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AVALIAÇÃO DA CENTRALIZAÇÃO DO PREPARO DO CANAL RADICULAR E DA FADIGA DO INSTRUMENTO COMPARANDO TRÊS SISTEMAS ROTATÓRIOS DE NÍQUEL-TITÂNIO

Porto Alegre

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Dissertação apresentada como parte dos requisitos obrigatórios para obtenção do título de Mestre em Endodontia, pelo Programa de Pós-Graduação da Faculdade de Odontologia da Pontifícia Universidade Católica do Rio Grande do Sul.

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Porto Alegre

2012

Dedico essa dissertação à minha família,

que sempre me estimulou a prosseguir...

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RESUMO

Introdução: Este estudo *in vitro* avaliou a capacidade de centralização do preparo, bem como o desgaste distorção e a fratura de três tipos de instrumentos rotatórios de níquel-titânio (Ni-Ti) – Wizard CD Plus (WP), Wizard Navigator (WN) e BioRace(BR). **Metodologia:** Foram utilizadas 90 raízes mésio-vestibulares (MV) de primeiros molares superiores (1^{os} MS) e 10 conjuntos de cada tipo de instrumento rotatório. A sobreposição de imagens tomográficas de feixe cônico pré e pós-instrumentação avaliaram a capacidade de centralização do preparo, a 2,0, 4,0, 6,0 e 8,0mm do ápice. Os instrumentos foram avaliados em microscopia eletrônica de varredura (MEV), antes e após até o terceiro uso, na sua ponta e a 5mm desta. Os dados foram analisados pelo Teste de Kruskal-Wallis, complementado pelo Teste de Tukey ($P<0.05$). **Resultados:** Houve transporte do canal radicular em todos os grupos, não havendo diferença estatística entre os mesmos ($P>0.05$). Não houve fratura e distorção a 5mm da ponta nos instrumentos analisados. O grupo BR apresentou mais distorção na ponta do instrumento do que o grupo WP ($P=0,011$). Houve mais desgaste do instrumento no grupo WP do que no BR ($P<0,001$). Ocorreu aumento progressivo da distorção na ponta do instrumento e do desgaste em relação ao uso no grupo BR (distorção $P=0,026$ e desgaste $P<0,001$), assim como do desgaste no grupo WP ($P<0,001$). **Conclusão:** Nenhum dos sistemas rotatórios empregados foi capaz de proporcionar preparos centralizados e o uso progressivo dos instrumentos aumenta a ocorrência de distorção e desgastes em sua topografia.

Palavras chave: canal radicular, preparo químico-mecânico; instrumentação rotatória; microscopia eletrônica de varredura; tomografia de feixe cônico

ABSTRACT

Introduction: This *in vitro* study evaluated the capacity of centralization of the preparation, as well as the wear, distortion and fracture of three rotary nickel-titanium (Ni-Ti) systems – Wizard CD Plus (WP), Wizard Navigator (WN) and BioRace(BR). **Methodology:** Were used 90 mesiobuccal roots (MV) of first upper molars (MS). The overlap of tomographic images before and after instrumentation was used to evaluate the transport of the preparation, at 2.0, 4.0, 6.0 and 8.0 mm from the apex. The instruments were observed by SEM before and after the third use, at its tip and at 5 mm of it. The data were analyzed by Kruskal-Wallis, complemented by Tukey test ($P<0.05$). **Results:** There was transport of the root canal in all groups, with no statistical difference between them (P> 0.05). There was no fracture and distortion at 5mm from the tip of the instruments. The group BR exhibited more distortion at the tip than the group WP ($P = 0.011$). There was more wear of the instrument in the group WP than in the BR ($P <0.001$). There was a progressive increase in distortion at the tip ($P = 0.026$) and of the wear ($P <0.001$) compared to the use in the group BR, as well as the wear in the group WP ($P<0.001$). **Conclusion:** None of the rotary systems employed was able to provide centralized preparation and the progressive use of the instruments did not favor the occurrence of fracture despite having increased the occurrence of distortion and wear.

Key words: root canal; rotary instrumentation; scanning electron microscopy; cone beam CT.

SUMÁRIO

1 INTRODUÇÃO

A instrumentação mecânica do sistema de canais radiculares é uma importante fase do preparo do canal radicular (Auerbach, 1948; Schilder, 1974), pois designa espaço para a ação de soluções irrigadoras e medicações intracanal a fim de combater bactérias e seus subprodutos. Entretanto, essa constitui a etapa com maior dificuldade da terapia endodôntica (Hulsmann, Peters *et al.*, 2005). Sugere-se que quanto mais alargado for o preparo do canal radicular (tão largo quanto a anatomia radicular permitir), somado ao uso frequente e abundante de soluções irrigadoras antimicrobianas, mais eficaz será o preparo químico-mecânico (Siqueira, Rocas *et al.*, 2002).

Mesmo a partir da década de 80, após o advento dos instrumentos de níquel-titânio (Ni-Ti) na Endodontia, a busca por técnicas e sistemas rotatórios que propiciem um preparo ideal permanece um desafio. Diferentes sistemas rotatórios vêm sendo propostos, os quais são utilizados em baixa-rotação em contra-ângulos acoplados a motores elétricos ou pneumáticos, esses sistemas buscam realizar preparos centralizados que proporcionem a manutenção do formato original do canal radicular e conicidade, sem a formação de degraus, zips, transportes e desvios (Hulsmann, Peters *et al.*, 2005; Hartmann, Barletta *et al.*, 2007; Lopez, Fachin *et al.*, 2008; Gergi, Rjeily *et al.*, 2010).

Durante o preparo do canal radicular, a remoção excessiva de dentina em uma única direção causa transporte do mesmo (Hartmann, Barletta *et al.*, 2007), o que compromete sua limpeza e aumenta os riscos de acidentes como perfurações. Os instrumentos de NiTi, devido a sua elasticidade, possuem capacidade maior de manter a centralização do canal radicular, resultando em um preparo mais satisfatório para canais radiculares com curvaturas acentuadas quando comparados com preparos feitos por instrumentos manuais. (Schafer, Tepel *et al.*, 1995; Chan e Cheung, 1996; Lopez, Fachin *et al.*, 2008).

Por outro lado, o uso continuado dos instrumentos de NiTi pode causar deformações na estrutura metálica da liga (Troian, So *et al.*, 2006), o que pode contribuir para um preparo inadequado, resultando em uma limpeza e modelagem insuficientes para a sanificação do sistema de canal radicular. Além disso, defeitos na superfície do instrumento endodôntico são capazes de favorecer a fratura dos mesmos (Kuhn, Tavernier *et al.*, 2001), o que diminui a segurança dos profissionais para a sua utilização (Plotino, Grande *et al.*, 2009).

Apesar da grande quantidade de estudos encontrados na literatura a respeito dos instrumentos de NiTi, constata-se que a relação entre possíveis alterações na topografia do instrumento, causadas pelo uso repetido, com a sua capacidade de proporcionar preparos centralizados dos canais não foi investigada. Além disso, os instrumentos Wizard Navigator e Wizard Plus, que apresentam secção transversal triangular e não possuem qualquer tipo de tratamento de superfície, não possuem investigações prévias quanto à centralização do canal e a possíveis alterações de sua superfície após o uso. Em contrapartida, os instrumentos BioRace, que possuem secção transversal triangular e superfície eletropolida(Bonaccorso, Cantatore *et al.*, 2009; Lopes, Elias *et al.*, 2010; Yamazaki-Arasaki, Cabrales *et al.*, 2011), são mais resistentes à fadiga cíclica (Lopes, Elias *et al.*, 2010), e apresentam resultados satisfatórios no preparo de canais radiculares curvos (Bonaccorso, Cantatore *et* *al.*, 2009). Além disso, demonstraram, por meio de microscópio de força atômica (AFM), alteração na topografia do seu terço cervical, após doze usos(Yamazaki-Arasaki, Cabrales *et al.*, 2011).

Assim, o presente estudo teve como objetivo avaliar a centralização do preparo do canal, mediante o primeiro uso dos sistemas Wizard CD Plus (Medin, Nové Město na Moravě, Czech Republic), Wizard Navigator (Medin, Nové Město na Moravě, Czech Republic) e BioRace (FKG Dentaire, Les Chaux-de-Fonds, Suíça), assim como a distorção de espiras, desgaste superficial e fratura dos mesmos antes e até após o terceiro uso.

2 ARTIGO 1

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Canal centering ability and stress suffered by Ni-Ti instruments: a comparison among Wizard CD Plus, Wizard Navigator and BioRace.

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Canal centering ability and stress suffered by Ni-Ti instruments: a comparison among Wizard CD Plus, Wizard Navigator and BioRace.

ABSTRACT

Introduction: This *in vitro* study evaluated the canal centering ability as well as the wear, distortion and fracture of three rotary nickel-titanium (Ni-Ti) systems – Wizard CD Plus (WP), Wizard Navigator (WN) and BioRace(BR). **Methodology:** 90 mesiobuccal roots (MB) of first upper molars (UM) were used. Canal transportation was evaluated at 2.0, 4.0 and 8.0mm from the apex, by means of subtracting tomographic images taken before and after preparation. The instruments were observed by SEM before and after the third use, at its tip and at 5 mm of it. The data were analyzed by Kruskal-Wallis, complemented by Tukey test ($P<0.05$). **Results:** Canal transportation occurred in all groups, and significant differences were not detected ($P> 0.05$). There was no fracture and distortion at 5mm from the tip of the instruments. The group BR exhibited more distortion at the tip than the group WP ($P = 0.011$). There was more wear of the instrument in the group WP than in the BR ($P <0.001$). In BR instruments, surface wear ($P<0.001$) and distortion of its tip ($P=0.026$) increased according to the number of uses, while for WP instruments only surface wear was affect ($P<0.001$). **Conclusion:** None of the rotary systems employed was able to provide centralized preparation and the progressive use of the instruments did not favor the occurrence of fracture until third use despite having increased the occurrence of distortion and wear.

Key words: centering ability; rotary instrumentation; cone beam CT; Endodontics

INTRODUCTION

Appropriate cleaning and shaping are essential for a successful root canal therapy (1-2). On this regard, a centralized enlargement allows the maintenance of root canal original shape and taper, provides more efficient disinfection and avoid root perforations (3-6). As a matter of fact, as of the 80’s. the introduction of nickel-titanium (Ni-Ti) instruments opened new perspectives in Endodontics, since their superelasticity helps on centering ability (4, 7-8). On the other hand, ideal instruments are still desired, and a wide range of rotary systems are constantly developed.

The instruments Wizard Navigator and Wizard Plus, which have triangular cross-section and do not have any surface treatment, have no prior investigations of canal centering ability and the possible changes in its surface after use. In contrast, BioRace instruments, which have triangular cross-section and electropolished surface (9-11), are more resistant to cyclic fatigue (10) and have satisfactory results in the preparation of curved root canals (11). Also, they demonstrated by means of an atomic force microscope (AFM), change in the topography of their cervical third after twelve uses (9).

On the other hand, the continuous use of Ni-Ti instruments may cause deformations in the metal structure of the alloy (12), which can contribute to an inadequate preparation, resulting in an insufficient cleaning and shaping for the disinfection of the root system. Moreover, defects in the surface of the endodontic instrument are capable of favoring their fracture (13), which reduces its security (14).

Despite the vast amount of research found in the literature regarding the NiTi tools, it is noted that the correlation between possible changes in the topography of the instrument caused by the repeated use, with its ability to provide centralized preparation of the canals has not been investigated.

Thus, the present study aimed to evaluate the canal cantering ability through the first use of the systems Wizard CD Plus (Medin, Nové Město at Moravě, Czech Republic), Wizard Navigator (Medin, Nové Město at Moravě, Czech Republic) and BioRace (FKG Dentaire, Les Chaux-de-Fonds, Switzerland) as well as the distortion of spirals, surface wear and their fracture before and after the third use.

MATERIALS AND METHODS

This study was approved by the Pontifical Catholic University of Rio Grande do Sul (PUCRS) institutional Ethics and research committees. (CEP 11/05622).

Ninety mesiobuccal roots were used (MB) of human first upper molars (UP) extracted, provided by PUCRS institutional bank of teeth.

The roots were radiographed with the direct digital system CCD Cygnus Ray MPS (Progeny - Buffalo Grove - IL-USA) and the device Gnatus 70X (Gnatus Medical and Dental Equipment Ltd - Ribeirão Preto - SP) in order to provide the stratified randomization of the sample, the degree of root canal curvature, measured as established by Schneider (15) and the distance from the beginning of the curve in relation to the root apex (16), were considered. Operated at 10 mA, 70 kVp, and with exposure time of 0.4 seconds. Teeth presenting previous endodontic manipulation, incomplete root formation, calcifications and/or root resorption were excluded.

Preparation of the canals

A single operator, trained for the use of rotary systems, performed the canals instrumentation. After the endodontic access and irrigation of the canal with NaOCl 1% (Liquid from Milton, Biodynamic, Ibiporã, Brazil), the working length (CT) was established retreating 1mm of the measurement obtained after the Instrument # 10 (Dentsply-Maillefer , Ballaigues, Switzerland) be juxtaposed to the apical foramen. In all cases the CT was between 16 and 18mm.

For the preparation of the root canals 10 sets of each rotatory system of Ni-Ti: Wizard CD Plus (WP); Wizard Navigator (WN) and BioRaCe (BR), were used. Each set of instruments was used to prepare three root canals.

Initially, manual tools # 10 and # 15 (Dentsply-Maillefer, Ballaigues, Switzerland) were used throughout the CT. Then, the rotary systems were used, in pecking movements, in electric motor (X-Smart, Dentsply-Maillefer, Ballaigues, Switzerland), with speed and torque adjusted as follow: 250 RPM and 0.2 to 3N.cm for WP ; 300RPM and 1.2 to 2.3 N.cm for WN, 600 RPM and the maximum torque for BR. At each change of instrument, the canals were irrigated with 2 ml of the same solution.

The sequence of instruments used in each of the systems can be found in Table 1.

Tomography

To perform the scans before and after root canal preparation, the teeth were fixed in a rectangular acrylic platform previously perforated (17) with the buccal surface toward its front end, and scanned (I-Cat cone beam, Imaging Sciences International, Hatfield, PA, USA, with 120,000 kV and 46.72 mA, acquisition time of 40 seconds, FOV = 6.0 cm, matrix 800/800 pixels and voxel of 0.2 mm). The raw scanning data were analyzed by the software Xoran-Cat (Imaging Sciences International, Hatfield, PA, EUA).

Evaluation of the centralization of preparation

The tomographic images before and after preparation were acquired through the DICOM files (17) obtained through the program Efilm (Merge HealthCare) and transferred to the Adobe Photoshop program (version CS3, Adobe Systems Inc, San Jose, CA, USA). In the axial sections corresponding to 2, 4, 6 and 8 mm from the apex, a point was marked at the center of the root canal (Fig. 1b-c).

The images before and after preparation were overlapped by the subtraction technique (Fig 1a). The distance between the marked points was measured, in pixels, in the directions buccal-palatal (BP) and mesiodistal (MD) (Fig. 1d). The closer to zero was the obtained measure, more centered was the canal preparation (6).

SEM of the instruments

The instruments were examined under a microscope Philips XL 30 (Eindhoven, North Brabant, Netherlands), in four periods: before the first and until after the third use, at its tip of and at 5mm from it, with x100 magnification. To do so, previously, they were washed in ultrasonic vat (Cristófoli, Campo

Mourão, Brazil), packed in surgical grade paper (Descapark, Sao Paulo, Brazil), and sterilized by autoclaving (Dabi Atlante, Ribeirão Preto, Brazil).

Evaluation of the instruments

The images were classified by a blinded calibrated investigator *(Spearman Correlation , P <0.05)* as to the distortion of the spirals (unwinding, reverse winding or shortening of the spirals along the surface examined), the superficial wear (surface defects of the instrument), and the fracture of the instrument, as described by Troian et al. (12) with some modifications (Figure 2).

Statistical analysis

The data regarding the centralization of the preparation of the canal and of the instruments were analyzed by the Kruskal-Wallis test, complemented by the Tukey test when necessary ($P<0.05$).

RESULTS

All techniques produced root canal transport, with no statistically significant difference among groups, both in the direction B-P (P = 0.093) and in the direction M-D (P = 0.063), regardless of the location of observation (2, 4, 6 and 8mm.) The results are shown in the graph of Figure 1E.

There was no fracture and distortion at 5 mm from the tip of the instruments analyzed. However, in relation to the distortion of spirals at the tip of the instrument, the group BR distorted more than the group WP *(P = 0.011).*

As to the wear on the tip and at 5 mm, there was statistically significant difference among the three groups. The WP group showed the greatest wear in both assessments and the group BR the smallest *(P <0.001).*

There was a progressive increase in the distortion at the tip of the instrument and in the surface wear, at the tip as well as at 5 mm of it, regarding the use in the group BR (distortion $P = 0.026$ and wear $P <0.001$), and also progressive increase of wear, in the tip as well as at 5 mm of it, in the group WP ($P <0.001$). Illustrative images of the instruments and the graph with the values of the mean scores are shown in Figure 2.

DISCUSSION

Even with the increasing evolution of rotary instruments in endodontics, there is still a constant search for centralized preparation, made by instruments that suffer the minimum degree of distortion, wear and fracture. The present research showed that there was transport of the root canal, regardless of the rotary system employed, of the sections and the senses analyzed, which agrees with the findings of other authors (6, 17, 18). However, even being the apical transport still frequent with the use of these instruments, it appears to be less frequent compared to manual techniques for preparation of the canal (19). As to the direction of transport, our results differ from those found by Oliveira et al (17), who demonstrated a greater tendency toward mesial transport.

Several studies, using simulated canals (9, 12 ,20) and extracted human teeth (3, 6, 18, 21-24) have been conducted to evaluate the centralization and transport of the preparation. To this end, methods of scanning of cross (18) and longitudinal (4) sections, photographic (25) and radiographic (23, 26) and, more recently, computed tomography (3, 6, 17) and microtomography (27-28) have been used. Extracted human molars were preferred in this study, rather than resin simulated canals due to the anatomical complexity (29-30) and because they require of the instrument a smaller number of revolutions to complete the preparation of the canal (31). Moreover, the resin is not as hard as the dentine, and the resin chips generated are larger, causing frequent blockages of the apical third (5).

In this study, no instruments ended up fractured, reinforcing the findings of Kawakami and Gavini (32) which showed that the use of instruments for up to seven times does not seem to influence the occurrence of fracture. However, in another study, the repeated use of Profile instruments significantly reduced the torque and the angle of rotation necessary to occur the fracture of these instruments (33).

Instrument BR showed greater distortion at the tip than the WP. Perhaps this fact may be related to the diameters of the apical widening, which were 0.40 mm and 0.30 mm, respectively. Although there was no difference among the BR and WN instruments in this regard, during the canal preparation with

BR, there was a perception of active cutting of the instrument, which was not perceived with the use of WP and WN.

The WP instruments presented higher superficial wear at the tip as well as at about 5 mm from it, followed by WN and BR instruments, which demonstrated the lowest scores. The surface treatment by electropolishing may have influenced these results.

The increase in the number of use of the instruments seems to have a direct effect on the distortion of spirals and on superficial wear of the instruments of the BR group, a fact also mentioned in other studies with respect to the instruments Race (12) and Profile (34). In this experiment, maximum speed and torque were used as recommended by the manufacturer, which may have favored a higher occurrence of distortion of spirals. In a recent study it was found that the torque had affected the resistance to the cyclic flexural fatigue of the instruments utilized, a factor that may also suggest a change in the morphology of the instrument (32). Also the WP instruments had a progressive increase of wear, with respect to use, which did not occur in the WN. The latter have instruments with the tip diameter of 0.10 mm and 0.15 mm, and may not have acted on the walls of the canal in apical, since, anatomically, the apical diameter of the MV root of the upper molars is of 0.24 mm, 0.28 mm and 0.31 mm in patients up to 24 years, among 25 and 40 years and over 40 years, respectively (35).

Further studies in the same research line, are necessary to better elucidate the relationship among the occurrence of apical transport and the presence of changes in the topography of the instruments.

Within the limitations of this study, it can be concluded that none of the rotary systems employed was able to provide centralized preparation and that the progressive use of the instruments until third use did not favor the occurrence of fracture despite having increased the occurrence of distortion and wear.

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LIST OF FIGURES

FIGURE 1 – Sequence of the overlapping of images (final over the initial) until approximation to the outer contour of the tooth (a-b), the center of the canal was marked with a red dot (1 pixel) (initial) and a yellow dot (1 pixel) (final) (c) and the transport of the canal was measured in the direction B-P (vertical) and MD (horizontal) - arrows (d). Chart showing median (med) and IIQ of the shifts of the different sections (expressed in mm).

FIGURE 2 - New WP, WN and BR Instruments (0), after the second (2) and third (3) use. Images obtained from the tip of the instrument (a) and 5mm from the tip (b); whitish areas on the surface of the WP and WN instrument corresponds to the surface wear (¤); is observed wear of the edge of the WN instrument after the second use and BR instrument after second and third use(*); instrument BR presented distortion in the spiral of the image of the tip of the instrument after the second and third use (#); graph expressing the mean of scores according to the number of uses. SCORES: <u>Spiral Distortion</u> – (0) No unwinding, reverse winding or shortening of spirals along the shaft examined, (1) Unwinding, reverse winding or shortening of only one spiral along the shaft examined, (2) Unwinding, reverse winding or shortening of more than one spiral along the shaft examined; <u>Surface Wear</u> – (0) No wear along the shaft examined, (1) Small amount of wear: one to three areas with defects along the shaft examined; (2) Moderate wear: four to five areas with defects along the shaft examined; (3) Severe wear: more than five areas with defects along the shaft examined.

LIST OF TABLES

TABLE 1 – Sequence of the instruments utilized

WP	WN	BR
30.08 as far as penetrates	25.07 as far as penetrates	BRO (25.08) at 12mm
#15 type K – manual on CT	#15 type K – manual on CT	
25.10 as far as penetrates	30.06 as far as penetrates	#15 type K – manual
#15 type K – manual on CT	#15 type K – manual on CT	
30.06 as far as penetrates	25.06 as far as penetrates	BR1 (15.05) on CT
#15 type K – manual on CT	#15 type K – manual on CT	
25.04 as far as penetrates on CT	20.06 on CT	BR2 (25.04) on CT
20.04 on CT	15.05 on CT	BR3 (25.06) on CT
20.02 on CT	10.04 on CT	BR4 (35.04) on CT
20.04 on CT	15.05 on CT	BR5 (40.04) on CT
25.04 on CT	20.06 on CT	
30.06 on CT	25.06 on CT	
	30.06 on CT	

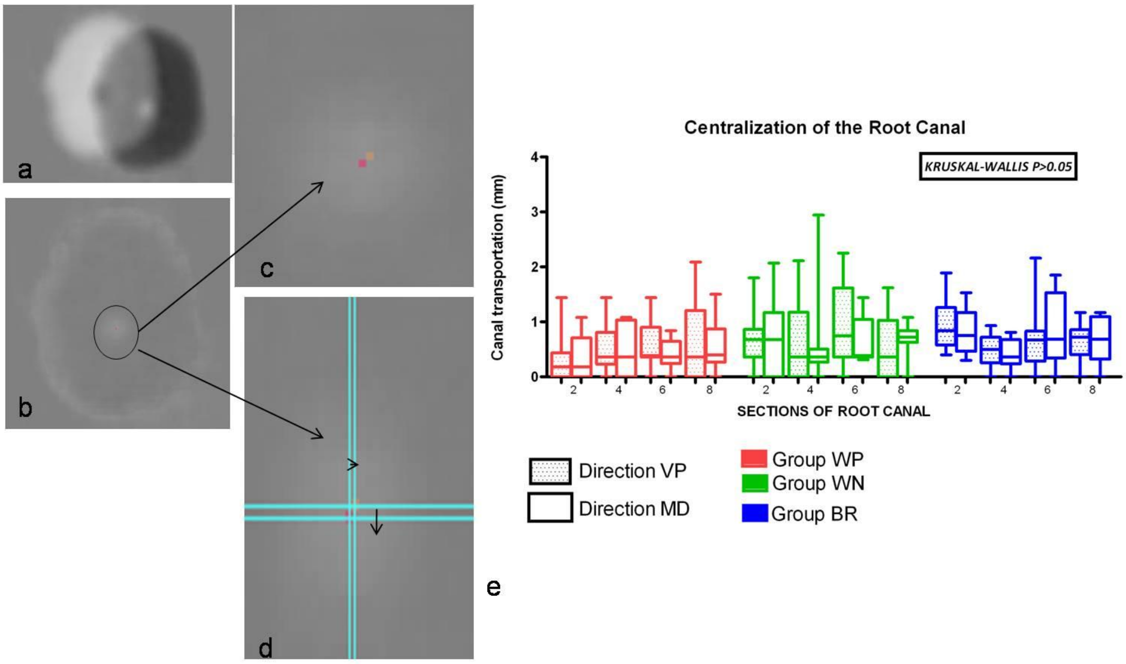

FIGURE 1

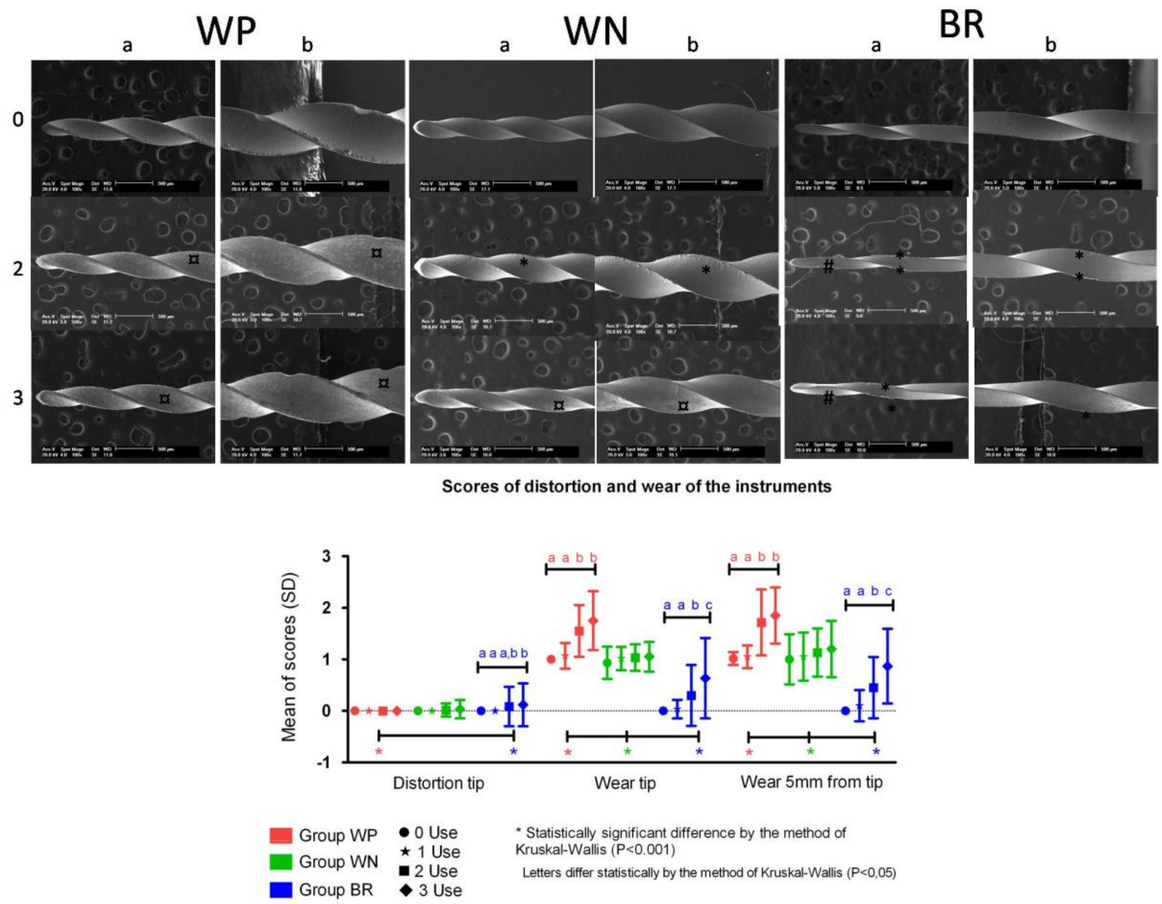

FIGURE 2

3 ARTIGO 2

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Canal centering ability and design of Ni-Ti instruments: a comparison among Wizard CD Plus, Wizard Navigator and BioRace.

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ABSTRACT

Aim: To evaluate the canal centering ability of BioRace (BR), Wizard CD Plus (WP) and Wizard Navigator (WN), associating it with the instruments designs. **Methodology:** The instruments surface and cross sections were observed by means of SEM and described. Additionally, upper first molars mesiobuccal roots were selected, morphologically balanced and divided into three groups (n=10 per group), according to the rotary system used for instrumentation. Canal transportation was evaluated at 2, 4, 6 and 8 mm from the apex, by means of subtracting tomographic images taken before and after preparation. The center of root canal pre- and postpreparation was marked, and the distance between these points was measured, in the buccal-palatal (BP) and mesio-distal (MD) directions. Data were analyzed by two-way ANOVA and Bonferroni *post-hoc* ($P<0.05$). **Results:** Only BR instruments showed a polished and regular surface. Canal transportation occurred in all groups, and in both directions. Significant differences were not detected among the groups, regardless the distance from root apex. Although all systems demonstrated triangular cross sections, BR files showed sharper angles. **Conclusion:** None of the rotary instruments presented ideal centering ability. Differences were found amongst instruments regarding quality of finishing and polishing, with better features for BR instruments.

Key words: centering ability; rotary instrumentation; cone beam; BioRace; Wizard Plus; Wizard Navigator

INTRODUCTION

Appropriate cleaning and shaping are essential for a successful root canal therapy (1-2). In this regard, a centralized enlargement allows the maintenance of root canal original shaping, provides more efficient disinfection and avoid root perforations (3-6). The introduction of nickel-titanium (Ni-Ti) instruments opened new perspectives in Endodontics, since their superelasticity contributes with the instrumentation centering ability (4,7-8). On the other hand, ideal instruments are still desired, and a wide range of rotary systems are constantly developed.

Among them, BioRace (BR) (FKG Dentaire, Les Chaux-de-Fonds, Switzerland), Wizard CD Plus (WP) (Medin, NovéMěsto at Moravě, Czech Republic) and Wizard Navigator (WN) (Medin, NovéMěsto at Moravě, Czech Republic) were recently introduced. These three rotary systems present instruments with iso-sized tips (9). Nevertheless, each one of them offer sequences of files with different tapers, i.e .02 to .08 for BR, .02 to .14 for WP and .04 to .07 for WN instruments.

Moreover, these instruments present differences regarding their design and surface treatment. According to the manufacture, WP instruments show grooves and discontinuous cutting edges, aiming at reducing the risk of torsional fracture (10). BR instruments show an electropolished surface (10,11-13), intending to improve its resistance to cyclic fadigue (13). These features, as well as other non-investigated aspects related to the files design, could affect the preparation centering ability. There are few studies on the capacity of BR instruments avoiding canal transportation (13), whereas WP and WN systems have yet to be studied in this regard.

Thus, the present study aimed at evaluating the canal centering ability of BR, WP and WN instruments, while associating it with the files features observed by means of SEM.

MATERIALS AND METHODS

This study was sanctioned by Pontifical Catholic University of Rio Grande do Sul (PUCRS) institutional ethics and research committees (11/05622). Thirty upper first molars, provided by PUCRS institutional bank of teeth, were selected. The molars were radiographed using a direct digital system (CCD Cygnus Ray MPS - Progeny - Buffalo Grove - USA). Teeth presenting endodontic manipulation, incomplete root formation, calcifications and/or root resorption were excluded. The maximum degree of mesiobuccal canal curvature and its position were determined as previously reported (14-15). In most of the samples, the canals showed curvatures between 25^o and 35^o degrees (ranging from 0.5^o to 58.1^o), and its beginning was observed between 6 and 7 mm from the apex (apical distance ranging from 3.96 to 14.35 mm). The selected samples were divided into three groups balanced for variations in canal anatomy, according to the rotary systems employed for preparation: BioRaCe (BR), Wizard CD Plus (WP) or Wizard Navigator (WN). Ten sets of each system were used, thus establishing a single use for the Ni-Ti files. Prior to the preparation, the mesiobuccal roots were sectioned at cementum-enamel junction, using a high-speed diamond bur (KG Sorensen, Cotia, Brazil) under water-cooling, and the instruments were analyzed by SEM.

SEM analysis of instruments designs

Surface features and the design of BR, WP and WN instruments were examined under SEM (Philips XL-30, Lichtenstein, Netherland) operating at 20kV under magnifications of 100x. The samples were mounted on a stub, in a standardized position so that the files shaft could be observed.

Additionally, one set of each rotary system, not employed for canals preparation, was used to assess the instruments cross section. The files were sectioned at its apical, middle and cervical portions, using a carburundum disc (Talmax, Curitiba, Brazil) under water cooling. Representative images were recorded in a TIFF format at a resolution of 300 dpi. Descriptive analysis was performed.

Canals Preparation

The working length (WL) was visually established, being set, in all samples, in 17 mm. A single trained operator performed the canals instrumentation. For all groups, #10 and #15 files (Dentsply-Maillefer, Ballaigues, Switzerland) were used throughout the WL. Then, the rotary systems were used with pecking motion. At each change of instrument, the canals were irrigated with 2 ml of 1% NaOCl (Biodynamic, Ibiporã, Brazil). The sequences of instruments, speed and torque are set in Table 1.

Cone Beam (CBCT) Imaging

Canal transportation was evaluated by means of subtracting CBCT images obtained before and after instrumentation. 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, USA), operated at 120000 kV and 46.72 mA. The images were captured in a small field of view (6 cm) using exposure time of 40 s, a matrix of 800 x 800 pixels and voxel of 0.2 mm. Xoran- Cat software (Imaging Sciences International, Hatfield, USA) was used for image reconstruction. Slices in the axial direction generated DICOM format archives (16).

Measurement of canal transportation

Centering ability analysis was performed by a single blinded, calibrated examiner. Images of the axial sections corresponding to 2, 4, 6 and 8 mm from the apex were transferred to the Adobe Photoshop program (version CS3, Adobe Systems Inc, San Jose, USA). At each section, images corresponding to the center of the canals pre and post-preparation were marked. These images were overlapped by the subtraction technique (Fig 1a), and the distance between the two points was measured in both BP and MD directions (Fig. 1b-d). The closer to zero was the obtained measure, the more centered was the canal preparation (6).

Statistical analysis

Measures of centering ability were analyzed using two-way ANOVA and Bonferroni *post-hoc* ($P<0.05$).

RESULTS

Instruments Designs

SEM analysis of BR instruments showed few irregularities and a polished surface. The files edges and tip presented well-defined contours. Nevertheless, both WP and WN instruments presented surface defects and irregular edges. Although all systems demonstrated triangular cross sections, BR files showed sharper angles (Figure 2).

Centering ability

Canal transportation occurred in all groups. Significant differences were not detected (Figure 1 e-f), regardless the apical distance (2, 4, 6 and 8 mm) and canal direction ($P<0.05$).

DISCUSSION

The present study analyzed the centering ability of three recently introduced rotary systems. The results observed herein showed that, generally, BR, WP and WN instruments produced similar canal transportation among them, which was also comparable with the amount of deviation produced by other commonly employed rotary systems (3,17). As a matter of fact, studies from others showed that Ni-Ti files did not avoid the occurrence of apical transportation (6,16,18), even if reducing it compared to hand techniques (3-5, 19).

Safe limits for canal transportation must be based on dental anatomical features. Thus, the measures of canal wall thickness at different apical distances are of paramount importance when determining the preparation security. Dental walls appear to be thicker toward the cervical portion. Regarding mesiobuccal canals of maxillary molars, approximately 2 mm from the apex, dental walls thickness are set between 0.84 and 2.15 mm, whilst, at an apical distance of about 8 mm, this measures are comprised between 1.23 and 1.58 mm (20). The correlation between these data and the present outcomes suggests that all groups promoted tolerable canal transportation in most of the samples. Meanwhile, particularly for BR and WN groups, and at 2 mm from apex, canal transportation was critical in some of the specimens if considering the possibility of iatrogenic complications. At this point, although not statistically significant, a clinically relevant advantage was detected for WP centering ability. This fact should be explained by the WP files greater tapers, which were designed intending to provide further elimination of cervical interferences (10).

A number of study models have been used to compare canal shape before and after instrumentation (3-4,6,8,13,16,18,21-22). However, taken into account the importance of dental tissues hardness and of the morphological complexity cited above, curved roots of human molars were preferred (23).

Moreover, to avoid the influence of confounding factors, the groups were balanced for variations in canal anatomy as recommended (14).

As well as previous studies (3,6,16,18), this investigation used CBCT images to assess the preparation centering ability. Besides being a non-destructive and more accurate method, this technique allows the observation in both MD and BP directions, which is not possible when applying conventional radiographs (25). The endodontic literature has yet to clearly established an association between canal curvature and transportation directions. Some studies using mesiobuccal canals showed a tendency toward mesial transportation (16,21), which has been attributed to the fact that curvatures were frequently observed in a distal position. Meanwhile, other authors state that the direction of canal curvature has no effect on the direction of transportation (26). One of the possible explanations for conflicting results is that the methods employed no longer evaluated the discrepancies between MD and BP transportation. The methodology adopted herein allowed this approach, showing similar canal transportation in both directions.

On the other hand, especially for WP and WN systems, the apical distance appears to have an influence on the discrepancies between MD and BP deviations. The greatest differences were observed 6 mm from the apex, showing a tendency toward BP transportation. This section, as showed herein, coincides with the beginning of canals curvatures in most of the samples, which could have affected the direction of enlargement. Besides, the lower amount of discrepancies observed for the BR group at this point was probably influenced by the instruments design and quality of surface finishing.

Unlike BR instrumentation, in which a regular and polished surface was observed, WP and WN instruments showed irregular edges. These features were tactile perceived by the friction during instrumentation, and should have affected the obtainment of circular and uniform preparations, thus producing greater transportations in one of the directions. Besides, files irregularities may have contributed with a poor standardization of centering ability, which was corroborated by the high standard deviations observed. Considering that in the present study a single use was established for the instruments, further studies are warranted to assess the influence of repeated uses on centering ability.

Although the quality of surface finishing did not promote statistically significant differences for the preparations centering ability, it is important to point out that BR instrumentation showed similar results compared to the other groups, regardless the use of a larger-sized master apical file, which could influence the maintenance of canals original position (4).

Conclusion

Taken into account the dimensions of root canal walls, it can be concluded that none of the rotary instruments presented ideal centering ability. Differences were found amongst instruments regarding quality of finishing and polishing, with better features for BR instruments.

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FIGURE LEGENDS

FIGURE 1 – Methodology used for measuring centering ability and the obtained results. (a) images pre and post-instrumentation were overlapped by the subtraction technique; (b-c) the central position of root canal was marker prior (red dot) and post-preparation (yellow dot); (d) canal transportation was measured in buccalpalatal (BP) and mesiodistal (MD) directions (arrows); (e-f) The resulting outcomes of canal transportation did not show statistically significant differences in both directions ($P>0.05$).

FIGURE 2 - Instrument surface and cross-sectional features under SEM. **(A)** 25.08 BR instrument showing round tip and transitional angle. 30.08 WP file presenting a transitional angle, although the tip had a grosser outline. 25.07 WN showing an abrupt transition from the instrument shank to its tip (arrows); Surface finishing was irregular for WP and WN files, and polished for BR instruments (*). **(B)** WP instrument flutes presented flattened cutting edges (∆) compared to BR and WN files, in which a sharp angle could be detected. **(C)** All rotary systems demonstrated triangular cross sections, in spite of the BR files sharper angles. **(D)** Intentional groove defects were found at the flutes of 30.08 WP files. Unintentional gross flute features could be detected along the

instrument differing from 25.07 WN and 25.08 BR instruments. BR files presented a well-defined and polished outline.

TABLE LEGEND

TABLE 1 - Sequence of instruments, speed and torque used for canals preparation

TABLE 1 – Sequence of instruments, speed and torque used for canals preparation

BR■	WP♦	WN●
25.08***	30.08*	25.07*
15 K –file**	15 K-file**	15 K –file**
15.05**	25.10*	30.06*
25.04**	15 K –file**	15 K –file**
25.06**	30.06*	25.06*
35.04**	15 K-file**	15 K –file**
40.04**	25.04*	20.06**
	20.04**	15.05**
	20.02**	10.04**
	20.04**	15.05**
	25.04**	20.06**
	30.06**	25.06**
		30.06**

*as far as penetrate; ** at the WL; ***at 12mm.

■600 RPM / maximum torque; ♦250 RPM / 0.2 -3 N.cm;

●300 RPM /1.2 - 2.3 N.cm.

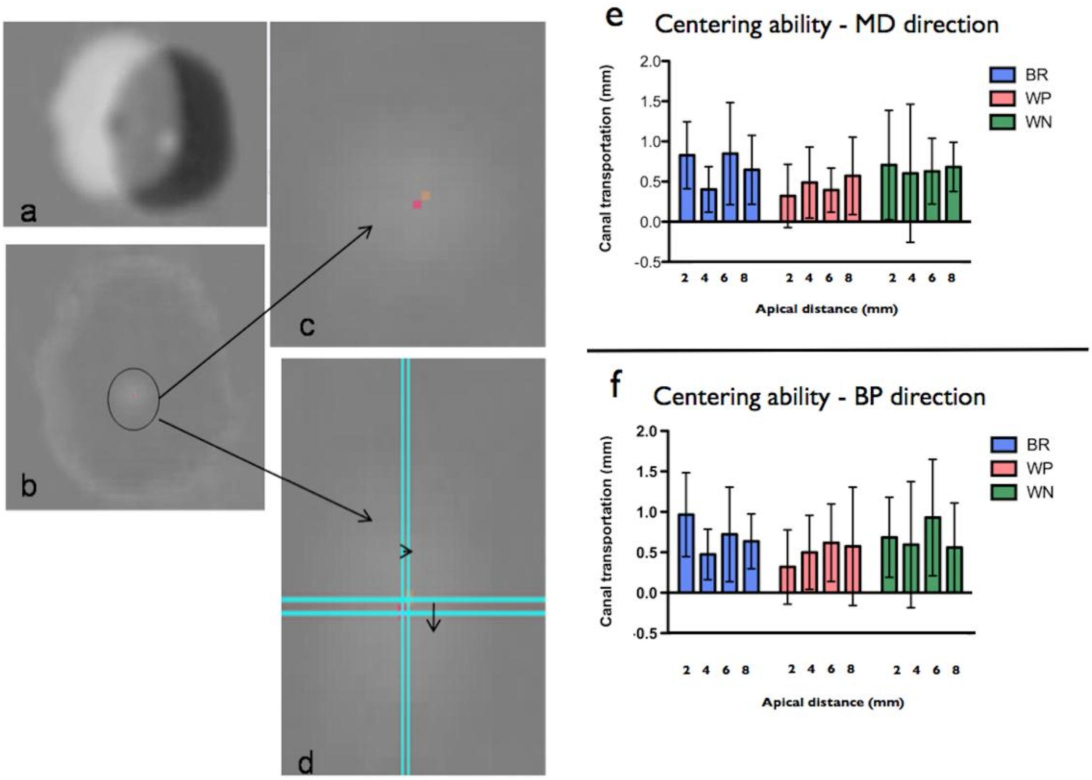

FIGURE1

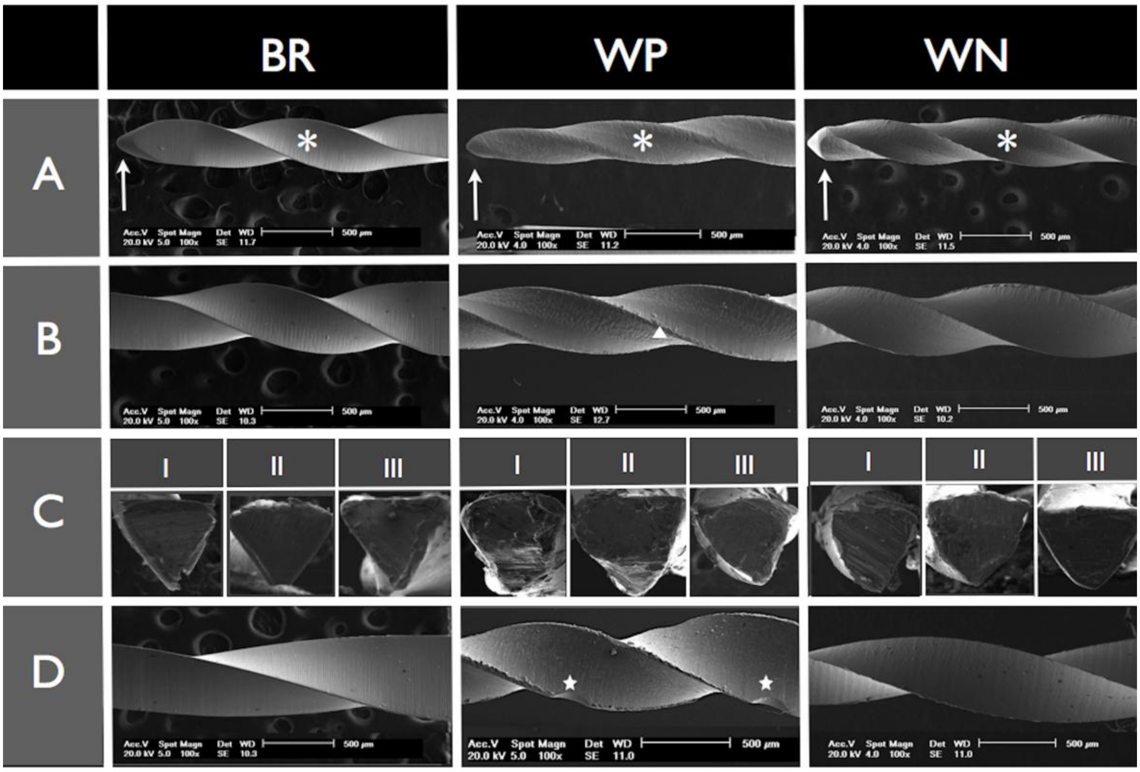

FIGURE 2

4 DISCUSSÃO

Apesar do avanço tecnológico na Endodontia, ainda há uma constante busca por preparos centralizados, realizados por instrumentos que sofram o mínimo grau de distorção, desgaste e fratura.

Vários estudos, empregando canais simulados (Troian, So *et al.*, 2006; Schafer e Oitzinger, 2008; Yamazaki-Arasaki, Cabrales *et al.*, 2011) e dentes humanos extraídos (Goldberg e Araujo, 1997; Sattapan, Nervo *et al.*, 2000; Ankrum, Hartwell *et al.*, 2004; Al-Sudani e Al-Shahrani, 2006; Hartmann, Barletta *et al.*, 2007; Cheung e Liu, 2009; Gergi, Rjeily *et al.*, 2010) vêm sendo conduzidos para avaliar a centralização dos preparos. Com este objetivo, métodos de scaneamento de seccções transversais (Al-Sudani e Al-Shahrani, 2006) e longitudinais (Lopez, Fachin *et al.*, 2008), fotográficos (Ersev, Yilmaz *et al.*, 2010) e radiográficos (Goldberg e Araujo, 1997; Schafer e Vlassis, 2004) e, mais recentemente, tomografias computadorizadas (Hartmann, Barletta *et al.*, 2007; Oliveira, Meurer *et al.*, 2009; Gergi, Rjeily *et al.*, 2010) e microtomografias (Peters, Boessler *et al.*, 2010; Peters e Paque, 2011) têm sido utilizados.

Por apresentarem uma anatomia complexa, as raízes mésio-vestibulares (MV) de molares superiores (MS) são capazes de reproduzir uma condição clínica adversa, que constitui um desafio para os profissionais. Isto por que a incidência, em relação ao número de canais na raiz MV, foi de 20%, 79,8%, 1,1% para um, dois e três, respectivamente (Degerness e Bowles, 2010). Além disso, nestas raízes, canais acessórios são mais localizados no terço apical

(3,6mm) e a presença de istmos é menos freqüente próximo do ápice (Somma, Leoni *et al.*, 2009).

Este estudo foi realizado com dentes humanos extraídos para que houvesse uma aproximação com a realidade clínica. Peters e Barbakow (Peters e Barbakow, 2002) avaliaram o torque gerado pelo instrumento endodôntico quando canais simulados curvos e estreitos são preparados comparando-os com o preparo em dentes humanos extraídos. Foi verificado que um maior número de rotações é necessário para completar o preparo do canal radicular quando são utilizados blocos de resina. Além disso, o tamanho de raspas de resina e dentina geradas durante o preparo biomecânico não são idênticas, resultando em frequentes bloqueios do terço apical e dificuldades para remover debris em canais simulados. Em contrapartida, a microdureza da dentina varia de 35-40Kg/mm^2 próximo ao espaço pulpar, enquanto a da resina utilizada em canais simulados varia de 20-22Kg/mm^2. Para tanto para remover dentina natural o dobro de força seria necessário(Hulsmann, Peters *et al.*, 2005).

Para análise do preparo do transporte do canal radicular com os diferentes instrumentos foi utilizada a sobreposição de imagens obtidas por meio da tomografia de feixe cônico. Outros autores (Hartmann, Barletta *et al.*, 2007; Oliveira, Meurer *et al.*, 2009; Gergi, Rjeily *et al.*, 2010) também utilizaram tomografia para análise da qualidade do preparo do canal radicular.

A presente pesquisa demonstrou que houve transporte do canal radicular, independente do sistema rotatório empregado, das secções e dos sentidos analisados, o que concorda com os achados de outros autores (Al-

Sudani e Al-Shahrani, 2006; Hartmann, Barletta *et al.*, 2007; Oliveira, Meurer *et al.*, 2009). No entanto, mesmo o transporte apical sendo ainda frequente com o uso desses instrumentos, parece ser menos frequente quando comparado com técnicas manuais de preparo do canal (Schafer e Lohmann, 2002). Quanto ao sentido do transporte, nossos resultados diferem dos encontrados por Oliveira et al (Oliveira, Meurer *et al.*, 2009), que demonstraram uma grande tendência de transporte na direção mesial, porém está de acordo com investigações anteriores que mostram que a direção do transporte do canal radicular não é influenciada pela direção da curvatura radicular (Kosa, Marshall *et al.*, 1999). Em contrapartida, nos grupos WP e WN a distância em relação ao ápice parece ter influência na diferença entre o desvio MD e VP, pois principalmente a 6mm do ápice houve a maior diferença entre as duas direções, essa região corresponde ao início da curvatura dos canais na maioria das amostras. Provavelmente, a menor diferença entre as direções MD e VP observada no grupo BR foi devido à secção transversal e ao desenho do instrumento. Tanto os instrumentos WP quanto os instrumentos WN apresentam diferentes secções transversais ao longo do instrumento, fator que pode ter influenciado um maior alargamento a 6mm do ápice. Além disso, os instrumentos WN e WP apresentaram arestas irregulares, o que pode ter produzido maior transporte em uma das direções observadas. Os instrumentos BR apresentaram superfície polida e arestas regulares.

As características anatômicas dentárias devem basear os limites de segurança para o transporte do canal radicular. No entanto, as medidas de espessura da parede do canal em diferentes distâncias apicais são de extrema importância para determinar a segurança do preparo. As paredes dentárias parecem ser mais espessa na porção cervical. Em relação aos canais mésio-vestibulares de molares superiores, a 2 mm do ápice, a espessura das paredes dental pode ser determinada entre 0,84 e 2,15 mm, enquanto que, a uma distância apical de cerca de 8 mm, essas medidas são compreendidas entre 1,23 e 1,58 mm (Degerness e Bowles, 2010). A correlação entre estes dados e os resultados deste estudo sugerem que todos os sistemas rotatórios testados promovem transporte do canal tolerável na maioria das amostras. Enquanto isso, particularmente para BR e grupos WN, e a 2 mm do ápice, o transporte do seria crítico em alguns dos espécimes se considerar a possibilidade de iatrogenias. Neste ponto, embora não estatisticamente significativa, uma vantagem clinicamente relevante, foi constatada para o grupo WP na capacidade de centralização. Esse fato pode ser explicado pois os instrumentos WP apresentam taper maiores, o que pode causar uma maior eliminação de interferências cervicais (Medin, 2011).

Os instrumentos WP e WN novos apresentaram bordos irregulares, diferentemente do grupo BR, em que uma superfície regular e polida foi observada. Porém a qualidade de acabamento superficial não promoveu diferenças estatisticamente significativas para a capacidade de centralização dos preparos, mas é importante ressaltar que o grupo BR apresentou resultados semelhantes aos demais grupos, independente do uso de um instrumento mestre maior porte apical, o que poderia influenciar a manutenção da posição original do canal radicular (4).

No presente estudo, nenhum instrumento fraturou reforçando os achados de Kawakami e Gavini (Kawakami e Gavini, 2007) que evidenciaram que a utilização dos instrumentos por até sete vezes parece não influenciar na ocorrência de fratura. Em contrapartida, em outra investigação, o uso repetido de instrumentos Profile reduziu significativamente o torque e o ângulo de rotação necessários para que ocorresse a fratura desses instrumentos (Yared, 2004).

A análise dos instrumentos em relação ao desgaste e distorção de espiras foi realizada por meio da MEV. Esse método foi utilizado em outros estudos (Zuolo e Walton, 1997; Troian, So *et al.*, 2006) e parece ser um método apropriado para avaliação dos instrumentos. O grupo BR apresentou maior distorção na ponta que os WP. Talvez este fato possa estar relacionado com o diâmetro de alargamento apical, que foram 0,40mm e 0,30mm, respectivamente. Apesar de não ter havido diferença entre os instrumentos WN e BR neste quesito, durante o preparo do canal com BR, havia uma percepção de corte ativo do instrumento, o que não foi percebido com o uso do WP e WN.

Os instrumentos WP apresentaram desgaste superficial maior, tanto na ponta quanto a 5 mm desta, seguidos pelos instrumentos WN e BR, que demonstraram os menores escores. O tratamento de superfície por eletropolimento pode ter influenciado estes resultados.

O aumento do número de uso dos instrumentos parece ter efeito direto na distorção de espiras e no desgaste superficial dos instrumentos do grupo BR, fato também mencionado em outros estudos, com relação aos instrumentos Race (Troian, So *et al.*, 2006) e Profile (Zuolo e Walton, 1997). No presente experimento, velocidade e torques máximos foram empregados, conforme recomendado pelo fabricante, o que pode ter favorecido a maior ocorrência de distorções de espiras. Em recente estudo, verificou-se que o torque afetou a resistência à fadiga cíclica flexural dos instrumentos utilizados, fator que pode também sugerir uma alteração na morfologia do instrumento (Kawakami e Gavini, 2007). Também os instrumentos WP tiveram um aumento progressivo do desgaste, em relação ao uso, fato que não ocorreu nos WN. Esses últimos possuem instrumentos com diâmetro na ponta de 0,10mm e 0,15mm, podendo não ter atuado nas paredes do canal em apical, uma vez que anatomicamente o diâmetro apical da raiz MV de MS é de 0,24mm, 0,28mm e 0,31mm em pacientes com até 24 anos, entre 25 e 40 anos e com mais de 40 anos, respectivamente (Vier, Tochetto *et al.*, 2004).

Novas investigações, nesta mesma linha de pesquisa, são necessárias para melhor elucidar a relação entre a ocorrência de transporte apical com a presença de alterações na topografia dos instrumentos.

Dentro das limitações desse estudo, pode-se concluir que nenhum dos sistemas rotatórios empregados foi capaz de proporcionar preparos centralizados e o uso progressivo dos instrumentos até o terceiro uso não favoreceu a ocorrência de fratura apesar de ter aumentado a ocorrência de distorção e desgastes.

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ANEXOS

ANEXO A: PARECER DO COMITÊ DE ÉTICA

Pontifícia Universidade Católica do Rio Grande do Sul
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
COMITÊ DE ÉTICA EM PESQUISA

OF. CEP-1767/11

Porto Alegre, 23 de novembro de 2011.

Senhora Pesquisadora,

O Comitê de Ética em Pesquisa da PUCRS apreciou e aprovou seu protocolo de pesquisa registro CEP 11/05622 intitulado **"Avaliação da centralização do preparo do canal radicular e da fadiga do instrumento comparando três sistemas rotatórios de níquel-titânio"**.

Salientamos que seu estudo pode ser iniciado a partir desta data.

Os relatórios parciais e final deverão ser encaminhados a este CEP.

Atenciosamente,

Prof. Dr. Rodolfo Herberto Schneider
Coordenador do CEP-PUCRS

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