Original Article

Three different removal protocols for a bioceramic and a calcium hydroxide dressings: A microcomputed tomography study

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Abstract

Context: The removal of intracanal medicament is necessary to promote adequate sealing.

Aims: This study evaluated three techniques (conventional irrigation, Ultrasonic activation, and XP-endo Finisher) to remove intracanal medication (Ultracal XS and Bio-C Temp) using micro-computed tomography.

Materials and Methods: The roots were randomly divided into six groups ($n = 10$) according to the intracanal medication and the irrigation protocol employed to remove the pastes: Ultracal and Manual (UC/M); Ultracal and XP-endo Finisher (UC/XP); Ultracal and Ultrasonic activation (UC/US); Bio-C Temp and Manual (BIO/M); Bio-C Temp and XP-endo Finisher (BIO/XP) and Bio-C Temp and Ultrasonic activation (BIO/US) The samples were then subjected to microcomputed tomography scan to assess the total volume of filling and remaining medication after removal protocol.

Statistical Analysis Used: The Shapiro–Wilk normality test indicated a normal distribution of the data. Then, to compare the groups, one-way ANOVA and Tukey's *post hoc* tests were performed. For all statistical tests used, the significance level established was 5%.

Results: When the samples were evaluated after applying the protocols regarding the root canal thirds, there was a greater remaining volume of Bio C Temp in the cervical third compared to the middle and apical thirds in the Bio C Temp/M and Bio C Temp/XP groups ($P < 0.05$). Ultrasonic activation removed the volume of Bio C Temp from the cervical third to similar levels of the middle and apical thirds ($P > 0.05$). In the cervical third, the Bio C Temp/XP, Bio C Temp/M group obtained a greater volume of remaining material than Bio C Temp/US, Ultracal/M, Ultracal/XP, and Ultracal/US ($P < 0.05$).

Conclusion: In the present study, the activation methods of intracanal medications did not differ in the removal capacity between the two types of root canal dressing and none of the removal protocols were able to completely remove dressings from the root canal.

Keywords: Calcium hydroxide; calcium silicate; endodontics; microcomputed tomography; ultrasonics

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INTRODUCTION

Root canal dressing is used to reduce the number of microorganisms after chemical–mechanical preparation into the root canals of teeth with pulp necrosis[1,2] Calcium

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hydroxide pastes are widely used as root canal dressing due to its antimicrobial and biological properties, such as high pH (12.5–12.8), its ability to inactivate endotoxins, and induction of the formation of mineralized tissue.[3,4] One of the most commonly used calcium hydroxide pastes is Ultracal XS (Ultradent Products, South Jordan, UT, USA) which is an intracanal medication composed of calcium hydroxide, barium sulfate, and methylcellulose, in an aqueous solution.

A new intracanal medication based on calcium silicate called Bio-C Temp (Angelus Industry Dental Products Ltda, Londrina, PR, Brazil) was recently launched on the market. According to the manufacturer, Bio-C Temp is indicated for the endodontic treatment of teeth with pulp necrosis, nonsurgical endodontic retreatment, persistent infection or sinus tract, and in the presence of exudate. Its chemical composition includes glycol salicylate ester, titanium oxide, calcium aluminate, calcium oxide, calcium tungsten, and calcium silicate. Bio-C Temp presented alkaline pH, adequate calcium release, and radiopacity.[5]

It is necessary to remove the intracanal medication from the root canal system before obturation to promote adequate sealing.[6] Furthermore, residues from intracanal medication can impair the penetration of root canal filing into the dentinal tubules and anatomical complexities.[7] Studies that aimed to investigate the relationship between calcium hydroxide paste and endodontic sealers observed that the presence of the calcium hydroxide paste can negatively affect the adhesion of endodontic sealers to dentin walls.[8,9]

Several techniques have been proposed to improve the removal of calcium hydroxide paste from root canals, including irrigation with sodium hypochlorite in association with chelating agents,[10] irrigation associated with manual instruments,[11] use of nickel–titanium rotary instruments,[12] or even the use of sonic and ultrasonic methods.[13] Passive ultrasonic irrigation (PUI) involves activating the chemical solution with a smooth ultrasonic insert inside the canal, 1 mm short of the working length, to increase the disinfection and clean the root canal system.[14-17] The acoustic cavitation effect during PUI is essential in its effectiveness.[18] This method and association with rotary instrumentation have shown a good capacity for removing calcium hydroxide pastes from the interior of the canals, especially when compared to techniques that use only conventional irrigation.[18]

Recently, an instrument called XP-Endo Finisher (FKG Dentaire, Swiss) was introduced on the market to improve the final cleaning of the root canal. The file changes its shape depending on the temperature. At room temperature, the file is straight and is in its martensitic phase (M phase).[19] However, when in contact with body temperature, it enters the austenitic phase (phase A) and takes the shape of a spoon. This rotary file has a nickel–titanium alloy, tip diameter of. 25, and no taper, being able to contact and clean the canal walls due to its expansion capacity but does not change the original shape of the canal, preserving the dentin[20]

Considering the importance of removing intracanal medication before root canal filling and the lack of literature regarding the new canal dressing (Bio-C Temp), the aim of this work is to assess three techniques (conventional irrigation, PUI, and XP endo Finisher) to remove intracanal medication (Ultracal XS and Bio C Temp) using micro computed tomography. The null hypotheses are: (1) there is no difference regarding the removal techniques and (2) there is no difference between the intracanal medications tested.

MATERIALS AND METHODS

Sample selection

This research was approved by the research committee under number 3.540.463.

The sample calculation was performed using G * Power v3.1 for Mac (Heinrich Heine, Universität Düsseldorf), selecting the T Student test. Data were obtained in another study.[15] An alpha error of 0.05 and a beta power of 0.95 were also stipulated. A total of 8 samples per group was indicated as the ideal size required for nonsignificant differences. An additional two specimens per group were used to compensate for possible losses.

Sixty mandibular incisor roots were randomly selected from a collection of extracted teeth from the Oral and Maxillofacial Surgery and Traumatology I discipline at the Faculty of Dentistry. All teeth donated by patients over 18 years of age were included in the research after visual examination and periapical digital radiography using the Time × 70E X-ray device (Gnatus Equipamentos Médico-Odontológicas Ltda, Ribeirão Preto, SP-Brazil). As an exclusion criterion, teeth that presented: (a) length <15 mm were removed; (b) root fracture or cracks; (c) previous endodontic treatment; and (d) internal or external resorptions. Removing remaining bone tissue, gingival tissue, and periodontal ligament was carried out using periodontal curettes of the Gracey type, nº 3 and 4 (Neumar Instrumentos Cirúrgicos Ltda, São Paulo-SP). Before the instrumentation of the canal, the roots were standardized to a length of 10 mm, and the crowns were sectioned with a machine cutter (Extec Labcut 1010, Enfield, CT).

The sample pairing was done through a volumetric analysis of the canal using microcomputed tomography before the procedure, selecting teeth with similar volumes, and excluding outliers. The image acquisition was performed by micro-computed tomography (CT) (SkyScan 1174 v2; SkyScan, Kontich, Belgium). The scanning procedures were performed by a single operator using the following parameters: 50 kV, 800 mA, and 28.24 mA voxel size. Then, scans with 512 × 652 pixels were obtained with a 0.7-s acquisition interval, resulting in a total of 360°. Images were visualized and quantified using ImageJ software and the Measure Stack plug-in.

Root canal preparation

Initially, the roots were placed in individual muffles to facilitate instrumentation and irrigation procedures. The canal was accessed with 1012 spherical diamond burs (KG Sorensen, São Paulo, Brazil) at high speed and under refrigeration. The root canal was negotiated with a K-15 file (Dentsply Maillefer, Ballaigues, Switzerland) until patency was obtained, and the working length was determined to be 1 mm short of the apical foramen. The canal instrumentation was performed with the BT Race rotary system (FKG Dentaire SA, Swiss) up to instrument #35.04 coupled to the VDW Silver engine (VDW, Munich, Germany), with speed and torque specified by the manufacturer.

Two milliliters of 2.5% sodium hypochlorite (NaOCl) (Asfer Indústria Química Ltda, São Caetano do Sul, São Paulo, Brazil) was used as an irrigating solution between each instrument. After finishing the preparation, the final irrigation was performed with 5 ml of 17% EDTA solution (Asfer Indústria Química Ltda, São Caetano do Sul, São Paulo, Brazil) for 3 min, followed by 2 ml of saline solution. All irrigation procedures were performed with an Ultradent syringe (Ultradent Products Inc., USA) and an Endo-Eze Tip needle (Ultradent Products Inc., USA) positioned 2 mm from the apical foramen. The solution was removed by aspiration, and the canals were dried with absorbent paper tips (Tanari, Amazonas, Brazil).

Insertion and removal procedures

Then, the specimens were removed from the muffles, and thirty teeth were filled with Ultracal using a McSpadden compactor number 45 (Dentsply Maillefer, USA) to reduce voids and obtain adequate filling and periapical radiographs, on mesiodistal direction, were performed to confirm the filling quality. Afterward, the roots were sealed with a Cavitec temporary obturator (CaiTHEC Industrial, Paraná). The apex was sealed with utility wax, and the samples were stored in an oven at 37°C for 7 days with 100% humidity. Then, a micro-CT scan (Micro-CT #1) was performed to measure the total volume (mm^3) of intracanal medication and the volume by thirds (cervical 2–4 mm, middle 4–6 mm, and apical 6–9 mm) using a microcomputed tomography (SkyScan 1174 v2; SkyScan, Kontich, Belgium) as described before.

The roots were randomly divided into six groups ($n = 10$) according to the intracanal medication and the irrigation protocol employed to remove the pastes [Tables 1 and 2]. Subsequently, the roots were replaced in individual muffles, and the temporary sealing was removed. The irrigation protocols for removing the medication are described below:

- Conventional irrigation: irrigation with 8 ml of 2.5% NaOCl. After each application of 2 ml of 2.5% NaOCl, the working length was with a #35 K-file. Afterward, the canal was irrigated with 2 ml of saline solution
- Passive ultrasonic irrigation: The canal was irrigated with 2 ml of 2.5% NaOCl, and for every 1 ml, the working length was with a #35 K-file. Afterward, the canal was filled with 2 ml of 2.5% NaOCl and PUI was performed for 1 min, in three periods of 20 s (van

Table 1: Mean values and standard deviation, pre- and postremoval, of the Bio C temp for the different removal protocols

	Bio C temp					
	Manual		XP		US	
	Before	After	Before	After	Before	After
Cervical	$1.238^{B}\pm0.612$	$0.062^{B,b}\pm0.068$	$1.818^{B}\pm0.470$	$0.123^{B,b}\pm0.027$	$1.797^{B}\pm0.707$	$0.003^{A,a}\pm0.004$
Middle	$0.540^{A}\pm0.378$	$0.011^{A,a}\pm0.027$	$0.585^{A}\pm0.230$	$0.028^{A,a}\pm0.056$	$0.653^{A}\pm0.202$	$0.003^{A,a}\pm0.006$
Apical	$0.539^{A}\pm0.217$	$0.009^{A,a}\pm0.025$	$0.657^{A}\pm0.268$	$0.019^{A,a}\pm0.054$	$0.696^{A}\pm0.225$	$0.001^{A,a}\pm0.001$
Total	2.303 ± 1.121	$0.095^{a}\pm0.089$	3.061 ± 0.7954	$0.170^{a}\pm0.199$	2.834 ± 0.972	$0.008^{a}\pm0.008$

Different capital letters in the column indicate different volumes of intracanal medication according to the third portion after ANOVA and Tukey's test ($P<0.05$), Different lowercase letters on the line indicate different volumes of intracanal medication after comparing the protocols using the ANOVA test and Tukey test ($P<0.05$)

Table 2: Mean values and standard deviation, pre- and postremoval, of the Ultracal for the different removal protocols

	Ultracal					
	Manual		XP		US	
	Before	After	Before	After	Before	After
Cervical	$1.087^{B}\pm0.303$	$0.029^{A,a}\pm0.039$	$1.039^{B}\pm0.257$	$0.045^{A,a}\pm0.057$	$1.068^{B}\pm0.300$	$0.005^{A,a}\pm0.009$
Middle	$0.391^{A}\pm0.101$	$0.006^{A,a}\pm0.009$	$0.351^{A}\pm0.079$	$0.012^{Aa}\pm0.015$	$0.520^{A}\pm0.128$	$0.002^{Aa}\pm0.003$
Apical	$0.362^{A}\pm0.100$	$0.075^{A,a}\pm0.100$	$0.345^{A}\pm0.094$	$0.058^{Aa}\pm0.035$	$0.553^{A}\pm0.168$	$0.056^{Aa}\pm0.116$
Total	1.845 ± 0.432	$0.106^{a}\pm0.101$	1.841 ± 0.365	$0.084^{a}\pm0.081$	2.206 ± 0.669	$0.064^{a}\pm0.121$

Different capital letters in the column indicate different volumes of intracanal medication according to the third portion after ANOVA and Tukey's test ($P<0.05$), Different lowercase letters on the line indicate different volumes of intracanal medication after comparing the protocols using the ANOVA test and Tukey test ($P<0.05$)

der Sluis *et al*., 2010).[18] The solution was renewed between each period by dispensing 2 ml of 2.5% NaOCl, totaling 8 ml of NaOCl. After ultrasonic activation, the canal was irrigated with 2 mL saline. To perform the PUI, the Irrissonic tip (Helse, SP, Brazil) was used 1 mm below the CT and the Acteon Booster ultrasound at 10% power (Acteon, Bordeaux, France)

- XP-Endo Finisher (XPF): For the XPF a hot water bath system was installed to control the temperature around corporal temperature (36.5°C) so that permits the change to austenitic phase of the instrument. The canal was irrigated with 2 ml of 2.5% NaOCl, and every 1 ml, the working length was recapitulated with a #35 K-file. And then irrigated with 2ml of a calcium-quelate agent (EDTA) and more 2 ml of saline solution Then, the canals were irrigated again with 2ml of 2.5% NaOCl and the XP-Endo Finisher activation (FKG Dentaire SA, Swiss) calibrated 1mm below the CT was performed. Before being introduced inside the canal, the instrument was coupled to the VDW Silver motor (VDW, Munich, Germany).. The file was used for a continuous period of 1 min at a speed of 900 rpm, making longitudinal movements with an amplitude of 7–8 mm covering the entire length of the canal and movements towards the lateral walls of the canal. Afterward, the XP-Endo Finisher was removed from the canal, still rotating, and the canal was irrigated with 4 ml of 2.5% NaOCl to remove suspended debris. Finally, a final irrigation was performed with 2 ml of saline solution.

All irrigation procedures were performed with an Ultradent syringe (Ultradent Products Inc., USA) and an Endo-Eze Tip needle (Ultradent Products Inc., USA) positioned 2 mm from the apical foramen. The solution was removed by aspiration, and the canals were dried with absorbent paper tips (Tanari, Amazonas, Brazil) and carried out by the same operator. The samples were subjected to a second micro CT scan (Micro CT #2) to assess the volume of intracanal medications remnants by thirds as described previously.

Statistical *a*nalysis

The collected data were exported into a spreadsheet (Microsoft Office Excel 2007, Microsoft Corporation, Redmont, WA, USA) and statistically analyzed using the SPSS for Windows program (SPSS Inc., Chicago, IL, USA). Shapiro–Wilk normality test indicated a normal distribution of the data. Then, to compare the groups, one-way ANOVA and Tukey's *post hoc* tests were performed. For all statistical tests used, the significance level established was 5%.

RESULTS

Tables 1 and 2 show that in an intragroup analysis, without preremoval, there was a greater volume of intracanal medication in the cervical third, regardless of whether it was Bio C Temp or Ultracal, compared to the middle and apical thirds for all protocols ($P < 0.05$). When the total volume of root canal dressing before applying the protocols was evaluated, no significant difference between the groups was observed ($P > 0.05$).

When the total volume was evaluated after applying the protocols [Figures 1 and 2], there was no significant difference between the protocols used on each root canal dressing ($P > 0.05$).

When the samples were evaluated after applying the protocols regarding the root canal thirds, there was a greater remaining volume of Bio C Temp in the cervical third compared to the middle and apical thirds in the Bio C Temp/M and Bio C Temp/XP groups ($P < 0.05$). Ultrasonic activation removed the volume of Bio C Temp from the cervical third to similar levels of the middle and apical thirds ($P > 0.05$). In the cervical third, the Bio C Temp/XP and Bio C Temp/M group obtained a greater volume of remaining material than Bio C Temp/US, Ultracal/M, Ultracal/XP, and Ultracal/US ($P < 0.05$).

DISCUSSION

Removing root canal dressing from the root canal system is necessary before filling due to the sealing ability and penetration.[6] Several studies have shown that root canal dressing on dentin walls can affect endodontic treatment results.[21,22] It has been reported that residual calcium hydroxide could also influence the adhesion of sealers to the root canal walls, compromising the quality of the seal provided by the root canal filling.[7,8,23]

Moreover, bioceramic products can react with the dentin and induce hydroxyapatite formation,[24] which could compromise its removal from the canal. Some methods have been proposed for the removal of calcium hydroxide dressing. Studies have shown that conventional irrigation with sodium hypochlorite alone is inefficient in removing this medication.[25,26] Alternatively, using rotary instruments and passive ultrasonic activation has been recommended.[12,27]

Tables 1 and 2 demonstrate that in an intragroup analysis, preprocedure of removal, there was a greater volume of intracanal medication in the cervical third, regardless of whether it was Bio C Temp or Ultracal, compared to the middle and apical thirds for all protocols ($P < 0.05$). This finding could be explained by the cervical portion of single-rooted or poly-rooted teeth having an area with a larger diameter of the root canal. This fact can be illustrated when a material is inserted into the root cavity, and a radiographic or microtomographic image checks the filling. It is expected to visualize the cervical portion with a greater

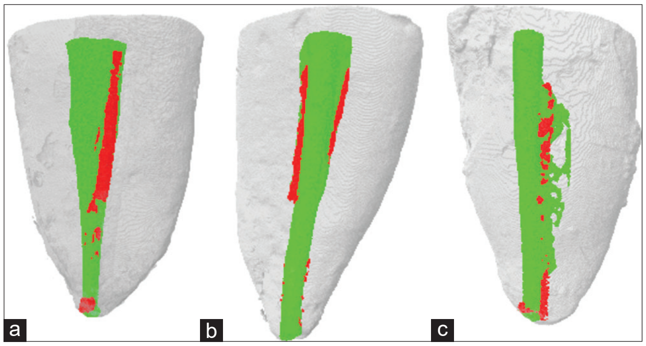

Figure 1: Three-dimensional reconstructions of Bio C Temp experimental groups. (a) Manual; (b) XP; (c) US. In green, the canal filled with material and in red, the remaining material after removal protocol are represented

volume of material, as the diameter of this root portion is larger compared to the middle and apical thirds – another study, according to this result, shows better filling and fewer empty spaces in the cervical third.[28]

When the samples were evaluated after applying the protocols, there was a greater remaining volume of Bio C Temp in the cervical third compared to the middle and apical thirds in the Bio C Temp/M and Bio C Temp/XP groups ($P < 0.05$). This fact can be explained due to the fluid dynamics that occur in each of the removal protocol techniques.[29] The conventional–irrigation and XP-Endo Finisher techniques use the principle of positive pressure and turbulence, respectively.[30,31] These two movements move the solution, especially in the middle and apical portions, where the instrument or the syringe needle is positioned. So, the irrigating solution is constantly moved in these canal portions (middle and apical) and may cause a deficit action of the irrigant on the cervical third.[32] The PUI technique acts differently. Piezoelectric units produce linear stroke patterns of vibration.[33] This oscillation acts through the cavitation phenomenon, which forms microbubbles that collide with the canal wall, moving the fluid just in a lateral way.[18] This phenomenon could have contributed to the more significant removal of root canal dressing in the cervical third.[34]

In an intergroup analysis, on the cervical third, the Bio C Temp/XP, Bio C Temp/M group obtained a greater volume of remaining material than Bio C Temp/US, Ultracal/M, Ultracal/XP and Ultracal/US ($P < 0.05$). Although more Bio C Temp groups presented a greater volume of remaining material than Ultracal groups, regardless of the activation method, it can be associated with the close relationship between bioceramic materials and dentin walls.[35,36] Bioceramic products can react with the dentin and induce hydroxyapatite formation,[24] which could compromise its removal from the canal.

Although all methods were effective in removing the medication from the canals without completely removing

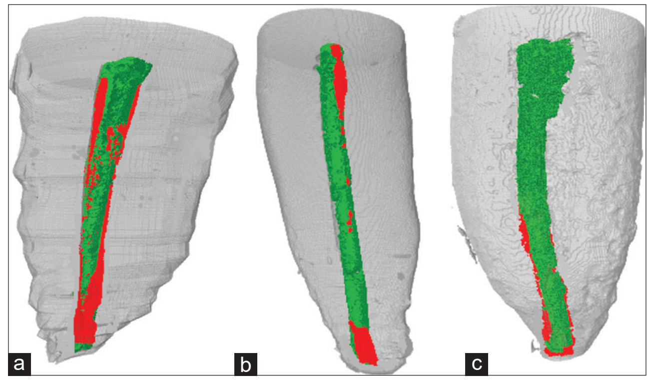

Figure 2: Three-dimensional reconstructions of Ultracal experimental groups. (a) Manual; (b) XP; (c) US. In green, the canal filled with material and in red, the remaining material after removal protocol are represented

it, the ultrasound technique was slightly superior to the other methods in terms of its effectiveness in removing the root canal dressings. This may be due to the cavitation phenomenon that creates microbubbles that collide with the canal wall, removing the medication from the canal lumen and also from the dentinal tubules.[15,16,19]

CONCLUSION

Finally, the present study has some limitations associated with the type of teeth used in this study. This study was performed with incisor teeth, which are easier to standardize than polyrooted teeth. However, it presents a larger canal diameter than polyrooted teeth and could differ from the clinical practice with other group of teeth. In the present study, the activation methods of intracanal medications did not differ in the removal capacity between the two types of root canal dressing. More studies are necessary to evaluate the efficacy of these methods with an intratubular evaluation and bond strength capacity.

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Conflicts of interest

There are no conflicts of interest.

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