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# Apical Displacement and Residual Root Canal Filling with Single-Cone After Post Space Preparation: A Micro-CT Analysis

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The purpose of this study was to evaluate the presence of residues after post space preparation (PSP) and establish whether the apical displacement of the gutta-percha was affected by the moments and methods of PSP in teeth filled by the single-cone technique. The root canals of 20 bovine incisor teeth were instrumented with Reciproc and filled with single-cone and AH Plus. The specimens were divided into 4 groups according to the moment and method of PSP (n=5): immediate with drill, immediate with thermoplasticizer, delayed with drill and delayed with thermoplasticizer. Micro-CT scans were performed before and after the PSP for residues of the root canal filling (1) and analysis of apical displacement (2). Data were analyzed by using 2-way repeated measurement ANOVA (1) and 2-way ANOVA (2) followed by the Tukey's test ($\alpha$=0.05). Significance effect on the residues percentage remaining for methods (p=0.044), for moments (p=0.006), for thirds repetition (p<0.001), and for interaction between methods and thirds (p<0.001), and moments and thirds (p=0.044). Significance effect on the apical displacement of root canal filing was detected for methods (p=0.008), however no difference was found between moments (p=0.617). In general, PSP using drill resulted in more homogeneous root canal preparation, mainly when made immediately. For all other combinations between methods and moments for PSP, the middle and apical thirds presented significant higher residues remaining. Thermo method performed in both moments and the drill method performed immediately had displacement in the apical direction, representing extrusion of the root filling material.

Key Words: micro-computed tomography, post space preparation, root canal filling, single-cone technique

## Introduction

Adequate filling of the root canal system constitutes a prerequisite to the long-term success of endodontic therapy (1). Gutta-percha is associated with different endodontic sealers that have been used as filling materials. Current filling techniques include cold lateral compaction, single-cone technique and methods based on thermoplasticized gutta-percha (2-4).

The single cone technique requires the use of cold gutta-percha point that matches the taper and diameter with motor-driven nickel-titanium files and sealer to fill irregularities (2,4). The widespread use of mechanized nickel-titanium instruments has become a popular single cone technique (5), because it is less operator dependent and time consuming than the cold lateral compaction technique (3,4). Considering that restoration of endodontically treated teeth with severe structure compromising may require a post (6) it is important to know the peculiarities of post space preparation (PSP) on teeth obturated by the single cone technique. In the present study, we tried to simulate a situation in which no additional preparation in dentin walls were required after PSP. Currently there is a tendency to use customized posts, such as those made by CAD-CAM technology, which would avoid dentin wear. At present, few studies have evaluated the characteristics related to the PSP in teeth obturated by the single cone technique (5,7), and it is often evaluated using microinfiltration by different methodologies.

PSP can be performed by several techniques including chemical, thermal or mechanical removal of the root filling material (8,9). Several studies have shown that the integrity of the remaining filling after removal of root canal filling materials may depend on a number of factors such as endodontic filling techniques (5,7), instruments used for removal (8,10), the length of the remaining materials (10), sealers (5) and the time of removal of the root filling (11-13). Specifically, in relation to PSP, ideally this should be performed with rubber dam by the same professional who performed the endodontic treatment, avoiding contamination and iatrogeny. The immediate PSP allows the root canal prepared to receive the post at the unique session (12). However, there is no consensus in the literature regarding the ideal moment for PSP and the most appropriate method (11-13). In fact, it is important not to disrupt the integrity of the root canal filling during the PSP (14). A hermetic apical seal is necessary to avoid

endodontic treatment failure as a result of reinfection. Another important point is related to the amount of filling material residues after PSP, which may negatively affect the bond strength between the dentin and adhesive systems used for post cementation (15).

Therefore, the aim of this study was to evaluate the effect of immediate versus delayed PSP using drills or thermoplasticizer (thermo) in terms of the presence of residues on the dentinal walls and apical displacement of filling with the single cone technique using micro-computed tomography (micro-CT). The null hypotheses tested were: 1) the methods and the moments for performing PSP would not affect the presence of residues into the root canal; 2) the methods and the moments for performing PSP would not affect the magnitude and the direction of the apical displacement of root filling material.

## Material and Methods

### *Preparation of Teeth*

Twenty extracted bovine incisors teeth with single root, similar root dimensions and shape were selected for this study. The selection criterion was performed in four stages. To standardize the samples, at first moment, visual similarity was considered in the external morphology of the teeth. Posteriorly, root dimensions were measured with digital caliper (Mitutoyo Sul Americana Ltda., Suzano, SP, Brasil) at the buccal-lingual and mesio-distal sides for the 3 root thirds. Root width size within a maximum deviation of 10% from the mean value (range between 3.2 mm and 5.5 mm for the mesio-distal distance; 4.1 mm and 6.7 mm for the buccal-lingual distance) were included. Crowns were removed to obtain a root length mean of 15.0±0.7 mm and the root face was polished to form a flat coronal surface using abrasive discs. Roots were selected whose canal anatomical diameter corresponded to a size 30 K-file (Dentsply Sirona, York, PA, USA). The teeth were positioned over a digital sensor – FIT T2 (Micro Imagem, Indaiatuba, SP, Brazil) and the radiographic exposure was performed using the Timex 70 E (Gnatus, Ribeirão Preto, SP, Brazil), exposing the specimens for 0.32s at 70 kV and 7.0 mA. The focal spot to object distance was set at 6 cm. Two exposures were performed for each sample, mesio-distal and buccal-lingual side. The digital radiographs were transferred to ImageJ software (Java-based image processing and analysis software developed at the National Institutes of Health, Bethesda, MD, USA) to measure the mean area of the root canals. The teeth were randomly allocated to the four experimental groups (n=5) and the mean area before procedures ($cm^2$) was 3.4±0.8 for mesio-distal (MD) direction and 2.0±0.4 for buccal-lingual (BL) direction. These volumes were statistically similar for MD (p=.0835) and for BL (p=.06).

The working length was determined with a #10 K-file (Dentsply Sirona) by subtracting 1.0 mm from the length when visible at the apical foramen. The roots were embedded in a polystyrene resin (Cristal, Piracicaba, SP, Brazil) to simulate the alveolar bone (16), and serve as support for the micro-CT scanning in a standardized way. The specimens were prepared and shaped using a reciprocating nickel-titanium file (Reciproc system, VDW, Munich, Baviera, Germany) with a #50 (50.05). Irrigation was performed using 10 mL 2.5% sodium hypochlorite (NaOCl). After complete preparation, the root canals were rinsed with 5 mL 17% EDTA followed by 5 mL 2.5% NaOCl, both for 1 min. Finally, the root canals were irrigated with 10 mL distilled water and dried with paper points.

### *Filling Procedure and Post Space Preparation*

The specimens were obturated using the single cone technique using AH Plus root canal sealer (Dentsply Sirona). A size 50.05 gutta-percha cone (VDW) was coated with the sealer and introduced into the root canal to the working length. In all groups, excess material was removed using a heated instrument in the orifice of the root canal. Thereafter, the teeth were randomly divided into 4 experimental groups (n=5) according to the method and the moment of PSP: immediate with drill, immediate with thermo, delayed with drill or delayed with thermo. An immediate PSP was performed within 30 min after filling. For the delayed analysis, the specimens were stored at 37°C in a moist environment for 14 days to allow the sealer to set. The coronal root filling material was removed with Peeso reamers (Dentsply Sirona) (size 2 and 3) or thermo using M and FM tips – Odous Touch (Odous De Deus Ind. e Com Ltda., Belo Horizonte, MG, Brazil) to 10 mm to create a post space according to each experimental group, leaving only 4 mm of filling material in the apical portion. Roots were prepared in a random sequence by a single operator and drills were changed after every 5 samples. The prepared post space was flushed with 10 mL saline and dried. A single experienced operator (L.V.O.) performed the instrumentation and filling of the root canals; a second operator (C.C.G.M) who was blinded to the groups performed the PSP procedures.

### *Micro-CT Analysis*

The specimens were scanned in a micro-CT (SkyScan 1272; Bruker micro-CT, Kontich, Belgium) for a nondestructive and quantitative assessment of the presence of residues on the dentinal walls after PSP (Fig. 1) and apical displacement of the filling (Fig. 2). To standardize and allow the analysis of images before and after PSP, the teeth were placed in the micro-CT in the same position on a custom device. The scanning conditions were 100 kV

source voltage, 100 µA anode current, a pixel size of 21.7 µm, 180° rotation around the vertical axis, rotation step of 0.8°, frame averaging of 2, and random movement of 20 using a 0.11-mm-thick copper filter and a camera exposure time of 1700 milliseconds. The scanning procedure took approximately 20 min per sample. The sequences of scans were reconstructed using NRecon software (version 1.6.3.3, Bruker micro-CT) with a beam hardening correction of 20%, a smoothing of 1 and ring artifact correction of 3. All scanning and reconstruction parameters were maintained at constant levels for the filling and PSP scans.

CTAn v.1.14.4.1 software (Bruker micro-CT) was used for quantitative measurements of the samples and to create 3D models (Fig. 3) to visualize the amount of residues after PSP. A region of interest (ROI) was selected around the root canal for each slice to calculate the volume (mm3).

For the residual filling analysis, the PSP was divided into cervical, middle and apical thirds with 130 slices in each section (Fig. 1A e 1B). The most apical slice was the closest of the remaining gutta-percha at the apical third. The original gray scale images were processed with an automatic segmentation threshold for the presence of filling material, separating the root dentin from the filling material. For each root third (Fig. 1A), ROI was chosen to allow the calculation the volume of the filling and residues. The residual filling material after PSP were calculated as a percentage of the total root filling volume using the formula VA*100/VB, where VA and VB mean the object volume and total volume ($mm^3$), respectively of the residues after PSP and filling, after each third analyzed.

The apical displacement analysis were expressed as volume ($mm^3$), in which the section was determined by identifying the slice closest to the apical forame (0-mm mark), both for the obturated samples and after the PSP, and then adding 150 slices in the coronal direction (Fig. 2A e 2B). The ROI was determined and the original gray scale images were also processed to calculate the volume of the remaining filling displacement. The root dentin and the filling material were distinguished and separated by automatic processes, and only filling volume was used. The global threshold was used for root canal segmentation. If the volume of remaining gutta-percha measured after PSP was greater than the initial volume (Fig. 2A), it was concluded that the material had moved towards the apical slice (represented by the term extrusion), whereas less remaining gutta-percha present in the analyzed section, represented a displacement in the coronal direction (represented by the term intrusion). All the measurements and evaluations were performed by one evaluator who

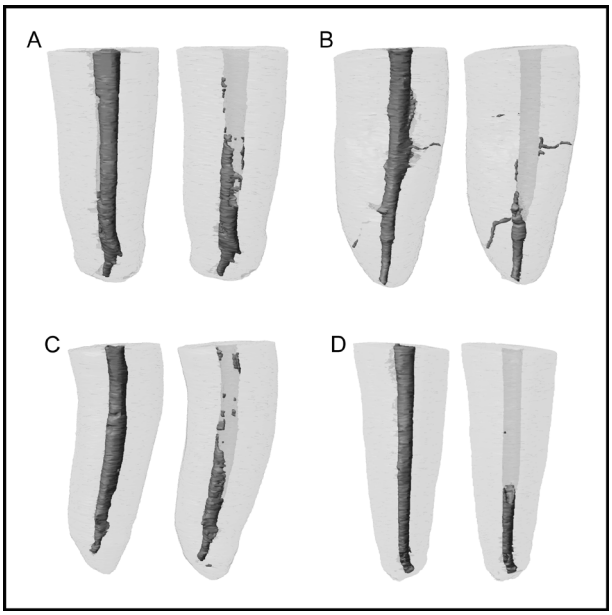


Figure 3. 3D representative image of root canals to visualize the amount of residual filling after post space preparation (PSP) for experimental groups: (A) Immediate PSP with thermo; (B) Immediate PSP with drill; (C) Delayed PSP with thermo; (D) Delayed PSP with drill.

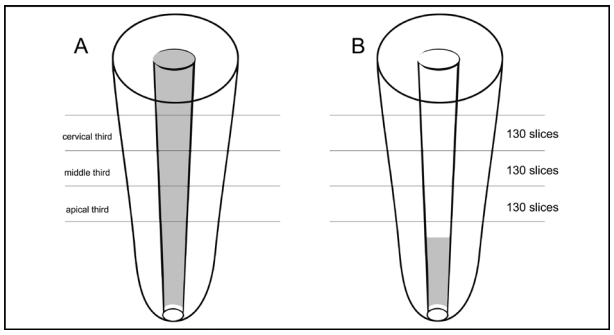


Figure 1. Illustrative scheme of the presence of filling material residues in the root canal: (A) filled root canal and thirds for analysis (cervical, middle and apical) of the percentage of filling material; (B) residual endodontic filling material after PSP with 130 slices in each third.

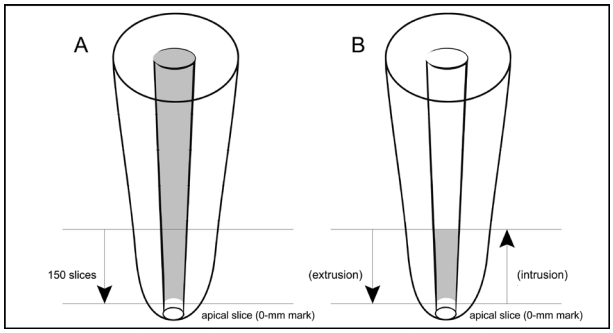


Figure 2. Illustrative scheme of apical displacement: (A) filled root canal with the apical region analyzed in 150 slices before PSP; (B) and residual endodontic filling material, where the same region was analyzed after PSP. Extrusion represents displacement in the apical direction; Intrusion represents displacement in the coronal direction.

was blinded to the stages of root filling and PSP for the specimens.

### *Statistical Analysis*

Data were analyzed for normal distribution and homoscedasticity using the Shapiro-Wilk test and Levene's test, followed by parametric statistical tests. A two-way repeated measure ANOVA was used for the presence of residues after PSP to compare methods, moments and thirds repetition. And 2-way ANOVA was used for apical displacement regarding methods and moments, both analyzes followed by the Tukey test. All tests used an $\alpha$=0.05 significance level and all analyses were carried out using SigmaPlot version 13.1 (Systat Software Inc., San Jose, CA, USA).

## Results

### *Residual Filling Analysis*

The mean and standard deviation of the residual filling material after PSP for different methods and moments in 3 root thirds are summarized in Table 1. Repeated measurement ANOVA detected significance for methods (p=0.044), for moments (p=0.006), for thirds repetition (p<0.001), and for interaction between methods and thirds (p<0.001), and moments and thirds (p=0.044). For both tested methods, the PSP performed immediately tend to resulted in lower residues into the root canal. Comparing thermo and drill methods irrespective of the moment, no difference was observed for cervical and middle thirds, however drill method resulted in lower residues at apical third. No significant difference was found between 3 root thirds for immediate drill. For all other combinations between methods and moments for PSP, the middle and apical thirds presented significant higher residues percentage. In general, PSP made using drill resulted in more homogeneous root canal preparation, mainly when made immediately (Fig. 4).

### *Apical Displacement Analysis*

The mean and standard deviation ($mm^3$) for apical displacement after PSP performed with drill or thermo in both moments are presented in Table 2. If the displacement occurred in the apical direction, it was categorized as extrusion, and the displacement for coronal direction it was categorized as intrusion. Two-way ANOVA showed significant differences between methods (p=0.008), however no difference was found between moments (p=0.617). The thermo method performed in both moments and the drill method performed immediately had greater displacement in the apical direction, representing extrusion of the root filling material.

## Discussion

The present study detected significance for the methods and the moments to perform PSP on the residues of filling material in different root dentin depths. Also significant difference on the apical displacement of filling material for the methods was found in endodontic treated teeth filled with single cone. Therefore, the first and second null hypotheses were rejected.

Several previous studies evaluated the effect of the methods (8,10), periods of time (11) and sealers used (13,14) on the performance of PSP. These studies evaluated the apical integrity using different infiltration methods or scanning electron microscopy. This is, in the author's knowledge, the first study using micro-CT to evaluate the presence of residues in dentinal walls after PSP and apical displacement of the single cone filling technique after PSP for receiving fiber posts, with different methods and moments of PSP. The micro-CT technique is increasingly used for noninvasive analyses and has become an important tool in the 3D analysis of the root canal area. Micro-CT uses high-resolution images and allows quantitative analyses by differentiating filling materials and tooth structures (5).

A recent study using micro-CT examined only the effect of PSP with drill in delayed moment on teeth filled with different techniques and concluded that PSP negatively influenced the apical integrity of the filling materials (5). In the current study, the focus was just single cone technique, which has gained support because the matching-taper



Table 1. The mean and standard deviation percentage values (%) for the residual filling material after post space preparation

| Methods of post space preparation | Immediate | | | Delayed | | |
|---|---|---|---|---|---|---|
| | Cervical | Middle | Apical | Cervical | Middle | Apical |
| Thermo | 1.1 ± 0.9 Aaα | 6.3 ± 2.6 Aaβ | 13.1 ± 2.5 Baγ | 5.3 ± 2.5 Aaα | 12.8 ± 5.5 Aaβ | 25.3 ± 4.8 Bbγ |
| Drill | 1.7 ± 1.0 Aaα | 2.8 ± 2.5 Aaα | 3.6 ± 2.9 Aaα | 5.1 ± 4.6 Aaα | 10.2 ± 6.6 Abαβ | 12.2 ± 4.9 Abβ |

Different letters and symbols indicate significant differences by Tukey test (p<0.05). Uppercase letters were used for comparing methods of post space preparation (columns), lowercase letters were used for comparing moments of post space preparation (rows), and the symbols were used for comparing the thirds within each moment and method used.

single-cone technique seems to effectively fill well-tapered root canals after adequate rotary instrumentation. Rotary root canal preparation followed by a matching-taper single-cone filling technique provides a reliable shaping of the root canal, with fewer technical errors and a more acceptable filling quality in terms of length and homogeneity in the apical third (17). Furthermore, studies using micro-CT demonstrated that in the apical region of root canals there are no differences between single cone and cold lateral compaction regarding the root canal filling ability and volume of voids (2). Single cone may be accepted as an equivalent alternative to contemporary filling techniques (4). However, this technique should be avoided in oval root canals, being better indicated for round canals (18), justifying the tooth type selected for this study.

The use of bovine teeth does not invalidate the study model, since these have often been used in laboratory studies in endodontics (19). Bovine teeth have morphological similarity with human tooth and the used of these teeth do not require approval of the ethics committee. In addition, in the present study, we try to mimic wide root canals ready to receive the fiber post after the PSP without the need for additional drills for post cementation. We followed the principle that the fiber post should fit the root canal preparation avoiding additional wear of the intact dentin, preserving the better biomechanical balance between fiber post diameter and more conservative root dentin preparation (6,20).

Considering that for the installation of fiber posts is necessary to remove the smear layer present in the dentin wall due to possible interferences in adhesive strategies (15), it is interesting to compare the effect of the methods and moments of PSP on the amount of residual material in different root dentin depths. In the present study, the methods and the moments of PSP exerted influence on the amount of residues in the middle and apical thirds, which is probably related to anatomical characteristics. No difference in the cervical third could be explained by the anatomical facility to access this third in root single teeth. Although these results cannot be directly correlated with fiberglass post adhesion studies, it is likely that the bond strength is related to the difficulty of cleaning the canal dentinal walls (21).

The higher amounts of residues found in groups that used thermo method probably is related to the technical difficulty of removal sealer and gutta-percha using heat instrument, mainly when performed later. The heating of gutta-percha can cause deeper interaction with the dentin walls during the movement of the tip of the instrument. It is important to emphasize that our results differ from previous study (22), which they recommended that preparation of the root canal for post cementation should be performed delayed. This is because there is probably a difference of filling technique and the use of drills only in PSP.

The presence of lower percentage of residues found for the PSP performed using drills immediately after root canal filling is probably related to the better capacity of the drill to remove totally the fresh root canal sealer and softer gutta-percha. After 30 min of mixing, the bond between the AH

Table 2. The mean and standard deviation volume values ($mm^3$) for apical displacement after post space preparation

| Post space preparation methods | Immediate | Delayed |
|---|---|---|
| Thermo | 0.25 ± 0.22 (extrusion) Ba | 0.18 ± 0.15 (extrusion) Ba |
| Drill | 0.14 ± 0.07 (extrusion) Aa | 0.11 ± 0.06 (intrusion) Aa |

Different letters indicate significant differences by Tukey test ($p<0.05$). Uppercase letters were used for comparing methods of post space preparation (columns) and lowercase letters were used for comparing moments of post space preparation (rows). Extrusion represents displacement that occurred in the apical direction; Intrusion represents displacement that occurred in the coronal direction.

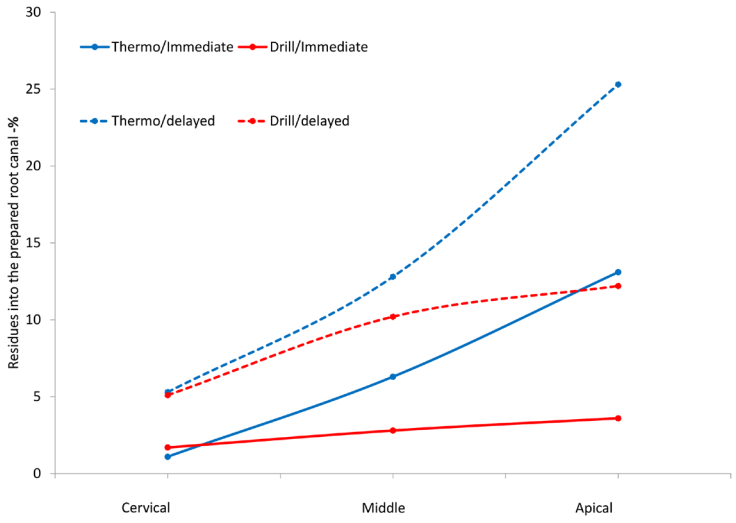


Figure 4. Filling material percentage remained into the prepared root canal in different depths (cervical, middle and apical thirds) regarding methods and moments used for PSP.

Plus sealer and dentin walls is not completed formed (5). In addition, the round anatomy of the root in the bovine incisors allows a greater contact of the drill with the canal walls, improving the cleaning process. New studies should be performed in root canals with irregular morphology.

Another concern regarding the preparation of obturated teeth by the single cone technique is the lower percentage of gutta-percha filled areas in the cervical third (4). The space in apical region is filled with large amounts of sealer (3), which could result in lower retention and displacement of the filling. Immediate PSP resulted the displacement always towards the apical foramen, resulting in extrusion of the filling material, probably because the sealer was still fresh. In the delayed group, where the sealer has already completely set, this tendency was not always observed, since delayed PSP performed with drill the displacement occurred in the coronal direction, representing the intrusion of the filling material. According to previous studies (23,24), the rotational forces generate by the drills during PSP may affect the integrity of the remaining filling material depending on the rigidity of the sealer, especially after the AH Plus setting time occurs approximately at 8 h. Considering that the samples in the delayed methods were prepared after 14 days, the filling is dislocated to the root canal and moved without the drill movements. All PSP methods result in some level of displacement of the filling. Although such results could not be extrapolated for teeth filled with other techniques, they highlighted the importance of the rubber dam use during PSP in teeth whose filling was performed by the single cone technique and adequate coronary sealing (25). Complementary studies are recommended for comparing different filling techniques and methods of PSP in teeth with more complex anatomy.

Despite the limitation of the present study was performed in vitro, the results may have impact on clinical practice for choosing the method and moment to perform the PSP aiming the installation of root post in single cone filled teeth. Clinicians should always perform as possible the PSP using drill immediately after root canal filling with single cone technique resulting in homogeneous cleanness of the root canal space. Additionally, the findings of this study reinforce the indication of the rubber dam use avoiding the negative impact on the endodontic treatment outcome after PSP and fiber post cementation.


## Resumo

O objetivo deste estudo foi avaliar a presença de resíduos após o alívio do canal (AC) e verificar se o deslocamento apical da guta-percha foi afetado pelos momentos e métodos de AC em dentes obturados pela técnica do cone único. Os canais radiculares de 20 dentes incisivos bovinos foram instrumentados com Reciproc e obturados com cone único e AH Plus. As amostras foram divididas em 4 grupos de acordo com o momento e método de AC (n=5): broca imediato, termocompactador imediato, broca tardio e termocompactador tardio. Escaneamentos em micro-CT foram realizados antes e após o AC para análise dos resíduos da obturação (1) e do deslocamento apical (2). Os dados foram analisados empregando ANOVA em 2 fatores com medida repetida (1), ANOVA em dois fatores (2), seguidas do teste de Tukey ($\alpha$=0,05). A porcentagem de resíduos remanescentes foi influenciada pelos métodos (p=0,044), momentos (p=0,006), pelo fator de repetição terços do canal (p<0,001), e pelas interações entre métodos e terços (p<0,001), e momentos e terços (p=0,044). Já para o deslocamento apical da obturação do canal radicular foi detectada influência significativa para os métodos (p=0,008), no entanto, nenhuma diferença foi encontrada entre os momentos (p=0,617). Em geral, AC usando brocas resultou em preparo mais homogêneo dos canais radiculares, principalmente quando realizado imediatamente após a obturação. Para todas as outras combinações entre métodos e momentos de AC, o terço médio e apical apresentaram significativamente maiores resíduos remanescentes. O método termo realizado nos dois momentos e o método broca de preparo realizado imediatamente resultaram em deslocamento na direção apical, representando a extrusão do material de obturação no canal radicular.



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