the surface of the canal. If the difference between the mesial and distal measures at a given point was equal to 0, the canal was considered as uniformly enlarged with no deviation, at least in the plane (mesiodistal) analysed.

Data were analysed by using the Statistical Package for the Social Sciences software (SPSS, version 19.0, IBM, São Paulo, Brazil). Intragroup analysis evaluated the isolated performance of the three systems. The difference of material removed from the mesial and distal walls of the canal at the eight measuring points was compared by using repeated-measures analysis of variance (ANOVA). This initial analysis permitted identification of points where significant differences occurred. Then, mesial and distal values for each level were compared by using the paired t-test to assess which side canal deviation occurred. Intergroup analysis was performed by using the one-way ANOVA for each level. For multiple comparisons, the Tukey post hoc test was used. Data were tested for normality before applying the parametric tests. The statistical significance level of 5% ($P < 0.05$) was established for all analyses.

Table 1 Pairwise comparisons of canal deviation at different levels from the apical terminus of simulated curved canal preparation with three different instrument systems.

Levels					
K3XF	*P* value	Mtwo	*P* value	BioRaCe	*P* value
0 × 1	1.000	0 × 1	0.331	0 × 1	1.000
0 × 2	1.000	0 × 2	1.000	0 × 2	1.000
0 × 3	1.000	0 × 3	1.000	0 × 3	1.000
0 × 4	1.000	0 × 4	1.000	0 × 4	0.119
0 × 5	0.575	0 × 5	1.000	0 × 5	0.403
0 × 6	1.000	0 × 6	1.000	0 × 6	1.000
0 × 7	1.000	0 × 7	1.000	0 × 7	1.000
1 × 2	1.000	1 × 2	1.000	1 × 2	1.000
1 × 3	0.272	1 × 3	1.000	1 × 3	1.000
1 × 4	0.353	1 × 4	0.002	1 × 4	0.020
1 × 5	0.368	1 × 5	0.001	1 × 5	0.119
1 × 6	1.000	1 × 6	0.616	1 × 6	1.000
1 × 7	1.000	1 × 7	1.000	1 × 7	1.000
2 × 3	0.481	2 × 3	0.711	2 × 3	1.000
2 × 4	0.431	2 × 4	0.000	2 × 4	0.035
2 × 5	0.492	2 × 5	0.000	2 × 5	0.140
2 × 6	1.000	2 × 6	0.721	2 × 6	1.000
2 × 7	1.000	2 × 7	1.000	2 × 7	1.000
3 × 4	1.000	3 × 4	0.000	3 × 4	0.003
3 × 5	1.000	3 × 5	0.001	3 × 5	0.135
3 × 6	1.000	3 × 6	1.000	3 × 6	1.000
3 × 7	1.000	3 × 7	1.000	3 × 7	1.000
4 × 5	1.000	4 × 5	1.000	4 × 5	1.000
4 × 6	1.000	4 × 6	0.010	4 × 6	0.041
4 × 7	1.000	4 × 7	0.003	4 × 7	1.000
5 × 6	1.000	5 × 6	0.001	5 × 6	0.105
5 × 7	1.000	5 × 7	0.002	5 × 7	1.000
6 × 7	1.000	6 × 7	1.000	6 × 7	1.000

Results

Intragroup analysis showed that all instruments promoted some canal deviation at virtually all levels (Table 1). This was evident after comparing the amount of material removed from the mesial and distal walls of the canals at the eight measuring points. There was a significant difference at most of the levels for all groups ($P < 0.05$), except for the 1-mm level of the K3XF ($P = 0.099$) and Mtwo ($P = 0.196$) groups, the 3-mm level of the BioRaCe group ($P = 0.071$) and the 7-mm level of the Mtwo ($P = 0.051$) and BioRaCe ($P = 0.257$) groups.

Canal deviation was observed at the distal canal wall at levels 3, 4, 5 and 6 from all groups, at level 2 from the K3XF and Mtwo groups, at level 1 only from the K3XF group and at level 7 only from the Mtwo and BioRaCe groups. At the mesial wall, deviation was observed at level 0 from all groups, at level 1 from the Mtwo and BioRaCe groups and at level 7 from the K3XF group (Table 1).

In the BioRaCe group, the levels with the greatest deviation were the following: 5 > 4 > 6 > 0. Level 2 showed the lowest deviation. In the Mtwo group, the levels with the greatest deviation were: 4 > 5 > 0 > 6. The lowest deviation was observed in level 1. In the K3XF group, the levels with the greatest deviation were: 4 > 7 > 6 > 5. Level 1 showed the lowest deviation and a significantly higher deviation occurred at 7 mm when compared with all levels.

Comparisons between level of deviation at all measuring points are shown in Table 2. Data from the intergroup analysis are also shown in Table 2. When the three groups were compared in terms of ability to enlarge the canal with minimal deviation, Mtwo instruments were significantly better than the others at level 1, while BioRaCe was significantly better than the others at level 2. Mtwo was also significantly better than K3XF at level 2, with no significant differences between the three systems for all the other levels.

Discussion

The three NiTi rotary systems used in this study have been commonly used for root canal treatment and have been the subject of previous research with favourable results[2,9,17-19]. However, no study so far compared their performance during instrumentation of simulated curved canals in resin blocks. The present results revealed that all systems showed some deviation of the root canal walls. At the 0-mm level (the WL), there was no significant difference between the systems. Nevertheless, at the 1-mm and 2-mm levels, Mtwo and BioRaCe performed significantly better, respectively.

All the instruments used in this study were designed to have improved properties with regard to canal preparation. The Mtwo instrument has an S-shaped cross-sectional design with two blades, a pos-

Table 2 Mean material removed (mm) at different levels from the apical terminus of simulated curved canals after preparation with three different rotary nickel-titanium instruments.

Sites	Instruments								
	K3XF			Mtwo			BioRaCe		
Level	Mesial	Distal	Difference*	Mesial	Distal	Difference*	Mesial	Distal	Difference*
0	0.116	0.060	0.055 ± 0.083	0.142	0.036	0.105 ± 0.106	0.092	0.040	0.051 ± 0.093
1†§	0.085¶	0.120¶	0.035 ± 0.090	0.100¶	0.078¶	0.022 ± 0.074	0.112	0.073	0.039 ± 0.050
2‡§	0.079	0.133	0.054 ± 0.090	0.093	0.132	0.039 ± 0.076	0.121	0.094	0.026 ± 0.054
3	0.068	0.155	0.087 ± 0.106	0.100	0.167	0.066 ± 0.093	0.112¶	0.143¶	0.030 ± 0.072
4	0.056	0.169	0.112 ± 0.131	0.054	0.203	0.149 ± 0.112	0.074	0.188	0.113 ± 0.088
5	0.046	0.152	0.105 ± 0.132	0.045	0.184	0.138 ± 0.108	0.061	0.194	0.133 ± 0.091
6	0.044	0.154	0.110 ± 0.120	0.069	0.150	0.080 ± 0.087	0.088	0.157	0.068 ± 0.097
7	0.423	0.154	0.111 ± 0.128	0.098¶	0.141¶	0.042 ± 0.091	0.118¶	0.149¶	0.031 ± 0.119

*Mean of the differences between the amount of material removed in mesial and distal walls. Statistically significant differences for deviation (Difference data): †between K3XF and Mtwo; ‡between K3XF and BioRaCe; §between Mtwo and BioRaCe.
¶Lack of statistically significant difference when comparing material removed in mesial and distal walls. For all the other levels and instruments, significant differences were observed.

itive rake angle and an increased pitch length from the tip to the shaft[20]. It has a non-cutting safety tip, which may help explain its significantly better performance at the 1-mm level. The BioRaCe instrument possesses a triangular cross-sectional shape with alternating cutting edges. During manufacturing, it is subjected to an electrochemical polishing process to improve superficial finishing and decrease the risks of fracture[21,22]. These instruments have been reported to maintain the original canal curvature[23-26], which is in agreement with the present study. The K3XF instrument differs from the conventional K3 in that it receives a heat treatment (R-phase) in order to present enhanced mechanical properties[4,27]. These effects, however, have not impacted on the performance of these instruments in curved canals when compared with the two other systems.

The three systems tested in this study used different rotary speed, as recommended by the manufacturers (K3XF: 350 to 500 rpm; Mtwo: 250 to 350 rpm; and BioRaCe: 500 to 600 rpm). If these differences can lead to different performances, including the instrument centring ability, its relationship to the results obtained remains to be determined.

Although NiTi instruments have been clearly shown to perform significantly better in curved canals than stainless-steel instruments[10,13,28,29], they are not perfect in the sense of providing preparations without deviation from the original canal anatomy. This study confirms this statement, in that all three rotary NiTi instruments showed some canal deviation during the preparation of curved canals in resin blocks. Thus, although a significant improvement in canal preparation followed the advent of NiTi instruments when compared to the stainless-steel precursors, there is still room for improvements in instrument performance during the preparation of curved root canals.

In the present study, simulated canals were prepared up to size 35/.04 at the WL. Although some authors recommended smaller apical preparations to avoid iatrogenic complications[30], the use of NiTi instruments has permitted increased apical enlargement with reduced risks of procedural errors. Large apical preparations have been shown to improve irrigation and disinfection of the root canal[17,31-34]. However, care must be taken to avoid excessive apical enlargement, especially with instruments with greater tapers, which can lead to weakening of the root coronally, predisposing to radicular cracks and fracture[35-37].

Several recent studies used micro computed tomography to examine the effects of instrumentation[17,38-40]. This method has some advantages, as it provides a three-dimensional view of the preparation in canals from natural teeth. However, the geometry of the canals is difficult to standardise and many teeth have to be included in the experiment to circumvent this variable. Simulated curved canals in resin blocks have the disadvantage that instruments are cutting a material with different characteristics from dentin, but they permit standardisation of the canal geometry and allow for direct visual comparison of the shaping ability of the instruments. Resin blocks have been widely used in previous investigations[16,41,42]. Techniques with superimposition of preoperative and postoperative canal outlines can easily be applied to resin models, thereby facilitating measurements of canal transportation at any point of the canals. This model guarantees a high degree of reproducibility and standardisation of the experimental design[2]. However, given the differences between resin and dentin, care should be taken when extrapolating the results[43-45]. As for the irrigant used, although sodium hypochlorite is largely used as the primary irrigant in root canal therapy, sterile water was used in this study to avoid any possible effects that sodium hypochlorite might have on the resin blocks.

Conclusion

In conclusion, this study demonstrated that all three rotary NiTi instruments showed some canal deviation during the preparation of simulated curved canals in resin blocks. It still remains to be determined how the degree of deviation may influence treatment outcome, but ideally, instruments should cause no significant deviation of the original canal anatomy. Due to the results of this study the null hypothesis has to be rejected as the instruments used caused different canal deviations during the preparation of simulated curved canals in resin blocks. Overall Mtwo showed a significantly better performance at the 1-mm level, while BioRaCe performed significantly better at the 2-mm level.

Acknowledgments

This study was supported by grants from two Brazilian Governmental Institutions: Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

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