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A micro-computed tomography evaluation of long-oval canal preparation using reciprocating or rotary systems

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Abstract

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Aim To evaluate, using micro-computed tomography, the preparation of long-oval root canals using a single reciprocating system versus a multiple-file rotary system.

Methodology Distal canals of thirty mandibular molars were selected and randomly assigned to one of two instrument groups ($n = 15$): Reciproc 40 (VDW, Munich, Germany) or BioRaCe system (FKG Dentaire, La Chaux-de-Fonds, Switzerland). The teeth were scanned before and after preparation of the canal by a SkyScan 1172 micro-computed tomography scanner at 11-μm resolution. Morphometric variations were measured by volume increases and by the remaining untreated canal surface area in the entire canal and as well as in each third of the canal. Data were compared using the Mann–Whitney test.

Results The Reciproc system left significantly more areas untouched ($P < 0.001$) in the cervical and middle thirds (18.14% and 21.82%) as compared to BioRaCe (8.14% and 11.35%). The Reciproc system had the greatest increase in volume of both the entire canal and the apical third ($P < 0.5$).

Conclusions Neither technique was able to completely prepare the outline of long-oval canals. The Reciproc system removed more tooth structure. The BioRaCe left fewer untouched dentine walls in the more coronal thirds of the canal, whilst Reciproc left fewer in the apical third.

Keywords: BioRaCe, long-oval canal, micro-computed tomography, reciproc, root canal preparation.

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Introduction

The anatomic complexity of oval and long-oval root canals remains a major challenge when aiming to shape root canals (Barbizam *et al.* 2002, Peters 2004, Paqué *et al.* 2009). Oval and long-oval root canals are difficult to prepare using full-sequence rotary systems because there is a tendency for the file to remain in the centre of the canal, which does not allow adequate preparation in the buccolingual dimension (Wu *et al.* 2000, Rödig *et al.* 2002, Weiger *et al.* 2002, Metzger *et al.* 2010, Paqué & Peters 2011).

Computerised microtomography (μCT) has emerged as a research tool allowing a detailed reproduction of internal and external tooth anatomy as well as a noninvasive three-dimensional assessment of instrument action on root canal walls (Rhodes *et al.* 1999, Peters *et al.* 2000, Bergmans *et al.* 2001, Peters 2004, Ikram *et al.* 2009, Paqué *et al.* 2009, 2012, Marending *et al.* 2012).

There are concerns that a single reciprocating motion system may jeopardise the preparation of oval

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root canals compared to sequential continuous rotary systems (Versiani *et al.* 2011, 2013, Capar *et al.* 2014). This article provides *ex vivo* evaluation of the quality of the preparation of the coronal, middle and apical thirds of long-oval root canals in mandibular molars when using the Reciproc (VDW, Munich, Germany) system compared to the BioRaCe system (FKG Dentaire, La Chaux-de-Fonds, Switzerland). The experimental hypothesis was that a single-file reciprocating system prepares oval root canals with the same efficacy as a full-sequence rotary system.

Materials and methods

Selection of teeth

After obtaining approval from the Research Ethics Committee (CAAE01835012.4.0000.0075), 30 extracted human mandibular molars with complete apices and a single distal canal with a curvature below 20° as determined by Schneider's method (Schneider 1971) were selected and placed in saline. The specimens were radiographed in both the buccal-lingual (BL) and mesiodistal (MD) directions and classified as long oval if the BL diameter of the distal root was two to four times as high as its MD diameter 5 mm from the root apex (Wu *et al.* 2000, Jou *et al.* 2004) (Image Tool, U.S. National Institute of Health, Bethesda, MD, USA). Tooth length was standardised at 18 mm (Freire *et al.* 2011). Subsequently, each tooth was dried and scanned at an isotropic resolution of 11.88 μm using a high-resolution microtomography scanner with aluminium and copper filters (SkyScan 1172 ; Bruker-microCT, Bruker, Aartselaar, Belgium) at 100 kV and 100 μA.

Access to the canals was obtained using high-speed diamond burs (n.1014, KG Sorensen, Sao Paulo, SP, Brazil). No coronal pre-flaring was performed before the procedure (Machado *et al.* 2013, Yared 2013), and the distal canals were only explored with a size 10 hand file until the tip of the instrument became visible with a dental operating microscope at X8 magnification (Alliance, São Paulo, Brazil) at the apical foramen. The working length (WL) was established 1 mm short of the distance measured by the K-file (Freire *et al.* 2011).

Teeth were randomly divided into two experimental groups consisting of fifteen specimens each which were then randomly assigned to one of the two preparation techniques: Reciproc (RP) or BioRaCe (BR). One operator (an endodontic specialist) with 12 years of clinical experience with rotary instruments prepared all samples.

Root canal preparation with Reciproc (R40)

As the distal roots accommodated a passive insertion of a size 20 K-file up to the WL, the instrument Reciproc R40 was selected according to the manufacture's protocol.

The Reciproc R40 (size 40, .06 taper) instrument was activated in a reciprocating motion by a VDW Silver electric motor (VDW GmbH, Munich, Germany). According to manufacturer's instructions, the activated instrument was gradually inserted in the canal using an in-and-out pecking motion of approximately 3 mm in amplitude with lateral brushing strokes. After three pecking motions, the instrument was removed and cleaned, and the canal was irrigated, aspirated and flooded with 6 mL of 2.5% sodium hypochlorite. After three cycles of three pecking motions, the file reached WL at which point a size 10 K-file was used to ensure patency. A total volume of 18 mL of the irrigation solution was used in every distal canal. As the Reciproc is a single-use instrument, a new file was used in every specimen.

Root canal preparation with BioRaCe (BR0–BR5)

Distal roots assigned to this group were prepared with BioRaCe instruments using a VDW Silver electric motor (VDW GmbH) adjusted to complete rotary motion at 500 rpm. The initial 4 to 6 mm of the cervical third was prepared with the BR0 size 25, 0.08 taper file. BR1 size 15, 0.05 taper, BR2 size 25, 0.04 taper and BR3 size 25, 0.06 taper files were used at WL. As the BR3 easily reached the WL, BR4 size 35, 0.04 taper and BR5 size 40, 0.04 taper files were used to perform the final apical preparation. Preparation involved pecking motions with lateral brushing strokes against the root canal walls. Every time the file was changed, irrigation was performed with 3 mL of 2.5% sodium hypochlorite yielding a total of 18 mL per specimen. To ensure patency, a size 10 K-file was taken beyond the foramen every time the instrument was changed. Each basic BioRaCe set was used only once.

In both groups, a final flush was performed with 5 mL of 17% EDTA followed by 5 mL of 2.5% sodium hypochlorite. The canals were aspirated with a capillary tip and dried with paper points. The pulp

chambers were filled with a temporary filling (Coltosol, Vigodent, Rio de Janeiro, Brazil), and the teeth were scanned, applying the same initial parameter settings.

Assessment of root canal preparation

The images of each tooth were reconstructed (NRecon v.1.6.6.0, Bruker micro-CT), and the area from root apex to the cementoenamel junction was assessed in 600 of 800 sections per specimen. Individual custom jigs were not fabricated (Versiani *et al.* 2011, 2013) as the superimposition of pre- and post-instrumentation imaging was performed by the imaging processing software (MatLab R2012b 8.0.0.783, Mathworks, Natick, MA, USA).

Volume was assessed using the CTAn v.1.12.0.0 software (Bruker micro-CT), according to the most classic and recent studies in the literature (Paqué *et al.* 2009, Paqué & Peters 2011), and the change in root canal volume was calculated by subtracting the post-preparation root canal volume from the pre-preparation volume. The mean volume increase (%△) was calculated using the values obtained before (B) and after (A) root canal preparation according to the following formula (23): %△ = (B * 100/A) − 100.

A quantitative analysis of unprepared surfaces was performed by superimposing cross-sectional images of the root canals obtained before and after preparation. The calculation of unprepared surfaces of the root canal walls was achieved by subtracting the number of static surface voxels from the total number of surface voxels (Peters *et al.* 2001, Paqué *et al.* 2010). The post-preparation scans were recorded and aligned with the pre-preparation scans using the MatLab software.

The MeshLab v.1.3.2 software (Istituto di Scienza e Tecnologie dell'Informazione, Pisa, Italia) provided three-dimensional visualisation and allowed for the qualitative assessment of prepared and unprepared root canal surfaces. By convention (Rhodes *et al.* 1999), preoperative root canal models were coloured in green, and postoperative models were coloured in red.

Statistical analysis

The nonparametric Mann–Whitney test was used to analyse the root canal volume and unprepared surfaces between the groups, whilst the Kruskal–Wallis test was used to compare the same preparation system at different root canal thirds.

Results

Changes in volume

Table 1 shows the means plus the standard deviations of pre-instrumentation root canal volume for the Reciproc and BioRaCe systems. There was no significant difference in volume between the groups ($P > 0.5$). The results for the three-dimensional analysis of volume increase are detailed in Table 2 for the entire canal and its thirds.

Instrumentation of the canals resulted predictably in increased canal volume. The Reciproc group were associated with a greater volume increase (in mm^3) along the entire canal and apical third than the BioRaCe ($P = 0.41$ and $P = 0.11$, respectively). In

Table 1 Morphometric changes (mean standard ± deviation) for pre-instrumentation volume values for the total canal and each of its thirds

	Pre-instrumentation Volume		
	Reciproc	BioRaCe	*P*-value
Total Canal	7.26 ± 2.77	6.96 ± 3.64	0.72
Coronal Third	4.37 ± 1.86	4.23 ± 2.06	0.57
Middle Third	2.17 ± 1.00	2.02 ± 1.07	0.58
Apical Third	0.67 ± 0.38	0.68 ± 0.41	0.75

No statistically significant difference.

Table 2 Morphometric changes (mean ± standard deviation) in absolute (△) and percentage (%△) values for increase in the volume of the root canal as a whole and of each of its thirds using the Reciproc and BioRaCe systems

Systems	Total	1/3 coronal	1/3 middle	1/3 apical
Reciproc				
△	2.52 ± 1.66[a]	1.53 ± 0.96	0.67 ± 0.44	0.45 ± 0.28
%△	27.52 ± 18.98	28.08 ± 18.55	26.04 ± 19.13	44.04 ± 18.64[a]
BioRaCe				
△	2.24 ± 1.96[a]	1.36 ± 1.30	0.68 ± 0.63	0.30 ± 0.19
%△	26.31 ± 18.39	26.22 ± 20.30	26.23 ± 19.29	35.43 ± 19.71[a]

[a]Statistically significant difference between the groups in the same vertical column ($P < 0.5$).

Table 3 Morphometric changes (mean ± standard deviation) in unprepared surfaces of the root canal as a whole and of each of its thirds prepared with Reciproc and BioRaCe systems, expressed as voxels (△) and percentages (%△)

Systems	Total	1/3 coronal	1/3 middle	1/3 apical
Reciproc				
△	40.10 ± 2.94[a]	57.10 ± 1.93[a]	59.89 ± 1.89[a]	3.30 ± 0.45[a]
%△	15.12 ± 10.32[a]	18.14 ± 8.37[a]	21.82 ± 9.55[a]	5.39 ± 3.26[a]
BioRaCe				
△	26.62 ± 2.75[a]	29.16 ± 1.39[a]	35.71 ± 1.32[a]	14.99 ± 0.86[a]
%△	9.73 ± 5.66[a]	8.14 ± 3.61[a]	11.35 ± 5.50[a]	9.70 ± 6.97[a]

[a]Statistically significant difference between the groups in the same vertical column ($P < 0.0001$).

percentage terms, there was no significant difference considering the entire canal when the experimental groups were compared. Therefore, considering only the apical third, the volume increase in the Reciproc was significantly greater ($P < 0.5$).

Unprepared surfaces

Table 3 describes the means and standard deviations for the unprepared surfaces for the entire canal and coronal, middle and apical thirds prepared with either the Reciproc or BioRaCe systems. The Reciproc group left 18.14% of unprepared surfaces in the coronal, 21.82% in the middle and 5.39% in the apical third. In the BioRaCe group, these values were 8.14%, 11.35% and 9.70%, respectively. These differences were significant ($P < 0.0001$).

Considering the entire canal, the Reciproc system left 15.12% of unprepared surfaces and the BioRaCe, 9.73% ($P < 0.0001$).

The reconstructed models from the Reciproc and BioRaCe groups are displayed in Fig. 1.

Discussion

Studies of several preparation techniques and a variety of instruments claiming to solve the problem of unprepared surfaces in root canal walls can be found in the literature (Paqué *et al.* 2010, Ruckman *et al.* 2013). The main purpose of this study was to evaluate the quality of shaping achieved in the coronal, middle and apical thirds of long-oval root canals when instrumentation was performed with a single-file, reciprocating motion system (Reciproc) compared to a system involving a sequence of files used in rotational motion (BioRaCe). The tip diameter was size 40 in both systems as for the selection of the Reciproc instrument, only a size 20 K-file passively reached the WL. A size 30 K-file was unsuited for the distal canals in this study.

Distal root canals in extracted human mandibular molars represent a model of long-oval canals (Paqué *et al.* 2010, Paqué & Peters 2011), with a mean diameter ratio of 1:3.58 in this study. The challenge of preparing these canals is related to the difficulty in removing the inner layer of dentine in the buccolingual dimension, more than in round canals (Wu *et al.*

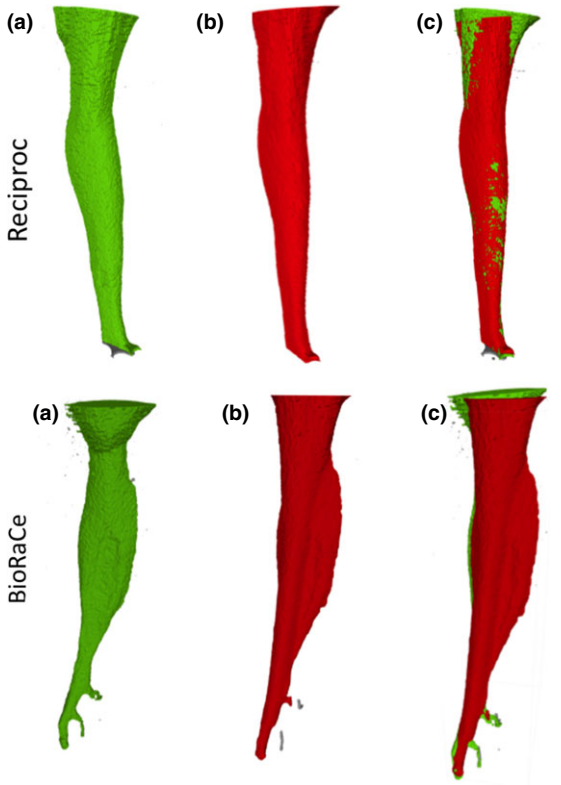

Figure 1 Three-dimensional reconstructions of the internal anatomy of the lower molar distal canals of both experimental groups before and after root canal preparation. (a) Lateral view of the canal before preparation. (b) Lateral view of the canal after preparation. (c) Superimposed lateral views of the canal before (green) and after (red) preparation.

2000, Rödig *et al.* 2002, Weiger *et al.* 2002, ElAyouti *et al.* 2008, Metzger *et al.* 2010, Paqué & Peters 2011).

The quality of preparation was assessed by volume increase and the amount of unprepared root canal surfaces. The evaluation was performed for the entire root canal and for each third separately; this approach prevented the loss of significant results for each third. When the percentage of volume increase of the entire canal was compared between groups, no significant difference was found (Versiani *et al.* 2011, Markvart *et al.* 2012). On the other hand, the volume increase in cubic millimetres revealed significant differences and was greater for the Reciproc.

Root canal preparation resulted in an increased total canal volume (Peters *et al.* 2000, Bergmans *et al.* 2001, Paqué *et al.* 2010, Paqué & Peters 2011) in both the Reciproc and BioRaCe groups. However, more dentine was removed from the entire root canal and from its apical third by the Reciproc instrument. The high cutting efficacy of the Reciproc instrument has been previously reported and is probably related to its S-shaped cross section and positive cutting angle (Capar *et al.* 2014, Plotino *et al.* 2014). A significantly larger per cent volume increase in the apical third was expected due to the comparatively larger taper of the Reciproc file along its first three millimetres and the rounder dimensions of the root canal in the apical third. Nonetheless, no difference was observed between the Reciproc and BioRaCe systems when comparing the volume increases in the coronal and middle thirds, probably because according to the manufacturer, the Reciproc instrument has a mean 4% taper after the first three millimetres, the same as the BioRaCe system.

This study differs from previous studies (Paqué *et al.* 2010, Paqué & Peters 2011, Versiani *et al.* 2011, 2013) as it measures unprepared surfaces not only by analysing the percentage of the number of static surface voxels to the total number of surface voxels but also by analysing the surface in absolute values, the number of surface voxels – not percentage, avoiding dilution of values. With absolute values and the specific evaluation of each third of the root canal, the results of this study differ from other recently published investigations (Versiani *et al.* 2011, 2013) that found single and complete sequence systems to have similar performance when comparing the prepared dentine walls after root canal shaping. However, the present study found that neither technique was capable of completely preparing long-oval root canals, as reported previously (Wu & Wesselink 2001, Barbizam *et al.* 2002, Weiger *et al.* 2002, Rüttermann *et al.* 2007, ElAyouti *et al.* 2008, Paqué *et al.* 2010, Versiani *et al.* 2011, 2013). The preparation strategy and the manufacturer instrumentation did not properly prepare nonround root canals, leaving some surface of the canal unprepared. Preoperative canal anatomy remains challenging, and the brushing motion after reaching the WL is important to prepare more dentine walls.

Conclusion

Both Reciproc and BioRaCe did not completely prepare long-oval root canals. Although the Reciproc system had a greater volume increase in the entire canal and in the apical third, untouched surfaces were identified. BioRaCe left fewer dentine walls untouched in the cervical and middle thirds of the root canal, and the Reciproc had less untouched walls in the apical third.

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