UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

MELISSA ESTHER RIVERA PEÑA

Analysis of novel ultrasonic tips for the instrumentation and removal of filling material in flattened/oval-shaped root canals: a micro-computed tomographic study

Avaliação de novos insertos ultrassônicos para preparo e desobturação de canais achatados: análise por microtomografia computadorizada

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ABSTRACT

ANALYSIS OF NOVEL ULTRASONIC TIPS FOR THE INSTRUMENTATION AND REMOVAL OF FILLING MATERIAL IN FLATTENED/OVAL-SHAPED ROOT CANALS: A MICRO-COMPUTED TOMOGRAPHIC STUDY

Aim: To analyse the influence of novel ultrasonic tips on the instrumentation and removal of filling material in flattened/oval-shaped canals. **Methodology:** Forty-five mandibular incisors were selected and randomly divided into three experimental groups according to different protocols. For the instrumentation procedures, the following protocols were used: Group PFCP: ProDesign Logic 25/.05 + Flatsonic + Clearsonic + Prodesign Logic 40/.01, Group FCP: Flatsonic + Clearsonic + ProDesign Logic 40/.01 and Group PP: Prodesign Logic 25/.05 + Prodesign Logic 40/.05. After the instrumentation procedures, the samples were randomly divided into three experimental groups for the removal of filling material: Group R: Reciproc R25/.08, Group RC: Reciproc R25/.08 + Clearsonic tip and Group CR: Clearsonic tip + Reciproc R25/.08. The teeth were scanned pre and post-operatively by the means of a micro-computed tomography system. The percentage values for increase in volume, non-instrumented surface area, dentine removal, degree of canal transportation, centering ratio and percentage of residual filling material between the experimental groups were examined. Data were analysed using non-parametric Kruskal-Wallis and Dunn's tests. The significance level was of $P<0.05$. **Results:** The instrumentation technique applied in group PFCP provided the greatest volume increase in the total portion of the root canal, showing the lowest percentage of non-instrumented surface area. Regarding the degree of transportation in the bucco-lingual direction, statistically significant differences between groups PFCP and PP were observed in the coronal third of the canal. In the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were observed. As for the centering ratio, statistically significant differences were found in the bucco-lingual direction. In the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were observed between the instrumentation protocols used in this study. Statistically significant differences between the experimental groups were found in the total portion of the root canal,

where group R provided the highest percentage of residual root canal filling material when compared to groups RC and CR. In group C, the lowest percentage of residual root canal filling material was observed. Concerning the percentage of residual root canal filling material in the apical third of the root canal, statistically significant differences were found between the different protocols used in this study. The technique used in group CR, provided the lowest percentage of residual root canal filling material. **Conclusions:** The protocol used in the PFCP group provided a significant increase in volume and reduced the percentage of non-instrumented walls during the shaping of oval-shaped canals. The use of the ClearSonic tip as the first instrument followed by the Reciproc 25/.08 file for the removal of filling material, resulted in the lowest percentage of residual filling material in the total portion and in the apical third of the root canal.

KEY-WORDS: Endodontics, Ultrasonics, X-Ray Microtomography, Root Canal Preparation, Retreatment.

RESUMO

AVALIAÇÃO DE NOVOS INSERTOS ULTRASSÔNICOS PARA PREPARO E DESOBTURAÇÃO DE CANAIS ACHATADOS: ANÁLISE POR MICROTOMOGRAFIA COMPUTADORIZADA

Objetivo: Analisar a influência de novos insertos ultrassônicos para o preparo e remoção de material obturador em canais achatados. **Metodologia:** Quarenta e cinco incisivos inferiores foram selecionados e divididos aleatoriamente em três grupos experimentais dependendo da técnica de preparo e remoção de material obturador. Para o preparo dos espécimes, os seguintes protocolos foram utilizados: Group PFCP: ProDesign Logic 25/.05 + Flatsonic + Clearsonic + Prodesign Logic 40/.01, Group FCP: Flatsonic + Clearsonic + ProDesign Logic 40/.01 and Group PP: Prodesign Logic 25/.05 + Prodesign Logic 40/.05. Posteriormente, os espécimes foram redistribuídos em três grupos experimentais para a remoção do material obturador: Group R: Reciproc R25/.08, Group RC: Reciproc R25/.08 + Clearsonic tip and Group CR: Clearsonic tip + Reciproc R25/.08. Os espécimes foram escaneados antes e após os procedimentos operatórios por meio de micro-tomografia computadorizada. Foram examinados os valores de aumento de volume, área de superfície não tocada, remoção de dentina, grau de transporte do canal, centralização do preparo e material obturador remanescente entre os grupos experimentais. Os dados foram analisados com os testes estatísticos não paramétricos de Kruskal-Wallis e Dunn. O nível de significância foi de 5%. **Resultados:** A técnica de preparo aplicada no grupo PFCP promoveu o maior aumento de volume na porção total do canal radicular, mostrando a menor porcentagem de área não tocada. Em relação ao grau de transporte no sentido vestíbulo-lingual, diferenças estatísticas significantes foram encontradas no terço cervical entre o grupo PCFP e PP. No sentido mesio-distal, não houve diferença estatística significante nos terços cervical, médio e apical. No que diz respeito a centralização do preparo, diferenças estatísticas significantes foram encontradas no sentido vestíbulo-lingual. Considerando a porcentagem de material obturador remanescente, foram observadas diferenças estatísticas significantes entre os

grupos experimentais na porção total do canal radicular, onde o grupo R apresentou a maior porcentagem de material obturador remanescente, quando comparado aos grupo RC e CR. No grupo CR, a menor porcentagem de material obturador remanescente foi constatada. Diferenças estatísticas significantes foram encontradas entre os grupos experimentais na porção apical do canal radicular. Desse modo, a técnica usada no grupo CR, promoveu a menor porcentagem de material obturador remanescente no terço apical. **Conclusões:** O protocolo utilizado no grupo PFCP promoveu a maior porcentagem de aumento de volume e reduziu a porcentagem de áreas não tocadas durante o preparo de canais achatados. A associação do inserto ultrassônico ClearSonic antes da utilização do instrumento reciprocante R25 para a remoção de material obturador, promoveu a menor porcentagem de material obturador remanescente na porção total e apical do canal radicular.

PALAVRAS-CHAVE: Endodontia, Ultrassom, Microtomografia computadorizada, Preparo biomecânico, Retratamento.

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1 INTRODUCTION

1 INTRODUCTION

The existence of root canals with an oval configuration has been reported in previous studies (Mauger et al, 1998; Wu et al, 2000; Versiani et al, 2011; de Almeida et al, 2013), being associated with major challenges during endodontic therapy (Coniglio et al, 2008; Busquim et al, 2015) and retreatment (Bernardes et al, 2015; Crozeta et al, 2016; Zuolo et al, 2016). The presence of pulp remnants and infected dentin on the uninstrumented areas of root canals prepared with nickel-titanium (NiTi) instruments have been observed, due to their tendency of creating a circular bulge in the center of the root canal and the existence of a greater bucco-lingual dimension in teeth with these anatomical features (Coniglio et al, 2008; Busquim et al, 2015; Coelho et al, 2016,). This leads to the formation of smear layer which may hinder the cleanliness of the untouched root canal walls (Coniglio et al, 2008). In the same way, it is well known that none of the actual systems remove all residual filling material from the root canal space (Zuolo et al, 2016). Many techniques and instruments have been described in the literature for the instrumentation and removal of filling material in oval-shaped canals. However, incomplete preparations (ElAyouti, 2008; Busquim et al, 2015; De-Deus, 2015; Coelho et al, 2016; Zuolo et al, 2017) as well as the presence of residual filling material were found (Bernardes et al, 2015, Crozeta et al, 2016, Kasam & Mariswamy, 2016; Zuolo et al, 2016). For this reason, new protocols to reduce the percentages of non-instrumented areas and the residual filling material should be studied. Microcomputed tomography (µ-CT) is a non-invasive research tool used for three-dimensional analysis of different instrumentation (Rodhes et al, 1999; Peters et al, 2000; Busquim et al, 2015) and retreatment techniques (Fruchi et al, 2014; Crozeta et al, 2016). This technology allows the acquisition of quantitative and qualitative data (Busquim et al, 2015; Versiani et al, 2016). Micro-computed tomography studies have revealed that more than half of the root canal walls (ranging from 59.6% to 79.9%) remain unprepared in oval-shaped canals, regardless of the instrumentation technique (De-Deus et al. 2015).

The use of ultrasonic tips in association to endodontic instruments has been recommended to improve the cleansing of the root canal during shaping (Weller et al, 1980; Lumley et al, 1993; Singh et al, 2017) and retreatment procedures (de Mello Jr, 2009; Kasam & Mariswamy, 2016). Studies have reported a percentage of residual remaining filling material of approximately 9% using this technology (de Mello Jr. et al. 2009, Kasan & Mariswamy, 2016). In addition, the combined use of ultrasonic tips and the dental operating microscope (DOM) has been suggested to improve precision during gutta-percha removal (de Mello Jr et al, 2009). In controlled memory (CM) technology, endodontic instruments are subjected to a special thermal process after machining from conventional NiTi wire, including high martensitic crystal content in order to improve their mechanical behavior (Peters et al, 2017). ProDesign Logic 25/.05 and 40/.05 (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) were recently introduced as controlled-memory (CM) rotary files. In addition, another CM rotary file with size 40 and taper 01 was presented. The use of another instrument with this taper for apical preparation has been previously reported in the literature (Rodrigues et al. 2016). Two novel ultrasonic tips (Flatsonic and Clearsonic, Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) with an arrow section have been proposed as auxiliary methods for endodontic procedures. On the other hand, the Reciproc single-use reciprocating system (VDW, Munich, Germany) has been indicated and successfully used for retreatment procedures (Özyürek & Demiryürek, 2016, Rodrigues et al, 2016, Zuolo et al, 2016). Therefore, new protocols for the instrumentation and removal of filling material in flattened/oval-shaped canals using ultrasonic tips as an auxiliary method, should promote satisfactory results. Consequently, values for increase in volume, non-instrumented surface area, dentine removal, degree of canal transportation, centering ratio and percentage of residual filling material between the experimental groups were examined. The null hypothesis tested was that these novel ultrasonics would not influence the instrumentation and removal of filling material in flattened/oval-shaped root canals.

2 ARTICLES

2 ARTICLES

The articles presented in this Dissertation were written according to the International Endodontic Journal instructions and guidelines for article submission.

- ARTICLE 1 – Analysis of a protocol using novel ultrasonic tips as an auxiliary method for the instrumentation of flattened/oval-shaped root canals: a micro-computed tomographic study.

- ARTICLE 2 – Analysis of a novel ultrasonic tip as an auxiliary method for the removal of filling material in flattened/oval-shaped root canals: a micro-computed tomographic study.

2.1 ARTICLE 1

ABSTRACT

Analysis of a protocol using novel ultrasonic tips as an auxiliary method for the instrumentation of flattened/oval-shaped root canals: a micro-computed tomographic study.

Aim: To evaluate the influence of novel ultrasonic tips as an auxiliary method for the rotary preparation of oval-shaped canals. **Methodology:** Forty-five mandibular incisors were selected and randomly divided into one of three experimental groups (N=15). Group PFCP: ProDesign Logic 25/.05 + Flatsonic + Clearsonic + Prodesign Logic 40/.01, Group FCP: Flatsonic + Clearsonic + ProDesign Logic 40/.01 and Group PP: ProDesign Logic 25/.05 + ProDesign Logic 40/.05. The teeth were scanned pre and post-operatively by the means of a micro-computed tomography system. The percentage values for increase in volume, non-instrumented surface area, dentine removal, degree of canal transportation and centering ratio between the experimental groups were examined. Data were analysed using non-parametric Kruskal-Wallis and Dunn's tests ($P<0.05$). **Results:** Group PFCP showed the greatest volume increase in the total portion of the root canal and the lowest percentage of non-instrumented surface area. Regarding the degree of transportation in the bucco-lingual direction, statistically significant differences between groups PFCP and PP were observed in the coronal third of the canal. In the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were observed. As for the centering ratio, statistically significant differences were found in the bucco-lingual direction. In the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were observed. **Conclusions:** The protocol used in the PFCP group provided a significant increase in volume and reduced the percentage of non-instrumented walls during the shaping of oval-shaped canals.

Introduction

The prevalence of mandibular incisors with flat-oval shaped root canals has been reported in the literature (Mauger et al. 1998, Wu et al. 2000, de Versiani et al. 2011, de Almeida et al. 2013, Azim et al. 2017). The presence of these anatomical features has been associated with complications during instrumentation with hand and engine-driven instruments, hindering the cleanliness of the root canal system (Wu et al. 2003, Weiger et al. 2002, Zmener et al. 2005, Zmener et al. 2006, Rüttermann et al. 2007, Coniglio et al. 2008, De-Deus et al. 2008, Zuolo et al. 2017). Nickel-titanium (NiTi) instrumentation tends to maintain a self-centered position while rotating, creating a circular bulge and producing smear layer in the prepared portions of the root canal walls, whereas pulp remnants and infected dentine remain on the areas untouched by the endodontic files (Coniglio et al. 2008). Micro-computed tomography studies have revealed that more than half of the root canal walls (ranging from 59.6% to 79.9%) remain unprepared in oval-shaped canals, regardless of the instrumentation technique (De-Deus et al. 2015). Micro-computed tomography (µ-CT) imaging technology allows the visualization of morphological characteristics of the teeth in detailed manner (de Almeida et al. 2013, De-Deus et al. 2015, Versiani et al. 2016). Thus, µ-CT has been proposed as a suitable outcome parameter to compare the shaping ability of different endodontic instruments and techniques, offering promising results (De-Deus et al. 2015).

In controlled memory (CM) technology, endodontic instruments are subjected to a special thermal process after machining from conventional NiTi wire, including high martensitic crystal content in order to improve their mechanical behavior (Peters et al. 2017). Lately, CM rotary files, ProDesign Logic 25/.05 and 40/.05 (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) were introduced. In addition, the manufacturer presented a new CM rotary file with size 40 and taper 01. The use of another instrument with this taper for apical preparation has been reported in the literature (Rodrigues et al. 2016). On the other hand, ultrasonic instrumentation has been proposed in the literature as an auxiliary approach, being combined with endodontic instruments for improving the cleanliness of the root canal system (Lumley et al. 1993, Weller et al. 1980). Two novel ultrasonic tips (Flatsonic and Clearsonic, Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) with an arrow section have been proposed as an alternative method for the instrumentation of oval-shaped canals. A combination of different instrumentation techniques should provide an adequate shaping of the root canal system by enhancing the preparation of the root canal surface. The aim of this study was to evaluate the influence of novel ultrasonic tips as an auxiliary method for the rotary preparation of oval-shaped canals, with the aid of the dental operating microscope (DOM). To our knowledge, this is the first publication to analyse the efficacy of these shaping protocols in flattened/oval-shaped canals. The null hypothesis tested was that these novel ultrasonic tips would not influence the root canal preparation of flattened/oval-shaped canals.

Materials and Methods

The sample calculation was performed using the G*Power v3.1 for Mac (Heinrich Heine, Universität Düsseldorf) by selecting the Wilcoxon-Mann Whitney test of the T test family. The data of a previous study of root canal instrumentation of oval canals (Coelho et al. 2016) was used and the effect size in the present study was established (=1.32). The alpha type error of 0.05, a beta power of 0.95, and a ratio N2/N1 of 1 were also stipulated. A total of 14 per group were indicated as the ideal size required for noting significant differences. An additional specimen per group was used to compensate possible loss during the realization of the experiments.

Forty-five mandibular incisors that were extracted from a Brazilian population for reasons unrelated to this study were acquired after the Ethics Committee in Human Research approved the study (CEP 2.112.063). Teeth with two root canals, an open apex or with previous endodontic treatment were excluded. The samples were scanned before and after the instrumentation protocols with a Skyscan 1174 micro-computed tomography system (Bruker-microCT, Kontich, Belgium). The parameters used were 50 kV, 800 mA, and a voxel size of 16.8-μm. The system includes a charge-coupled device camera (1304_1024 pixels). Radiographic images of each sample were reconstructed by using the NRecon software (Bruker-microCT Kontich, Belgium). Three-dimensional models were reconstructed after the segmentation and binarization processes with CTAn v.1.12 software (Bruker-microCT Kontich, Belgium). CTVol v.2.2.1 and Data Viewer softwares (Bruker-micro CT Kontich, Belgium) were used for visualization and evaluation of the internal anatomy according to a novel classification (Ahmed et al. 2017). Only $^{1}TN^{1}$ mandibular incisors with an oval-shaped configuration were selected. An oval canal was identified when the bucco-lingual diameter was twice as long or longer than the mesio-distal diameter (ElAyouti et al. 2008). CTan v.1.12 software (Bruker-microCT Kontich, Belgium) was also used to calculate the volume of the samples from all the root canal walls (mesial/distal/buccal/lingual).

During the experimental procedures, all the specimens were placed in a custom metallic muffle prepared for each specimen and fixed internally with silicone impression material to simulate clinical conditions. Access cavities were performed with a size 2 high-speed diamond bur (FG 1012 KG Sorensen, São Paulo, Brazil) under water spray. The working length was determined by placing a size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal until it was visible at the root apex under the dental operating microscope (Alliance Microscopia, São Carlos, Brazil), being established 1 mm short of this length. The samples (N=45) were randomly divided into one of the three experimental groups according to the preparation technique. An endodontic specialist performed all the procedures under a dental operating microscope at 6x magnification (Alliance Microscopia, São Carlos, Brazil).

Experimental groups:

Group PFCP: ProDesign Logic 25/.05 + Flatsonic (coronal and middle thirds) + Clearsonic (coronal and middle thirds) + ProDesign Logic 40/.01 (N=15)

A size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was passively inserted into the working length of the root canals. The instrument ProDesign Logic 25/.05 was operated in rotating motion powered by a torque-limited electric motor (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) at 950 rpm and 4 N/cm torque in accordance with the manufacturer's instruction. The instrument was introduced into the root canal until resistance was felt and a brushing motion of 3 mm in amplitude was applied thrice. Subsequently, the instrument was removed and cleaned and the root canal was irrigated with 3 mL of 1% sodium hypochlorite (NaOCl). This sequence was repeated until reaching 2/3 of the working length. An ultrasonic tip with a flattened arrow-design (Flatsonic, Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) (0.25 mm diameter tip) (Figure 1 a, b) mounted in an ultrasonic device (NSK Brasil Ldta, São Paulo, Brazil) in a frequency of 30 kHz was used, being activated for three cycles of 20 seconds in the buccal-lingual direction in order to touch these walls. This procedure was repeated thrice and after each cycle, 3 mL of 1% sodium hypochlorite (NaOCl) were used. This protocol was determined after a pilot study. Another ultrasonic tip with a convex arrow-design (Clearsonic, Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) (0.50 mm diameter tip) (Figure 1 c, d) was used, applying the same protocol for the ultrasonic instrumentation of the root canal as previously described. The instrument ProDesign Logic 40/.01 was operated at 350 rpm and 1 N/cm torque in accordance with the manufacturer's instructions and under the experimental conditions described for the use of these rotary files. Then, the instrument was removed and cleaned and the root canal was irrigated with 3 mL of 1% sodium hypochlorite (NaOCl). This sequence was repeated until reaching the working length of the root canal. Subsequently, a final irrigation protocol was used. 2 mL of 2.5% NaOCl were refreshed and ultrasonically activated with an ultrasonic device (NSK, Brasil Ldta, São Paulo, Brazil) using an Irrisonic tip (size 20, 0.01 taper) (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) set to low power, three times for 20 seconds each. The specimens were flushed with 17% EDTA for 3 minutes and ultrasonically activated for 60 seconds. The root canals were flushed with 2 mL of 2.5% NaOCl and ultrasonically activated thrice for 20 seconds each (van der Sluis et al. 2010). A final rinse with saline solution was performed and the specimens were dried with sterile paper points. Then, the samples were scanned for the last time using standardised parameters as previously explained before.

Group FCP: Flatsonic (coronal and middle thirds) + Clearsonic (coronal and middle thirds) + ProDesign Logic 40/.01 (N=15)

A size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was passively inserted into the working length of the root canals. Afterwards, these instruments were used under the same experimental conditions as described in Group 1.

Group PP: Prodesign Logic 25/.05 + Prodesign Logic 40/.05 (N=15)

A size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was passively inserted into the working length of the root canals. The instrument ProDesign Logic 25/.05 was operated in rotating motion powered by a torque-limited electric motor (Easy Equipamentos Odontológicos, Belo Horizonte, Minas Gerais, Brazil) at 950 rpm and 4 N/cm torque in accordance with the manufacturer's instruction. The instrument was introduced into the root canal until resistance was felt and a brushing motion of 3 mm in amplitude was applied thrice. Subsequently, the instrument was removed and cleaned and the root canal was irrigated with 3 mL of 1% sodium hypochlorite (NaOCl). This sequence was repeated until reaching the working length. Afterwards, the instrument ProDesign Logic 40/.05 was operated) at 950 rpm and 4 N/cm torque in accordance with the manufacturer's instruction. The instrument was introduced into the root canal until resistance was felt and a brushing motion of 3 mm in amplitude was applied thrice. Subsequently, the instrument was removed and cleaned and the root canal was irrigated with 3 mL of 1% sodium hypochlorite (NaOCl). This sequence was repeated until reaching the working length and the samples were scanned for the last time.

Measurement of canal volume and surface area

Reconstructed images after the different instrumentation protocols were geometrically registered with the preoperative data sets using the DataViewer software (Bruker-microCT, Kontich, Belgium), for a quantitative comparison of the morphological parameters before and after the shaping procedures (Amoroso-Silva et al. 2017). The measurement of canal volume (mm^3) and surface areas (i.e. amount of dentine removal) were calculated by subtracting the scores for the treated canals from those recorded for the untreated counterparts using the CTAn v.1.12 software (Bruker-microCT, Kontich, Belgium) (Gergi et al. 2015, Amoroso-Silva et al. 2017). Matched images of the surface areas of the canals before and after the action of the endodontic instrument and/or ultrasonic tips were examined to evaluate the amount of unprepared canal wall surface after the instrumentation techniques used in this study. This parameter was expressed as a percentage of the number of static voxel surface to the total number of surface voxels (Gergi et al. 2015, Amoroso-Silva et al. 2017). The pre- and post-instrumentation scans were superimposed to determine the percentage of volume increase and non-instrumented surface area.

Evaluation of centering ability

According to Gambill et al. (1996), 'the mean centering ratio' indicates the ability of the instrument to stay centered in the canal. Using the CTAn v.1.12 software (Bruker-microCT, Kontich, Belgium), cross-sectional images of the teeth were obtained. A modification of this method was applied in order to obtain the centering ability in the bucco-lingual direction as well. The dimensions were determined by measuring the shortest distance from the edge of the unprepared canal to the edge of the tooth in the mesio-distal and bucco-lingual directions and then compared to the values measured from the prepared canals. The measurements of the distance of the points of interest were taken with the CTAn v.1.12 software (Bruker-microCT, Kontich, Belgium) for each level (Gergi et al. 2015).

This ratio was calculated for each section using the following ratio:

$$\frac{(X_1 - X_2)}{(Y_1 - Y_2)} \text{ or } \frac{(Y_1 - Y_2)}{(X_1 - X_2)}$$

According to our modification of the method developed by Gambill et al. (2015), X_1 is the shortest distance from the buccal aspect of the root to the periphery of the unprepared canal; X_2 is the shortest distance from the buccal aspect of the root to periphery of the prepared canal; Y_1 is the shortest distance from the lingual aspect of the root to the periphery of the unprepared canal; Y_2 is the shortest distance from the lingual aspect of the root to the periphery of the prepared canal. A result of '0' indicated no canal transportation.

If these numbers were not equal, the lower figure was considered as the numerator of the ratio. According to this formula, a result of '1' indicates perfect centering.

Canal transportation

To analyse the extent of canal transportation, a method designed by Gambill et al. (2015) was used, as well as a modification of this technique as previously described. Transportation was evaluated at three levels (cervical, middle and apical third) using the CTAn v.1.12 software (Bruker-microCT, Kontich, Belgium). The dimensions were determined by measuring the shortest distance from the edge of the unprepared canal to the edge of the tooth in both mesio-distal and bucco-lingual directions and then compared to the values measured from the prepared root canals.

The following formula was used for the transportation calculation:

$(X_1\text{-}X_2) – (Y_1\text{-}Y_2)$.

A result of ‘0’ indicated no canal transportation.

Statistical analysis

For the analysis of the data the Graph Pad Prism 6's (GraphPad Software, Inc., California, United States of America) software was used, performing the non-parametric Kruskal-Wallis and Dunn's tests due to the presence of a non-normal distribution as confirmed by the Shapiro-Wilk's test. The significance level was of 5%.

Results

Volume Increase and Non-instrumented Surface Area

Regarding the volume increase and non-instrumented surface area, statistically significant differences between groups PFCP and PP were found in the total portion of the root canal ($P<0.05$; Table 1). The PFCP group provided the greatest percentage of volume increase (171%), showing the lowest percentage of non-instrumented surface area (18%) ($P<0.05$; Table 1; Figure 2). On the other hand, no statistically significant differences between groups PFCP and FCP were observed. Regarding the percentage of volume increase in the apical third, no statistically significant differences between the instrumentation techniques used in this study were found.

Dentine Removal

Regarding the mesial wall, statistically significant differences were found in the middle third, between groups FCP and PP ($P<0.05$; Table 2). The PP provided the greatest percentage of dentine removal (17%) when compared to group FCP (8%). No statistically significant differences were found in the coronal and apical thirds in the mesial wall. Concerning the distal wall, statistically significant differences were only found in the apical third ($P<0.05$; Table 2). Between groups FCP and PP, PP provided the greatest percentage of dentine removal (23%). No statistically significant differences were found in the coronal and middle thirds in the distal wall. In the buccal wall, statistically significant differences were observed in the coronal third between groups FCP and PP ($P<0.05$; Table 2). As a result, the percentage of dentine removal was greater for group FCP (12%). No statistically significant differences were found in the middle third for the buccal wall. Furthermore, statistically significant differences between groups PFCP and PP were observed in the apical third of the root canal. In this case, the highest percentage of dentine removal was provided by the instrumentation protocol used in the PP (18%). As for the lingual wall, statistically significant differences in the coronal third were found ($P<0.05$; Table 2). When compared to groups PFCP and FCP, the PP showed the lowest percentage of dentine removal (7%). No statistically significant differences were observed in the middle third of the root canal, between the instrumentation protocols used in this study. In the apical third of the lingual wall, statistically significant differences were found between groups FCP and PP, where group PP showed the greatest percentage of dentine removal (18%).

Transportation Values

In the bucco-lingual direction, transportation occurred in the lingual aspect of the root in the majority of the instrumented root canals, showing statistically significant differences between groups PFCP and PP in the coronal third of the root canal ($P<0.05$; Table 3). PP showed the lowest transportation values. Statistically significant differences in the middle and apical thirds were not found. In the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were observed between the three instrumentation protocols used in this study ($P<0.05$; Table 3).

Centering Ratio

In the bucco-lingual direction, statistically significant differences between groups PFCP and PP and between groups FCP and PP in the coronal third of the root canal were observed ($P<0.05$; Table 3). Thus, PP showed the greatest centering ratio in the coronal third of the root canals prepared with the three instrumentation protocols evaluated in this study. No statistically significant differences were found in the middle third of the root canals. In the apical third, statistically significant differences were observed between groups PFCP and PP. Therefore, group PFCP displayed the greatest centering ratio. In the mesio-distal direction, no statistically significant differences in the coronal third were observed between the three instrumentation protocols used in this study ($P<0.05$; Table 3). However, statistically significant differences between groups FCP and PP were found in the middle third of the root canal. The greatest centering ratio was displayed by the instrumentation protocol used in group FCP. In the apical third, statistically significant differences were observed between groups PFCP and PP. Therefore, group PFCP displayed the greatest centering ratio.

Discussion

Proper biomechanical preparation of the root canal space is essential for success in endodontic therapy (Goldman et al, 1988). The shaping and cleaning of oval-shaped canals represents a challenge, due to the tendency of endodontic instruments to remain in the center of the canal and the presence of a greater bucco-lingual dimension in these root canals (Coniglio et al. 2008, Busquim et al. 2015, Coelho et al. 2016). This leads to non-instrumented areas that could influence the outcome of the treatment (Coniglio et al. 2008, Coelho et al. 2016, Zuolo et al. 2017). However, the efficacy of instrumentation is more dependable on canal anatomy and pathosis than on the use of any mechanical devices (Langeland et al, 1985). Ultrasonic instrumentation has been proposed as an alternative debridement approach, being combined with endodontic instruments for improving the cleaning of the root canal system (Goldman et al. 1988, Lumley et al. 1993, Weller et al. 1980, Singh et al. 2017). The majority of systems were based upon the ultrasonic energizing of a file for mechanical canal preparation and debris removal, as well as ultrasonic activation of an irrigant for enhanced penetration, solvent and bactericidal action (Goldman et al. 1988). Ultrasound with its cavitation, heating, stirring, agitation and acoustic streaming, can dislodge debris from surfaces unreached by mechanical instrumentation (Goldman et al. 1988). The introduction of the dental operating microscope (DOM) has been widely accepted as an important technological revolution in endodontics (Carr and Murgel. 2010, Perrin et al. 2013). DOM can be a powerful asset to improve clinical accuracy (Mittal et al. 2014) and the predictability of endodontic procedures (Michaelides, 1996, Wu et al. 2011). The use of new auxiliary methods should favourably influence the treatment prognosis (Langeland et al. 1985).

The null hypothesis that these novel ultrasonic tips would not influence the root canal preparation of flattened/oval-shaped root canals was rejected. The current study had several variables: changes in volume and surface area, centering ability, degree of canal transportation and percentage of dentine removal provided by different instrumentation protocols. These protocols included the combination of rotary CM instruments with ultrasonic tips. The influence of these protocols on the instrumentation of oval-shaped canals was determined by µ-CT scans. µ-CT imaging is a high-resolution research tool that allows the development of accurate three-dimensional models and the acquisition of quantitative data (Versiani et al. 2016). This technology has been described as non-invasive and serves as a reproducible method for the analysis of different shaping techniques without the destruction of the samples (Rhodes et al. 1999, Peters et al. 2000).

The different instrumentation protocols used in this study produced significant gains in canal volume and surface area, resulting in a considerable reduction of non-instrumented areas (Table 1; Figure 2). The instrumentation technique applied in group PFCP provided the greatest volume increase in the total portion of the root canal, showing the lowest percentage of non-instrumented surface area ($P<0.05$). These results suggest that when a rotary instrument (ProDesign Logic 25/.05) was used before the ultrasonic tips (Flatsonic and Clearsonic), a significant reduction of the percentage of non-instrumented surface area (18%) was observed. Therefore, the use of an engine-driven instrument to create a glide path is recommended to aid the action of the FlatSonic tip with its flattened design and a diameter of 0.25 mm in areas of anatomical complexity. This protocol facilitated the use of the ClearSonic tip, which has a 0.5 mm diameter, corresponding to ISO size 50 file. However, no statistically significant differences between groups PFCP and FCP were found, indicating that both protocols where ultrasonic tips were used showed coinciding and favourable results. A higher percentage of volume increase provides a lower percentage of non-instrumented areas and may improve the cleaning of the root canal system. In the same way, no statistically significant differences between the experimental groups were found when the percentage of volume increase in the apical third was evaluated. These results could be explained by the use of solely rotary instruments in the apical third. Weller et al. (1980), observed similar results in a study where the use of ultrasound after manual instrumentation contributed to an 88% (in human teeth) to 92% (in resin blocks) of debridement as evaluated by the loss of radioactivity method. Since this is the first publication regarding the association of these rotary files with ultrasonic tips for the shaping of oval-shaped root canals, the presence of discrepancies in experimental designs and results between studies should be emphasized.

Canal volume is a variable used to analyse the effects of canal instrumentation on dentine removal (Gergi et al. 2015). As for the mesial wall, the statistically significant differences in the middle third could be explained by the use of ProDesign Logic 25/.05 and ProDesign Logic 40/.05 file in PP, which provided a greater wear in this portion of the root ($P<0.05$; Table 2). Concerning the distal wall, statistically significant differences were only found in the apical third, where PP showed the highest percentage of dentine removal as well. These results could be explained by the use of an instrument of a larger taper in this region. The larger the taper, the higher the amount of prepared surface area in the root canal walls (De-Deus et al, 2015). Larger apical preparations have been associated to improvements in the disinfection and cleaning procedures, reducing the bacterial load in the root canal system (De-Deus et al, 2015). In the buccal wall, statistically significant differences were observed in the coronal third between groups FCP and PP, where the protocol used in group FCP demonstrated a significant increase in dentine removal. These results might be related to the use of the ultrasonic tips before the creation of a glide path with an engine-driven instrument and to their direction of action in the bucco-lingual orientation. At the apical third, the greatest percentage of dentine removal was detected in the protocol where only rotatory instruments (Group PP) were used. Concerning the lingual wall, statistically significant differences were observed in the coronal third for group PFCP, possibly related to the direction of action of the ultrasonic tips in the bucco-lingual orientation. However, statistically significant differences were found in the apical third, where only rotatory instruments (Group PP) were used, showing the greatest percentage of dentine removal. These results could be associated to the use of ProDesign Logic 40/.05, which has a greater taper, being more rigid and producing a greater wear in this area (Elayouti et al. 2008).

When analysing the transportation values, statistically significant differences between groups PFCP and PP were observed in the coronal third of the root canal, where PP showed the lowest transportation values ($P<0.05$; Table 3). These results are associated to the protocol without the use of ultrasonic tips as an auxiliary method for shaping oval-shaped root canals. These results could be explained by the use of the ultrasonic tips in the bucco-lingual direction, having a greater action in this region. This suggests that the use of ultrasonic tips in the coronal third should be done with precaution. These results are in agreement with another study (Pinheiro et al. 2017), where the Prodesign Logic system showed one of the lowest transportation values in the coronal third. Regarding the transportation values in the middle and apical third for the bucco-lingual direction, no statistically significant differences were found. On the other hand, in the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were observed between the three experimental groups. Consequently, all the protocols showed a satisfactory performance concerning the transportation values in this study. The results of this study diverge from other traditional publications where ultrasonic instrumentation created an irregular shape in the root canal, particularly in 3 to 6 mm from the root apex (Moriya, 1984, Yamaguchi et al. 1988). However, when compared to the current study, these investigations differ in technological advances as well as in the experimental designs used by the authors.

To date, there are not studies comparing the centering ability of these protocols for the instrumentation of oval-shaped canals (Table 3). Thus, in the bucco-lingual direction, PP showed the greatest centering ratio in the coronal third of the root canals prepared with the three instrumentation protocols evaluated in this study. In this group, only rotary instruments were used and the literature has revealed that NiTi instruments produce few changes in canal anatomy during shaping of the root canal system (Pinheiro et al. 2017). These results could be associated to the activation of the ultrasonic tips in the bucco-lingual direction, as previously mentioned. Despite these facts, all of the techniques used in this study have proved to be safe regarding their centering ability. No statistically significant differences were found in the middle third of the root canals. In the apical third, statistically significant differences were observed between groups PFCP and PP. Therefore, group PFCP displayed the greatest centering ratio. This could be explained by the use of ProDesign Logic 40/.01 file in group PFCP, in contrast with ProDesign Logic 40/.05 which has a greater taper. This makes ProDesign Logic 40/.05 more rigid and may produce greater wear in this area (Elayouti et al. 2008). In the mesio-distal direction, no statistically significant differences in the coronal third were observed between the three instrumentation protocols used in this study. However, statistically significant differences between groups FCP and PP were found in the middle third of the root canal. The greatest centering ratio was displayed by the instrumentation protocol used in group FCP. This implies that the use of ultrasonic tips combined with

ProDesign Logic 40/.01 provided a most centered preparation in the middle third of the root canal than the protocol where ProDesign Logic 25/.05 and ProDesign Logic 40/.05 were used. These results could be related to the presence of flattened areas in oval-shaped canals and the action of an instrument of greater taper in this portion of the root, which may produce a greater lateral cutting (Elayouti et al. 2008). In the apical third, statistically significant differences were observed between groups PFCP and PP. Therefore, group PFCP displayed the greatest centering ratio, explained by the use of ProDesign Logic 40/.01 file in group PFCP, in contrast with ProDesign Logic 40/.05 which has a greater taper.

Conclusion

Based on the experimental design of this study, it can be concluded that the protocol used in group PFCP provided a significant increase in volume and reduced the percentage of non-instrumented areas. Regarding the dentin removal, the protocol used in group PP presented the higher percentage of dentin removal in the middle third (mesial wall) and in the apical third of the root canal (distal/buccal/lingual walls). The protocol used in group FCP showed the higher percentage of dentin removal in the coronal third (buccal wall). The protocol used in group PFCP showed the higher percentage of dentin removal in the coronal third (lingual wall). Concerning the transportation values, the protocol used in group PP showed the lowest values in the coronal third (bucco-lingual direction). As for the centering ratio, the protocol used in group PP presented the most centered preparation in the coronal third (bucco-lingual direction). The protocol used in group FCP showed the greatest centering ratio in the middle third (mesio-distal) and group PFCP displayed the greatest centering ratio in the apical third (mesio-distal and bucco-lingual direction).

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The authors deny any conflict of interest.

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Figure Legends

Figure 1 (a) Ultrasonic FlatSonic tip, (b) Scanning electron microscopy (SEM) image of the FlatSonic tip (original magnification, 35x), (c) Ultrasonic ClearSonic tip and (d) SEM image of the ClearSonic tip (original magnification, 35x).

Figure 2 Representative reconstructions of the superimposed specimens before (red) and after (green) endodontic instrumentation in each experimental group. Frontal and lateral views (a)buccal (b)lingual (c)mesial (d)distal. (e) Representative cross-sections of the superimposed flattened/oval-shaped mandibular incisors before (red) and after (green) endodontic instrumentation in each experimental group at the coronal (c), middle (m) and apical (a) thirds.

Tables

Table 1 Percentage values for increase in volume in the total portion and apical third of the root canal and for the non-instrumented surface area in the total portion of the root canal (median, minimum-maximum).

Group	Total	Apical 1/3	NISA- Total
PFCP			
%	171.9 (57.28-383.6) [a]	30,30(9,80-138,2) [a]	18.25(7.50-37.76) [a]
FCP			
%	118.4 (36.55-252.2) [ab]	37,70(2,70-122,1) [a]	26.64(11.80-63.60) [ab]
PP			
%	46.75 (22.24-157.1) [b]	68,00(12,20-215,1) [a]	38.90(4.80-60.80) [b]

Different letters in each column indicates statistically significant difference ($P < 0.05$).
NISA: Non-instrumented surface area.

Table 2 Percentage values of dentine removal in each third and in each wall of the root canal (median, minimum-maximum)

Group	Mesial Wall Coronal 1/3	Mesial Wall Middle 1/3	Mesial Wall Apical 1/3
PFCP %	11.00(0.0-40.00) [a]	11.00(0.0-40.00) [ab]	7.00(0.0-30.00) [a]
FCP %	15.00(0.0-45.00) [a]	8.00(0.0-40.00) [b]	14.00(0.0-28.00) [a]
PP %	21.00(2.00-44.00) [a]	17.00(7.00-41.00) [a]	22.00(6.00-39.00) [a]
	Distal Wall Coronal 1/3	**Distal Wall Middle 1/3**	**Distal Wall Apical 1/3**
PFCP %	11.00(0.0-40.00) [a]	10.00 (0.0-33.00) [a]	5.00(0.0-26.00) [a]
FCP %	17.00(0.0-28.00) [a]	10.00(0.0-22.00) [a]	15.00(0.0-38.00) [ab]
PP %	19.00(0.0-39.00) [a]	17.00(2.00-41.00) [a]	23.00(4.00-51.00) [b]
	Buccal Wall Coronal 1/3	**Buccal Wall Middle 1/3**	**Buccal Wall Apical 1/3**
PFCP %	10.00(0.0-29.00) [ab]	4.00(0.0-35.00) [a]	0.00(0.0-24.00) [a]
FCP %	12.00(0.0-39.00) [b]	2.00(0.0-46.00) [a]	6.00(0.0-56.00) [ab]
PP %	3.00(0.0-12.00) [a]	7.00(0.0-11.00) [a]	18.00(0.0-57.00) [b]
	Lingual Wall Coronal 1/3	**Lingual Wall Middle 1/3**	**Lingual Wall Apical 1/3**
PFCP %	26.00(0.0-50.00) [a]	4.00 (0.0-26.00) [a]	7.00(0.0-49.00) [ab]
FCP %	25.00(5.0-47.00) [a]	5.00(0.0-9.00) [a]	10.00(0.0-22.00) [b]
PP %	7.00(0.0-21.00) [b]	8.00(0.0-17.00) [a]	18.00(6.00-42.00) [a]

Different letters in each of the M, D, B and L wall's columns, separately indicates statistically significant difference ($P < 0.05$). M: Mesial, D: Distal, B: Buccal, L: Lingual.

Table 3 Transportation of the canal after the different instrumentation protocols. A result of '0' indicates no canal transportation. Centering ratio. A result of *one* indicates perfect centering ability (median, minimum-maximum).

	Transportation			Centering ratio		
Group	B/L Coronal 1/3	B/L Middle 1/3	B/L Apical 1/3	B/L Coronal 1/3	B/L Middle 1/3	B/L Apical 1/3
PFCP	-0.413(0.036-1.219)[a]	0.091(0.004-0.648)[a]	0.220(0.049-1.316)[a]	0.453(0.078-1.043)[a]	0.875(0.127-1.042)[a]	1.158(0.400-1.868)[a]
FCP	-0.391(0.131-0.906)[ab]	-0.063(0.007-0.890)[a]	0.220 (0.011-0.771)[a]	0.420 (0.084-1.112)[a]	0.969 (0.619-1-149)[a]	0.758(0.027-1.140)[ab]
CG	-0.111(0.000-0.431)[b]	0.054(0.000-0.353)[a]	-0.117(0.000-0.503)[a]	0.938(0.652-1.204)[b]	0.877(0.654-1.044)[a]	0.581(0.046-0.969)[b]
	M/D Coronal 1/3	M/D Middle 1/3	M/D Apical 1/3	M/D Coronal 1/3	M/D Middle 1/3	M/D Apical 1/3
PFCP	-0.092(0.016-0.338)[a]	-0.104(0.011-0.271)[a]	-0.062(0.014-0.182)[a]	0.766 (0.256-1.069)[a]	0.781(0.427-0.935)[ab]	0.921 (0.585-1.242)[a]
FCP	0.146(0.003-0.470)[a]	0.100(0.016-0.336)[a]	-0.055(0.004-0.212)[a]	0.616(0.200-1.009)[a]	0.821 (0.493-1.027)[b]	0.779 (0.555-0.996)[ab]
CG	0.090(0.000-0.233)[a]	0.063(0.000-0.194)[a]	0.103(0.000-0.344)[a]	0.590(0.040-0.935)[a]	0.629(0.035-0.901)[a]	0.521 (0.146-0.808)[b]

B/L: Bucco-lingual direction; M/D: Mesio-distal direction.
Different letters in each of the B/L or M/D columns separately indicates statistically significant difference ($P < 0.05$).
Positive values indicate buccal or mesial direction of transportation; Negative values indicate lingual or distal direction of transportation.

2.1 ARTICLE 2

Analysis of a novel ultrasonic tip as an auxiliary method for the removal of filling material in flattened/oval-shaped root canals: a micro-computed tomographic study.

Abstract

Aim: To evaluate the influence of a novel ultrasonic tip as an auxiliary method for the removal of filling material of oval-shaped canals. **Methodology:** Forty-five mandibular incisors were selected and randomly divided into one of three experimental groups (N=15) according to different protocols for the removal of root canal filling material. Group R: Reciproc R25/.08, Group RC: Reciproc R25/.08 + Clearsonic tip and Group CR: Clearsonic tip + Reciproc R25/.08. The teeth were scanned pre and post-operatively by the means of a micro-computed tomography system. Data were analysed using non-parametric Kruskal-Wallis and Dunn's tests ($P<0.05$). **Results:** The percentage of residual root canal filling material between the experimental groups was examined. Statistically significant differences between the experimental groups were found in the total portion of the root canal, where group R provided the highest percentage of residual root canal filling material when compared to groups RC and CR. In group CR, the lowest percentage of residual root canal filling material was observed. In the apical third of the root canal, statistically significant differences were found between the different protocols used in this study. The technique used in group CR, provided the lowest percentage of residual root canal filling material. **Conclusion:** The use of the ClearSonic tip as the first instrument followed by the Reciproc 25/.08 file for the removal of filling material, resulted in the lowest percentage of residual filling material in the total portion and in the apical third of the root canal.

Introduction

Non-surgical retreatment should be the considered as the first and most conservative approach for endodontic failures (Rios et al. 2014, Rodrigues et al. 2016). An adequate removal of the endodontic filling material is essential to assure a favourable treatment prognosis (Rios et al. 2014). Different methods have been suggested for this purpose, including the use of heat, solvents, nickel-titanium (Ni-Ti) files, ultrasonic tips or a combination of these techniques (de Mello Jr et al. 2009, Kasan &

Mariswamy, 2016; Özyürek & Demiryürek, 2016). The combined use of the dental operating microscope with specially designed ultrasonic tips has been recommended for endodontic retreatment procedures (de Mello Jr et al. 2009). The clarity and details of the magnified observed field could improve precision during gutta-percha removal (de Mello Jr et al. 2009). The Reciproc system (VDW, Munich, Germany) consists of single-use reciprocating files that have also been indicated for retreatment purposes (Özyürek & Demiryürek, 2016). According to some studies (Rodrigues et al. 2016, Zuolo et al. 2016), reciprocating files have shown satisfactory results in retreatment procedures when used with a brushing motion against the root canal walls. Complete removal of filling materials should enable instruments and irrigating solutions to reach different areas of the root canal system (Rossi-Fedele et al. 2017). The achievement of patency and cleaning as near as possible to the apical region have been identified as prognostic factors related to periapical healing (Rossi-Fedele et al. 2017). For this reason, new protocols to reduce the percentages of filling material during retreatment procedures should be studied. Ultrasonic retreatment tips have been introduced for the removal of filling material from the root canal walls, offering a promising outcome (de Mello Jr. et al. 2009, Kasan & Mariswamy, 2016). Studies have reported a percentage of residual remaining filling material of approximately 9% this technology (de Mello Jr. et al. 2009, Kasan & Mariswamy, 2016). Recently, a novel ultrasonic tip (Clearsonic, Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) with an arrow section has been proposed as an auxiliary method for the removal of endodontic filling materials in flattened or oval-shaped canals. A literature review revealed that there are no previous studies using this novel ultrasonic tip as an auxiliary method for the removal of filling material in flattened/oval-shaped canals. Thus, the purpose of this study was to evaluate the efficacy of different protocols for the removal of filling material from oval/flattened root canals with the aid of the dental operating microscope (DOM) and analysed by micro-computed tomography (μ-CT). The null hypothesis tested was that a novel ultrasonic tip would not influence the removal of filling material in flattened/oval-shaped canals.

Materials and Methods

Specimen Selection

The sample calculation was performed using the G*Power v3.1 for Mac (Heinrich Heine, Universität Düsseldorf) by selecting the Wilcoxon-Mann Whitney test of the T test family. The data of a previous study with a similar number of samples was used (Zuolo et al. 2016) and the effect size in the present study was established (=1.32). The alpha type error of 0.05, a beta power of 0.95, and a ratio N2/N1 of 1 were also stipulated. A total of 14 per group were indicated as the ideal size required for noting significant differences. An additional specimen per group was used to compensate possible loss during the realization of the experiments.

Forty-five mandibular incisors that were extracted from a Brazilian population for reasons unrelated to this study were acquired after the Ethics Committee in Human Research approved the study (CEP 2.112.063). The teeth were selected according to a novel classification (Ahmed et al. 2017). Only $^{1}TN^{1}$ mandibular incisors with an oval-shaped configuration were selected. To be considered as an oval-shaped canal, a bucco-lingual diameter at least twice as wide as the mesio-distal diameter throughout the coronal two-thirds had to be found (Bernardes et al. 2015, Crozeta et al. 2016). Teeth with two root canals, an open apex or with previous endodontic treatment were excluded.

Root Canal Filling Procedures

During the experimental procedures, all the specimens were placed in a custom metallic muffle prepared for each specimen and fixed internally with silicone impression material to simulate clinical conditions. The specimens were prepared according to different instrumentation protocols using rotary files (Prodesign Logic 25/.05 + Prodesign Logic 40/.05) or a combination of rotary files and novel ultrasonic tips (ProDesign Logic 25/.05 + Flatsonic + Clearsonic + Prodesign Logic 40/.01 or Flatsonic + Clearsonic + ProDesign Logic 40/.01) for the debridement of flattened/oval-shaped root canals, as reported on a previous study. Subsequently, a final irrigation protocol was used. 2 mL of 2.5% NaOCl were refreshed and ultrasonically activated with an ultrasonic device (NSK, Brasil Ldta, São Paulo, Brazil) using an Irrisonic tip (size 20, 0.01 taper) (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) set to low power, three times for 20 seconds each. The specimens were flushed with 17% EDTA for 3 minutes and ultrasonically activated for 60 seconds. The root canals were flushed with 2 mL of 2.5% NaOCl and ultrasonically activated thrice for 20 seconds each (van der Sluis et al. 2010). A final rinse with saline solution was performed and the specimens were dried with sterile paper points. Root canals were filled by the continuous wave of condensation technique, using a size 25/.04 or 40/.04 master gutta-percha points (Dentsply Tulsa Dental Specialties, Tulsa, Oklahoma, United States of America) according to the instrumentation protocol applied. Sealer Plus (MK Life, Porto Alegre, Brazil) was used as the sealer in all groups. A FF or MF (depending on the master's cone size) heat carrier tip (Friendo, Endo Apex, Dentazon Corporation, Gyeonggi-do, Korea) set at 170°C was inserted 5 mm from the working length and activated for 10 seconds. Then, it was reactivated for 1 second and removed from the canal (Zuolo et al. 2016). The middle and coronal portions of the root canals were filled with Gutta Easy, (Endo Apex, Dentazon Corporation, Gyeonggi-do, Korea) at a temperature of 180°C and compacted with compatible Shilder's pluggers (Dentsply Maillefer. Ballaigues, Switzerland). The specimens were temporarily restored with Cavit (3M ESPE, Seefeld, Germany) and then stored at 100% humidity and 37°C for 30 days to allow the complete setting of the sealer before the micro-computed tomography scans.

Micro-computed tomographic analysis:

The specimens were scanned with a Skyscan 1174 micro-computed tomography system (Bruker-microCT, Kontich, Belgium). The parameters used were 50 kV, 800 mA, and a voxel size of 16.8 um. The system includes a charge-coupled device camera (1304_1024 pixels). The radiographic images of each specimen were reconstructed by using the NRecon software (v. 1.6.3, Bruker-microCT). The CTAn software (v.1.12, Bruker-microCT) was used for measuring the volume of radiopaque filling material (mm^3) and the presence of residual filling material was calculated as a percentage (Crozeta et al. 2016). Qualitative two-dimensional and three-dimensional analysis of the presence of residual filling material in the total and apical portion of the root canal were assessed on cross-sectional images and 3D models by using the CTAn (v.1.12, Bruker-microCT) and CTVol (v.2.3.1, Bruker-microCT) softwares.

Filling Removal Technique

For the filling removal procedures, a dental operating microscope (Alliance Microscopia, São Carlos, Brazil) at x6 magnification was used. The specimens were divided into three groups, selecting five specimens from each instrumentation protocol in order to reallocate them in new experimental groups according to the filling removal technique.

Group R: Reciproc R25/.08 (N=15).

In this group, the Reciproc R25 (VDW, Munich, Germany) instrument was used with the VDW Silver motor in an in-and-out pecking motion until reaching the working length using the RECIPROC ALL mode. Subsequently, a brushing motion was applied until no visual evidence of residual filling material under the DOM was confirmed. A single operator performed all filling removal procedures. One drop (0.8 mL) of xylene solvent was placed in the pulp chamber for 1 minute before starting the removal of the filling material. The root canals were irrigated using a total of 24 mL of 1% sodium hypochlorite (NaOCl). The specimens were scanned using the parameters previously described through a Skyscan 1174 micro-computed tomography system (Bruker-microCT, Kontich, Belgium).

Group RC: Reciproc R25/.08 + Clearsonic (N=15).

The Reciproc R25 (VDW, Munich, Germany) instrument was used under the same experimental conditions as described for the specimens in Group A Thus, an ultrasonic tip with an arrow-design R1 Clearsonic, (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil; Fig. 1) mounted in an ultrasonic device (NSK Brasil Ldta, São Paulo, Brazil) in a frequency of 30 kHz was used, being activated for six cycles of 20 seconds in the bucco-lingual direction using an in-and-out pecking motion in order to remove the filling material within the coronal and middle thirds of the root canal for a total time of 2 minutes. The root canals were irrigated using a total of 24 mL of 1% sodium hypochlorite (NaOCl). The specimens were scanned for the last time.

Group CR: Clearsonic + Reciproc R25/.08 (N=15).

Firstly, the Clearsonic (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil) ultrasonic tip was used for the removal of the filling material, following the same protocol applied for the specimens in Group B. The Reciproc R25 (VDW, Munich, Germany) instrument was used under the same experimental conditions as previously described. The root canals were irrigated using a total of 24 mL of 1% sodium hypochlorite (NaOCl) and the specimens were scanned for the last time.

Statistical Analysis

For the analysis of the data the Graph Pad Prism 6's (GraphPad Software, Inc., California, United States of America) software was used, performing the non-parametric Kruskal-Wallis and Dunn's tests due to the presence of a non-normal distribution. The significance level was of 5%.

Results

Regarding the percentage of residual root canal filling material in the total portion of the root canal, statistically significant differences between groups R and RC were found ($P<0.05$; Table 1; Fig. 2). In the same way, group R showed statistically significant differences with group CR ($P<0.05$; Table 1; Fig. 2). Group R provided the highest percentage of residual root canal filling material (76%) when compared to groups RC (24%) and CR (16%), where the lowest percentage of residual root canal filling material was observed. Concerning the percentage of residual root canal filling material in the apical third of the root canal, statistically significant differences were found when group R (86%) and RC (100%) were compared to group CR (21%). The technique used in group CR, showed the lowest percentage of residual root canal filling material ($P<0.05$; Table 1; Fig 2).

Discussion

Failure in endodontic treatment has been associated to the presence of residual bacteria or reinfection of an endodontically treated tooth, because of inadequate cleaning, disinfecting, shaping or filling of the root canals (Crozeta et al. 2016). The objective of endodontic retreatment is the removal of contaminated filling material (Zuolo et al. 2013) and bacterial remnants from the root canal space (Bernardes et al. 2015). Complete removal of filling materials enable instruments and irrigating solutions to reach different areas of the root canal system (Rossi-Fedele et al. 2017). The achievement of patency and cleaning as near as possible to the apical region have been identified as prognostic factors related to periapical healing (Rossi-Fedele et al. 2017). In the current study, the efficacy of different protocols for the removal of filling material from oval/flattened root canals with the aid the dental operating microscope (DOM) was assessed by micro-computed tomography (µ-CT). The use of engine-driven instruments is convenient for retreatment procedures due to their agility and safety, contributing to minimize the operator´s and patient´s fatigue (Rodrigues et al. 2016). Oval canals were selected for this study because the non-circular anatomy of these teeth represents a challenge for the removal of filling material (Bernardes et al. 2015, Crozeta et al. 2016, Zuolo et al. 2016). Therefore, the use of ultrasonic technology for the removal of filling material in the coronal and middle thirds (Hess et al. 2011) as well as the dental operating microscope has been recommended during endodontic retreatment (Rios et al. 2014). Studies have reported that none of the actual systems remove all residual filling material from the root canal space (Zuolo et al. 2016). Xylene was used as a solvent to facilitate the removal of gutta-percha due to its efficient dissolving action (Fruchi et al. 2014, Kasam & Mariswamy, 2016). However, practitioners may find difficulties during retreatment procedures even with the aid of magnification and ultrasound. (Zuolo et al. 2013, Zuolo et al. 2016). Micro-computed tomography (μ-CT) imaging is a non-invasive and reproducible method that allows the development of accurate three-dimensional models and the acquisition of quantitative data without the destruction of the samples (Rhodes et al. 1999, Peters et al. 2000, Versiani et al. 2016). This technology is considered as ideal to quantify the volume of filling material before and after its removal (Fruchi et al. 2014, Crozeta et al. 2016).

The null hypothesis that there would be no significant differences between the protocols used for the removal of filling material was rejected. The results of this study revealed that none of the protocols were able to completely remove the filling material in oval-shaped canals. Consequently, residual filling material was found in all specimens. Regarding the percentage of residual root canal filling material in the total portion of the root canal, statistically significant differences were observed, where Group R provided the highest percentage of residual root canal filling material when compared to groups RC and CR. This suggests that the use of only Reciproc 25/.08 was not enough to promote a substantial reduction in the percentage of residual filling material in oval-shaped canals, possibly due to the difficulties related to the anatomy of these teeth. Otherwise, the lowest percentage of residual root canal filling material was found in group CR. In the apical third of the root canal, statistically significant differences were found when group R and RC were compared to group CR. The technique used in group CR, showed the lowest percentage of residual root canal filling material. According to these results, the use of ClearSonic for the removal of filling material in the coronal and middle thirds, followed by Reciproc 25/.08, significantly reduced the percentage of residual filling material in the total portion and apical third of the oval-shaped canals. These results are in agreement with a previous study, where the use of the DOM associated to an ultrasonic tip for endodontic retreatment, improved the removal of filling material compared with the control group where this technology was not utilized (de Mello Jr et al. 2009). Increased visualization of a properly illuminated field plays an important role during the procedure (de Mello Jr et al. 2009). However, the use of an ultrasonic instrument is essential to promote the dislodgement of the filling material by using the cutting effect of lower piezoelectric oscillation (de Mello Jr et al. 2009). The use of hybrid techniques and larger diameters of preparation may enhance the cleanliness of the root canal walls (Rossi-Fedele & Ahmed). Although, the removal of filling material depends on preoperative factors, such as root canal morphology, filling materials, preparation size and diameter (Rossi-Fedele & Ahmed, 2017). In a study by Kasam & Mariswamy (2016) the use of an ultrasonic tip for the retreatment of mandibular premolars was described. The authors explained that the ultrasonic tip removed material from the root canals within a short period of time and producing little extrusion. The ultrasonic vibration from the ultrasonic tip promoted the displacement of filling material from the root canal walls by enhancing the removal of sealer (Kasam & Mariswamy, 2016). The occurrence of frictional heat produced by the ultrasonic instrument causes a synergistic effect on gutta-percha, leading to its softening and displacement from the root canal (Kasam & Mariswamy, 2016). In the same study (Kasam & Mariswamy, 2016), the authors showed that the best results for removal of filling material were observed in the coronal (6%) and middle (7%) thirds of the canal compared to the apical third (14%) due to the diameter of the tip (.06) which prevented it from reaching the apical third. Similarly, the protocols used in our study showed a higher percentage of filling material in the apical third. These results could be explained by the diameter of the ClearSonic ultrasonic tip, which corresponds to an ISO size 50 file (0.5 mm), restricting its access to the apical third of the root canal. Crozeta et al. (2016) reported a 43% of residual filling material in the total portion and 70% in the apical third of oval-shaped canals prepared with Reciproc 50/.05. In this case, a size 50 file was considered as the ideal instrument for the preparation of oval-shaped distal canals of mandibular molars. These results were supported by the tendency of the reciprocating motion to induce the instrument to progress forward continuously, pushing debris toward the apex (Crozeta et al. 2016, Lu et al. 2013). In light of this fact, the presence of higher percentages of residual filling material in the apical third could also be expected in the present study.

A new epoxy-based endodontic sealer (Sealer Plus, MK Life, Porto Alegre, RS, Brazil) was used in the present study. This sealer contains calcium hydroxide, radiopaque fillers such as calcium tungstate and zirconium oxide (Cintra et al. 2017). The ideal endodontic sealer must exhibit adequate biocompatibility, physicochemical properties, bioactivity and antimicrobial action. Despite the variety of endodontic materials in the market, there is still no sealer to reach all these properties (Cintra et al. 2017). Sealer Plus showed adequate physicochemical properties in accordance with specification No. 57 of ANSI/ADA and ISO 6876, when compared to AH Plus (Vertuan et al. 2018). There is only one publication regarding its cytotoxicity and biocompatibility, where it exhibited a superior response compared to AH Plus, Endofill and SimpliSeal (Cintra et al. 2017). These results could be related to the addition of calcium hydroxide to the formulation of this sealer, improving its biological properties (Cintra et al. 2017). Our results are in accordance with another study that showed difficulties regarding the removal of filling materials such as epoxy resin-based sealers (Kim et al. 2015). This could be related to the penetrability of these sealers into the root dentin. Authors suggest that in order to remove this sealer completely, it would be necessary to remove up to 40%-60% of additional root dentin, being an impracticable approach for endodontic practice (Kim et al. 2015).

On the other hand, Bernardes et al. (2015) studied the amount of residual filling material in flattened canals after using different techniques with or without ultrasonic activation of the irrigants. In the specimens where the ultrasonic activation of the irrigants was done and the Reciproc 50/.05 file was used, their results showed a percentage of 1.6% of residual filling material, similar to where only the Reciproc instrument was used (4%). Rossi-Fedele et al. (2017) showed that the use of larger sizes of reciprocating systems removes filling material more effectively than rotary retreatment systems. However, reciprocating motion may cause the instrument to progress forward continuously, pushing debris toward the apex (Lu et al. 2013, Crozeta et al. 2016, Rossi-Fedele et al. 2017). The efficiency of the Reciproc file for the removal of filling materials has been described in previous studies that utilized circular or curved canals (Zuolo et al. 2013, Fruchi et al. 2014, Rios et al. 2014, Bernardes et al. 2015, Özyürek & Demiryürek, 2016, Rodrigues et al. 2016). To our knowledge, this is the first publication to assess the efficacy of this novel ultrasonic tip compared to the Reciproc 25/.08 file for the removal of filling material in flattened or oval-shaped mandibular incisors. However, it is important to clarify that in this study, only the removal of filling material was examined and not the ability of the instruments to re-prepare the oval-shaped root canals. This was achieved by the means of only the Reciproc 25/.08 file or by the association of this instrument to the ClearSonic tip, in order to test the efficacy of this protocol considering the anatomy of the specimens.

Conclusion

Within the limitations of this study, the presence of residual filling material was observed in the oval/flattened root canals, regardless of the protocol used. The use of the ClearSonic tip before the Reciproc 25/.08 file provided the lowest percentage of residual filling material in the total portion and in the apical third of the root canals. Further research should be performed in order to compare the efficacy of different endodontic instruments to find the most suitable protocol to achieve lower percentages of residual filling material in flattened/oval-shaped canals.

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The authors deny any conflict of interest.

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Figure Legends

Figure 1 (a) Ultrasonic Clearsonic tip and (b) scanning electron microscopy (SEM) image i of the Clearsonic tip (original magnification, 35x).

Figure 2 Representative reconstructions of the superimposed specimens before (a and c) and after (b and d) the removal of filling material in each experimental group. Frontal (a and b) and lateral views (c and d). Representative cross-sections of the superimposed flattened/oval-shaped mandibular incisors (e) after the removal of filling material in each experimental group at the coronal (c), middle (m) and apical (a) thirds.

Table

Table 1 Percentages of residual filling material (median, minimum-maximum) at the total portion and apical third of the root canal.

Group	Total	Apical 1/3
R		
%	76.10(2.800-99.40) [a]	86.70(0.0-100.0) [a]
RC		
%	24.80(6.500-86.00) [b]	100.0(81.40-100.0) [a]
CR		
%	16.20(3.500-48.00) [b]	21.90(0.0-93.20) [b]

Different letters in each column indicates statistically significant difference ($P < 0.05$).

3 DISCUSSION

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In the present study, the influence of different protocols using ultrasonic tips as an auxiliary method for the instrumentation and removal of filling material in flattened/oval-shaped canals was assessed by micro-computed tomography. For this purpose, changes in volume and surface area, centering ability, degree of canal transportation, percentage of dentine removal and residual filling material were examined. Success or failure in endodontics depends on many factors (Langeland et al, 1985). Proper biomechanical preparation of the root canal space is essential for success in endodontic therapy (Goldman et al, 1988). The use of new auxiliary methods should favorably influence the treatment prognosis (Langeland et al, 1985). In addition to hand instrumentation, several mechanical devices have been introduced to facilitate instrumentation (Langeland et al, 1985). Different techniques utilizing ultrasonics have been reported (Goldman et al, 1988). The majority of systems were based upon the ultrasonic energizing of a file for mechanical canal preparation and debris removal, as well as ultrasonic activation of an irrigant for enhanced penetration, solvent and bacteriocidal action (Goldman et al, 1988).

Significant gains in canal volume and surface area were observed in all the experimental groups, reducing the non-instrumented areas of the flattened/oval-shaped canals. The lowest percentage of non-instrumented surface area resulted in the greatest increase in canal volume for group PFCP ($P<0.05$). When a controlled-memory rotary file (ProDesign Logic 25/.05) was used before the ultrasonic tips (Flatsonic and Clearsonic) as an auxiliary method, 18% of non-instrumented surface area was found. These results suggest that the protocol used in group PFCP should be adopted in order to improve the shaping of flattened/oval-shaped canals. The usage of endodontic files beforehand seems to aid the action of the FlatSonic tip with its flattened design and a diameter of 0.25 mm in areas of anatomical complexity. This protocol facilitated the use of the ClearSonic tip, which has a 0.5 mm diameter, corresponding to ISO size 50 file. In another study by Weller et al (1980) the use of ultrasound after manual instrumentation contributed to 88% of debridement in human teeth and 92% in resin blocks. However, differences in experimental designs and results between studies should be considered.

As explained by Gergi et all. (2015), canal volume is a variable used to analyse the effects of canal instrumentation on dentine removal. As for the mesial wall, statistically significant differences were only found in the middle third. The use of ProDesign Logic 25/.05 and ProDesign Logic 40/.05 file in group PP, produced a greater wear in this portion of the root, coinciding with the results of the distal wall, where statistically significant differences were observed merely in the apical third. This protocol includes the use of a file of greater taper and more rigidity, which may be associated to a greater wear in this area (ElAyouti et al, 2008). The larger the taper, the higher the amount of prepared surface area in the root canal walls (De-Deus et al, 2015). Larger apical preparations have been associated to improvements in the disinfection and cleaning procedures, reducing the bacterial load in the root canal system (De-Deus et al, 2015). In the buccal and lingual walls, statistically significant differences were found in the coronal third where the use of ultrasonic tips contributed to a significant increase in dentine removal. This could be explained by their direction of action in the bucco-lingual orientation. Statistically significant differences were also found in the apical third, where ProDesign Logic 25/.05 and ProDesign Logic 40/.05 (PP) were used, providing the greatest percentage of dentine removal.

Concerning the degree of transportation in the bucco-lingual direction and in the coronal third, the lowest values were found in group PP, where ultrasonic tips were not used as an auxiliary method during the shaping procedures ($P<0.05$). Due to the action of the ultrasonic tips in the bucco-lingual direction, it is expected to observe a greater wear in this region. No statistically significant differences were found in the middle and apical thirds ($P<0.05$). In the mesio-distal direction, no statistically significant differences in the coronal, middle and apical thirds were found ($P<0.05$). Thus, all the protocols used in this study showed an adequate performance concerning the degree of transportation. These results differ from other studies where the application of ultrasound for instrumentation procedures created an irregular shape in the root canal, particularly in 3 to 6 mm from the root apex (Moriya, 1984; Yamaguchi et al, 1988;). Eventhough, the authors apointed ultrasonic instrumentation as an acceptable method to use in endodontics due to its superiority for debris removal when compared to manual files (Yamaguchi et al, 1988). It is important to mention that when compared to the current study, these investigations diverge in technological advances as well as in the the variety of experimental protocols used by the authors. Goldman et al (1998) reported that the use of ultrasonic energizing of a file for the instrumentation of root canals showed no statistically significant difference, when compared to manual files in maxillary central incisors. Walker & del Rio (1989) showed similar results, when ultrasonic instrumentation was compared to hand and sonic devices. Another study (Langeland et al, 1985) observed that ultrasonic instrumentation was comparable to hand and sonic instruments, demonstrating an acceptable performance in straight circular canals. Despite the favourable results, the authors suggested to proceed with caution to prevent perforations due to the greater efficiency of these devices (Langeland et al, 1985). In addition, Nagy et al (1997) found low values of asymmetry of preparation when ultrasonically-powered instruments were used.

In the bucco-lingual direction, group PP showed the greatest centering ratio in the coronal third of the root canals ($P<0.05$). These results could be associated to the activation of the ultrasonic tips in the bucco-lingual direction, as previously mentioned. Despite these facts, all of the techniques used in this study demonstrated an acceptable centering ability. No statistically significant differences were found in the middle third of the specimens ($P<0.05$). In the apical third, statistically significant differences were observed between groups PCFP and PP ($P<0.05$). Therefore, group PFCP displayed the greatest centering ratio. This could be explained by the use of ProDesign Logic 40/.01 file in group PFCP, in contrast with ProDesign Logic 40/.05 which has a greater taper. This makes ProDesign Logic 40/.05 more rigid and may produce a greater wear in this area (ElAyouti et al, 2008). In the mesio-distal direction, no statistically significant differences in the coronal third were observed between the three instrumentation protocols used in this study. However, statistically significant differences between groups FCP and PP were found in the middle third of the root canal. The greatest centering ratio was displayed by the instrumentation protocol used in group FCP ($P<0.05$). This implies that the use of ultrasonic tips combined with ProDesign Logic 40/.01 provided a most centered preparation in the middle third of the root canal than the protocol where ProDesign Logic 25/.05 and ProDesign Logic 40/.05 were used. These results could be related to the presence of flattened areas in oval-shaped canals and the action of an instrument of greater taper in this portion of the root, which may produce a greater lateral cutting (ElAyouti et al, 2008). In the apical third, statistically significant differences were observed between groups PFCP and PP ($P<0.05$). Therefore, group PFCP displayed the greatest centering ratio, explained by the use of ProDesign Logic 40/.01 file in group PFCP, in contrast with ProDesign Logic 40/.05.

Failure in endodontic treatment has been associated to the presence of residual bacteria or reinfection of an endodontically treated tooth, because of inadequate cleaning, disinfecting, shaping or filling of the root canals (Crozeta et al. 2016). The aim of endodontic retreatment is the removal of contaminated filling material (Zuolo et al, 2013) and bacterial remnants from the root canal space (Bernardes et al, 2015). Complete removal of filling materials enable instruments and irrigating solutions to reach the different areas of the root canal system (Rossi-Fedele et al. 2017). The achievement of patency and cleaning as near as possible to the apical region have been identified as prognostic factors related to periapical healing (Rossi-Fedele et al. 2017). Retreatment is a tedious and time consuming process that could lead to many procedural errors (Kasam & Mariswamy, 2016). Different methods have been suggested for the removal of filling material, including the use of heat, solvents, nickel-titanium (Ni-Ti) files, ultrasonic tips or a combination of these techniques (de Mello Jr et al, 2009, Kasan & Mariswamy, 2016; Özyürek & Demiryürek, 2016).The use of engine-driven instruments is beneficial for retreatment procedures due to their agility and safety, contributing to minimize the operator´s and patient´s fatigue (Rodrigues et al, 2016). Oval canals were selected for this study because the non-circular anatomy of these teeth represents a challenge for the removal of filling material (Bernardes et al, 2015; Crozeta et al, 2016; Zuolo et al, 2016). For this reason, the use of the dental operating microscope has been recommended during endodontic retreatment (Rios et al, 2014). None of the current systems remove all residual filling material from the root canal space (Zuolo et al, 2016). Consequently, xylene was used as a solvent to facilitate the removal of gutta-percha due to its efficient dissolving action (Fruchi et al, 2014; Kasam & Mariswamy, 2016). However, practitioners may find difficulties during retreatment procedures even with the aid of magnification and ultrasound. (Zuolo et al 2013, Zuolo et al 2016). Micro-computed tomography (μ-CT) imaging is a reproducible method considered as ideal to quantify the volume of filling material before and after its removal (Fruchi et al, 2014; Crozeta et al, 2016).

Residual filling material was found in all specimens. Therefore, none of the protocols used in this study were able to completely remove the filling material in flattened/oval-shaped canals. Statistically significant differences concerning the percentage of residual filling material were found in the total portion of the root canal. Group R provided the highest percentage of residual filling material when compared to groups RC and CR ($P<0.05$). This suggests that the use of only Reciproc 25/.08 was not enough to promote a substantial reduction in the percentage of residual filling material in flattened/oval-shaped canals, possibly due to the difficulties related to the anatomy of these teeth. Although, the removal of filling material depends on preoperative factors, such as root canal morphology, filling materials, preparation size and diameter (Rossi-Fedele and Ahmed, 2017). Otherwise, the lowest percentage of residual filling material in the apical portion of the canal was found in group CR ($P<0.05$). The technique used in group CR, showed the lowest percentage of residual root canal filling material. According to these results, the use of ClearSonic for the removal of filling material in the coronal and middle thirds, followed by Reciproc 25/.08, significantly reduced the percentage of residual filling material in the total portion and apical third of the oval-shaped canals. . This could be explained by the diameter of the ClearSonic ultrasonic tip, which corresponds to an ISO size 50 file (0.5 mm), restricting its access to the apical third of the root canal. These results are in agreement with a previous study, where the use of the DOM associated to an ultrasonic tip for endodontic retreatment, improved the removal of filling material compared with the control group where this technology was not utilized (de Mello Jr et al, 2009). Increased visualization of a properly illuminated field plays an important role during retreatment procedures (de Mello Jr et al, 2009). However, the use of an ultrasonic instrument is essential to promote the dislodgement of the filling material by using the cutting effect of lower piezoelectric oscillation (de Mello Jr et al, 2009). The use of hybrid techniques and larger diameters of preparation may enhance the cleanliness of the root canal walls (Rossi-Fedele & Ahmed, 2017). Although, the removal of filling material depends on preoperative factors, such as root canal morphology, filling materials, preparation size and diameter (Rossi-Fedele & Ahmed, 2017). In a study by Kasam and Mariswamy (2016), the use of an ultrasonic tip for the retreatment of mandibular premolars was described. The authors explained that the ultrasonic tip removed material from the root canals within a short period of time and producing little extrusion. The ultrasonic vibration from the ultrasonic tip promoted the displacement of filling material from the root canal walls due to the occurrence of frictional heat by enhancing the removal of sealer (Kasam & Mariswamy, 2016). In the same study, the authors (Kasam & Mariswamy, 2016) showed that the best results for removal of filling material were observed in the coronal (6%) and middle (7%) thirds of the canal compared to the apical third (14%). These results were associated to the diameter of the tip (.06), which prevented it from reaching the apical third. Crozeta et al (2016) reported a 43% of residual filling material in the total portion and 70% in the apical third of oval-shaped canals prepared with Reciproc 50/.05. In this case, a size 50 file was considered as the ideal instrument for the preparation of oval-shaped distal canals of mandibular molars. Rossi-Fedele et al. (2017) showed that the use of larger sizes of reciprocating systems removes filling material more effectively than rotary retreatment systems. However, reciprocating motion may cause the instrument to progress forward continuously, pushing debris toward the apex (Lu et al. 2013, Crozeta et al. 2016, Rossi-Fedele et al. 2017). In light of this fact, the presence of higher percentages of residual filling material in the apical third could also be expected in the present study. To our knowledge, this is the first study to assess the influence of this novel ultrasonic tip compared to the Reciproc 25/.08 file for the removal of filling material in flattened or oval-shaped mandibular incisors. However, it is important to clarify that in this study, only the removal of filling material was examined and not the ability of the instruments to re-prepare the oval-shaped root canals. This was achieved by the means of only the Reciproc 25/.08 file or by the association of this instrument to the ClearSonic tip, considering the anatomy of the specimens.

4 CONCLUSIONS

4 CONCLUSIONS

The null hypothesis that novel ultrasonic tips would not influence the instrumentation and removal of filling material on flattened/oval-shaped root canals was rejected. Based on the experimental design of this study, it can be concluded that the protocol used in group PFCP provided a significant increase in volume and reduced the percentage of non-instrumented areas. Regarding the dentin removal, the protocol used in group PP presented the higher percentage of dentin removal in the middle third (mesial wall) and in the apical third of the root canal (distal/buccal/lingual walls). The protocol used in group FCP showed the higher percentage of dentin removal in the coronal third (buccal wall). The protocol used in group PFCP showed the higher percentage of dentin removal in the coronal third (lingual wall). Concerning the transportation values, the protocol used in group PP showed the lowest values in the coronal third (bucco-lingual direction). As for the centering ratio, the protocol used in group PP presented the most centered preparation in the coronal third (bucco-lingual direction). The protocol used in group FCP showed the greatest centering ratio in the middle third (mesio-distal) and group PFCP displayed the greatest centering ratio in the apical third (mesio-distal and bucco-lingual direction). Residual filling material was found in the oval/flattened root canals, regardless of the protocol used. The use of the ClearSonic tip before the Reciproc 25/.08 file provided the lowest percentage of residual filling material in the total portion and in the apical third of the root canals.

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APPENDIX

APPENDIX

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN DISSERTATION

We hereby declare that we are aware of the article, **Analysis of a protocol using novel ultrasonic tips as an auxiliary method for the instrumentation of flattened/oval-shaped root canals: A micro-computed tomographic study --- Part 1** will be included in the Dissertation of the student Melissa Esther Rivera Peña was not used and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, 11 de dezembro de 2017.

Melissa Esther Rivera Peña
Author
Signature

Marco Antônio Húngaro Duarte
Author
Signature

Murilo Priori Alcalde
Author
Signature

Flaviana Bombarda de Andrade
Author
Signature

Rodrigo Ricci Vivan
Author
Signature

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN DISSERTATION

We hereby declare that we are aware of the article, **Analysis of a novel ultrasonic tip as an auxiliary method for the removal of filling material in flattened/oval-shaped root canals: A micro-computed tomographic study --- Part 2** will be included in the Dissertation of the student Melissa Esther Rivera Peña was not used and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, 11 de Dezembro de 2017.

Melissa Esther Rivera Peña
Author
Melissa Rivera
Signature

Marco Antônio Húngaro Duarte
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Murilo Priori Alcalde
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ARTICLE 1

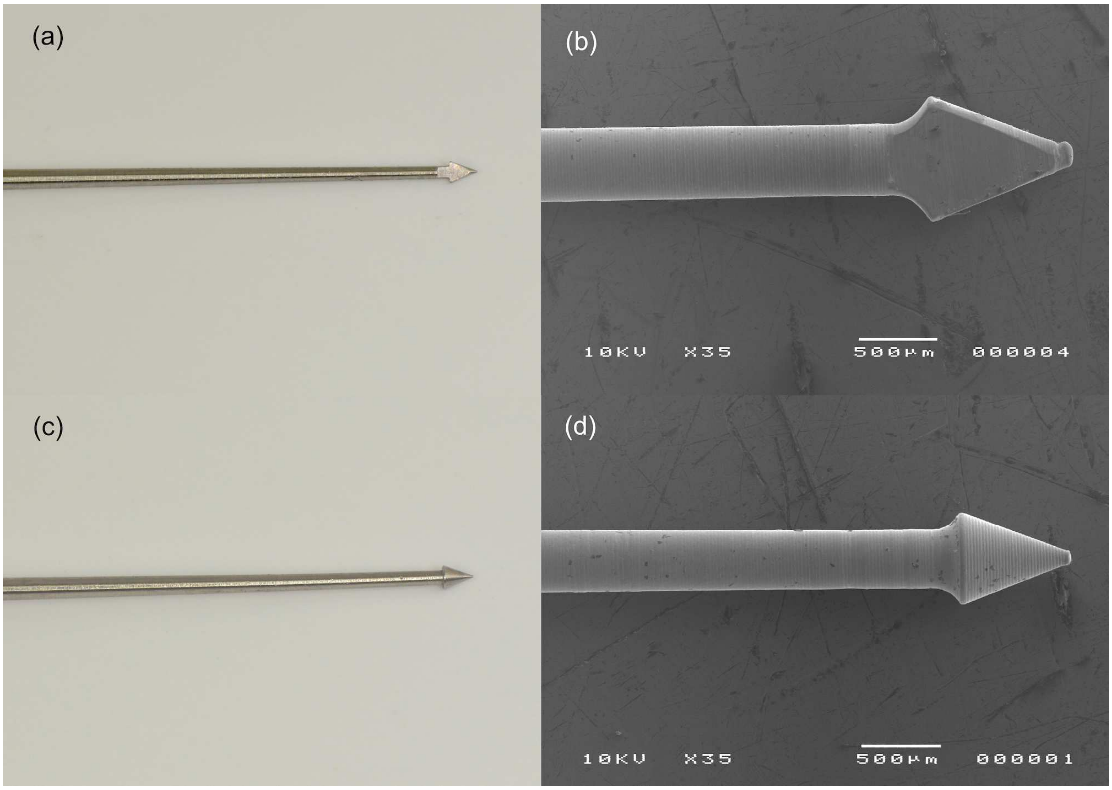

Figure 1

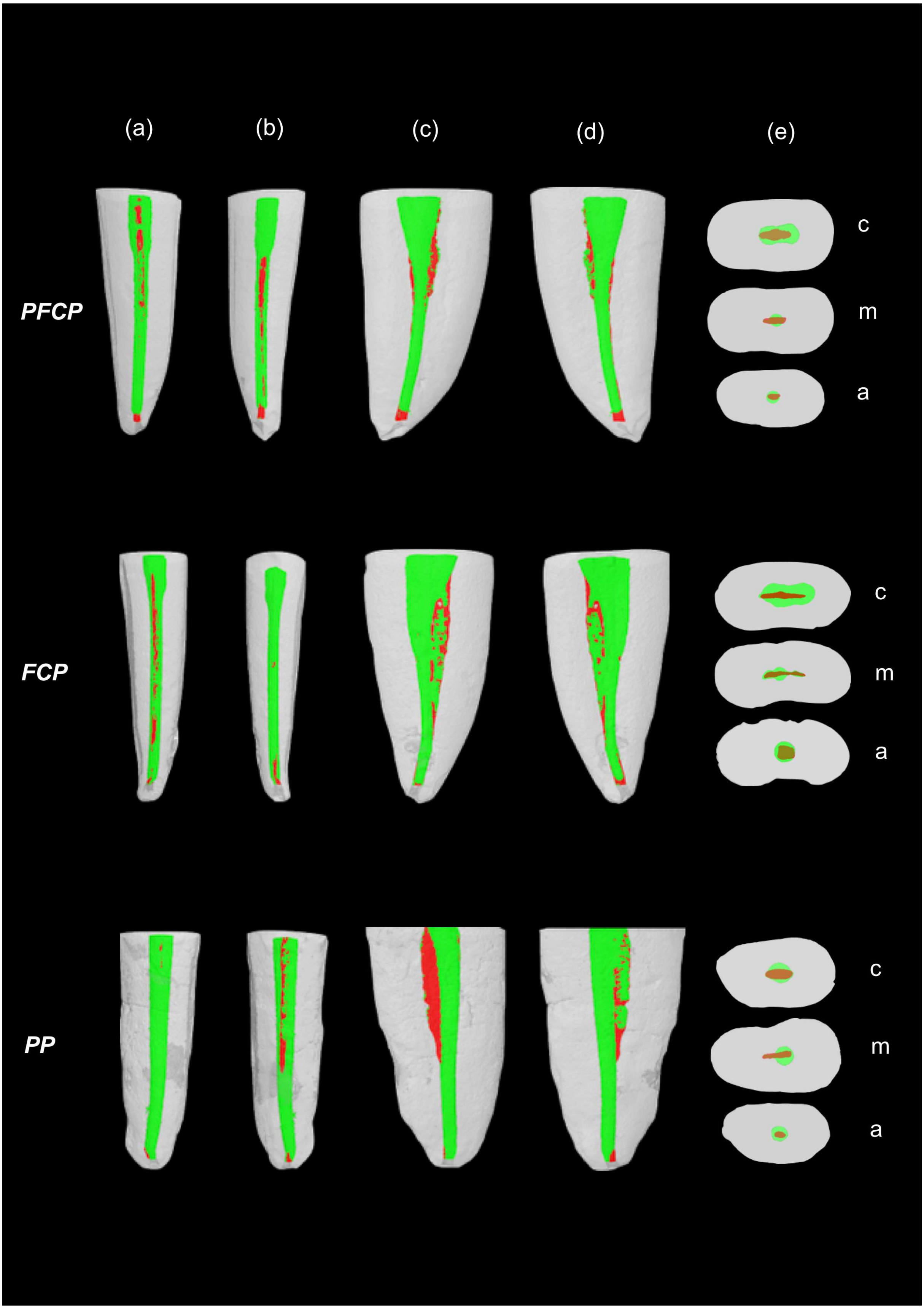

Figure 2

ARTICLE 2

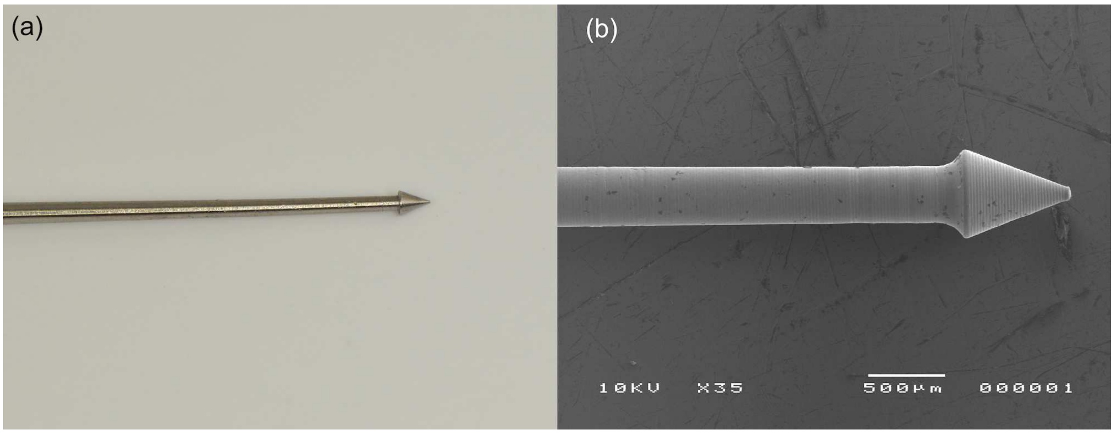

Figure 1

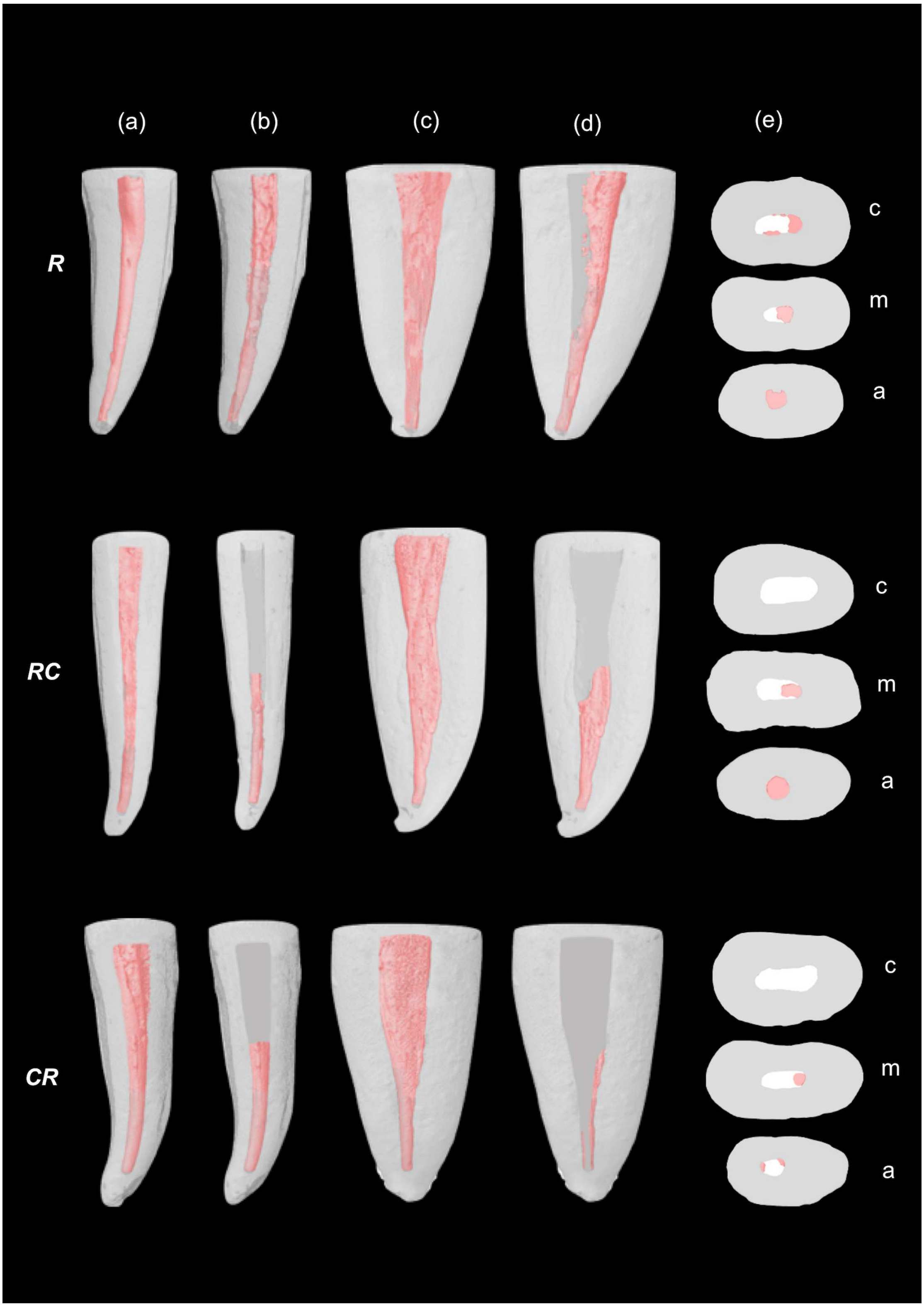

Figure 2

ANNEX

ANNEX

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Title Analysis of a protocol using novel ultrasonic tips as an auxiliary method for the instrumentation of flattened/oval-shaped root canals: A micro-compu tomographic study --- Part 1.

Authors Rivera-Peña, Melissa
Duarte, Marco
Alcalde, Murilo
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Title Analysis of a novel ultrasonic tip as an auxiliary method for the removal of filling material in flattened/oval-shaped root canals: A micro-computed to study --- Part 2.

Authors Rivera-Peña, Melissa
Duarte, Marco
Alcalde, Murilo
Andrade, Flaviana
Vivan, Rodrigo

Date Submitted 09-Dec-2017

USP - FACULDADE DE ODONTOLOGIA DE BAURU DA USP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Avaliação de novos insertos ultrassônicos para preparo e desobturação de canais achatados: Análise por microtomografia computadorizada.

Pesquisador: Melissa Esther Rivera Peña

Área Temática:

Versão: 2

CAAE: 66285617.7.0000.5417

Instituição Proponente: Universidade de São Paulo - Faculdade de Odontologia de Bauru

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.112.063

Apresentação do Projeto:

Trata-se de estudo utilizando 45 espécimes correspondentes a incisivos inferiores com canal único (Vertucci tipo I), divididos em três grupos de 15 cada, para avaliação de área tocada e não tocada em preparo e remoção de material obturador por meio de novos insertos ultrassônicos. Mais 15 espécimes para o projeto piloto, totalizando 60 dentes. A intenção é comparar a utilização de inserto ultrassônico achatado em forma de faca (recentemente lançado no mercado endodôntico) para se trabalhar em áreas de complexidade anatômica e o instrumento R25 durante a instrumentação e desobturação de canais radiculares com achatamento. A comparação será feita entre 3 grupos: 1-preparo e desobturação com instrumento R25; 2-preparo e desobturação com insertos ultrassônicos flatsonic e flat-apical; 3- preparo e desobturação com instrumento R25 e insertos ultrassônicos flatsonic e flat-apical. Cada espécime será escaneado quatro vezes (pré e pós-instrumentação; após a obturação e a desobturação) por meio de microtomógrafo computadorizado, reconstruído, processado e controlado por um software no computador. Será considerada toda a extensão dos canais radiculares, desde o terço cervical até o terço apical. Serão aplicados testes estatísticos para a avaliação do padrão de normalidade, com o intuito de decidir a utilização de teste estatístico paramétrico ou não-paramétrico. O nível de significância será de 5%. Segundo a autora, não há relatos na literatura sobre esse novo inserto e de desenvolvimento de

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Continuação do Parecer: 2.112.063

novos materiais para esta área.

Objetivo da Pesquisa:

Avaliar área tocada e não tocada em preparo e remoção de material obturador por meio de novos insertos ultrassônicos.

Avaliação dos Riscos e Benefícios:

Riscos: Não há, pois tratam-se de dentes cedidos.

Benefícios: científicos, para talvez a posterior utilização clínica de novo inserto ultrassônico para o preparo e desobturação dos canais radiculares, favorecendo o sucesso do tratamento endodôntico.

Comentários e Considerações sobre a Pesquisa:

Todas as pendências foram acatadas e corrigidas ou explicadas.

Considerações sobre os Termos de apresentação obrigatória:

Todos os termos foram apresentados.

Conclusões ou Pendências e Lista de Inadequações:

Aprovado.

Considerações Finais a critério do CEP:

Esse projeto foi considerado APROVADO na reunião ordinária do CEP de 07.06.2017, com base nas normas éticas da Resolução CNS 466/12. Ao término da pesquisa o CEP-FOB/USP exige a apresentação de relatório final. Os relatórios parciais deverão estar de acordo com o cronograma e/ou parecer emitido pelo CEP. Alterações na metodologia, título, inclusão ou exclusão de autores, cronograma e quaisquer outras mudanças que sejam significativas deverão ser previamente comunicadas a este CEP sob risco de não aprovação do relatório final. Quando da apresentação deste, deverão ser incluídos todos os TCLEs e/ou termos de doação assinados e rubricados, se pertinentes.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_762536.pdf	16/05/2017 16:11:57		Aceito
Folha de Rosto	folhaderostoatualizadacep.pdf	16/05/2017 16:11:08	Melissa Esther Rivera Peña	Aceito
Outros	QUESTIONARIOTECNICOPESQUISAC	16/05/2017	Melissa Esther	Aceito

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Continuação do Parecer: 2.112.063

Outros	.pdf	12:55:16	Rivera Peña	Aceito
Recurso Anexado pelo Pesquisador	TermoCessaoDentesCirurgiaoDentista.docx	12/05/2017 18:32:52	Melissa Esther Rivera Peña	Aceito
Projeto Detalhado / Brochura Investigador	CEPProjetodePesquisa.docx	12/05/2017 18:31:26	Melissa Esther Rivera Peña	Aceito
Declaração de Pesquisadores	DECLARACAODECOMPROMISSO.pdf	20/03/2017 11:30:20	Melissa Esther Rivera Peña	Aceito
Declaração de Instituição e Infraestrutura	COMITEDEETICA.pdf	20/03/2017 11:28:53	Melissa Esther Rivera Peña	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

BAURU, 09 de Junho de 2017

Assinado por:
Ana Lúcia Pompéia Fraga de Almeida
(Coordenador)

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