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Evaluation of different methods of calcium hydroxide removal from root canals with simulated internal resorptions

Avaliação de diferentes métodos de remoção de hidróxido de cálcio de canais radiculares com reabsorções internas simuladas

Hermano Camelo PAIVA[1], Amanda Mourão Ley BARROS[2], George Táccio de Miranda CANDEIRO[2,3], Luiza Riomar PAZ[1], Elaine Faga IGLECIAS[1], Laila Gonzales Freire GUSUKUMA[1], Giulio GAVINI[1]

1 - Universidade de São Paulo, Faculdade de Odontologia, Departamento de Dentística. São Paulo, SP, Brazil.
2 - Universidade Federal do Ceará, Departamento de Odontologia Restauradora. Fortaleza, CE, Brazil.
3 - Centro Universitário Christus, Programa de Pós-graduação em Ciências Odontológicas, Forlateza, CE,Brazil.

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ABSTRACT

Objective: This study evaluated different methods of calcium hydroxide (CH) removal from root canals with simulated internal resorptions using microcomputed tomography (micro-CT). **Material and Methods:** Sixty acrylic resin blocks with simulated root canals and internal resorptions were prepared using a Reciproc R25 file and then filled with CH. The blocks were divided into five test groups (n=12) according to the method used for CH removal: hand files (HF), Easy Clean (EC), passive ultrasonic irrigation (PUI), XP-Endo Finisher (XP), XP-Endo Finisher + PUI (XP+PUI). The blocks were scanned using a SkyScan 1172 scanner before and after CH removal to measure the volume and percentage of CH removal. The OriginPro 2017 software was used for statistical analyses. The level of significance was set at $p<0.05$ for all tests. **Results:** No method under study removed all CH. All methods had similar results in the cervical third ($P>0.05$). The percentage of CH removal was significantly greater in the area of internal resorption and along the total length of the canal in the XP+PUI group ($P<0.05$). The best results of CH removal were found in the apical third of roots in the XP+PUI and PUI groups ($P>0.05$). **Conclusion:** No method removed all CH from the root canals, but the combined XP+PUI method removed more CH than the other methods, especially from the area of the internal resorption.

KEYWORDS

Calcium hydroxide; Dental instruments; Dental pulp cavity; Root resorption; X-ray microtomography

RESUMO

Objetivo: Este estudo avaliou diferentes métodos de remoção de hidróxido de cálcio (CH) de canais radiculares com reabsorções internas simuladas por meio de microtomografia computadorizada (micro-CT). **Material e Métodos:** Sessenta blocos de resina acrílica com canais radiculares simulados e reabsorções internas foram preparados com lima Reciproc R25 e posteriormente preenchidos com CH. Os blocos foram divididos em cinco grupos de teste (n=12) de acordo com o método utilizado para remoção de CH: limas manuais (HF), Easy Clean (EC), irrigação ultrassônica passiva (PUI), XP-Endo Finisher (XP), XP -Endo Finalizador + PUI (XP + PUI). Os blocos foram escaneados usando um scanner SkyScan 1172 antes e depois da remoção do CH para medir o volume e a porcentagem de remoção do CH. O software OriginPro 2017 foi utilizado para análises estatísticas. O nível de significância foi estabelecido em $p<0,05$ para todos os testes. **Resultados:** Nenhum método em estudo removeu todos o CH. Todos os métodos tiveram resultados semelhantes no terço cervical ($P>0,05$). A porcentagem de remoção de CH foi significativamente maior na área de reabsorção interna e ao longo do comprimento total do canal no grupo XP+PUI ($P<0,05$). Os melhores resultados de remoção de CH foram encontrados no terço apical

das raízes nos grupos XP+PUI e PUI (P>0,05). **Conclusão:** Nenhum método removeu todo o CH dos canais radiculares, mas o método combinado XP+PUI removeu significativamente mais CH do que os outros métodos, especialmente da área de reabsorção interna.

PALAVRAS-CHAVE

Hidróxido de cálcio; Instrumentos dentais; Cavidade pulpar dentária; Reabsorção radicular; Microtomografia de raios X

INTRODUCTION

Root resorptions, which may be classified as internal or external, are caused by the progressive reabsorption of hard dental tissue due to the action of osteoclasts [1]. Teeth with an internal root resorption should undergo endodontic treatment and total removal of inflammation [1].

The endodontic treatment of teeth with an internal root resorption poses some difficulty for endodontists, as resorption defects are difficult to access. Because of the limitations of endodontic files to treat these cases, intracanal medicaments have to be used, and calcium hydroxide (CH) is the most frequently used to promote disinfection, necrotize residual tissue and stop bleeding [2-5].

CH should be completely removed from the canal before obturation. If any of it remains inside a root canal, it may affect the penetration of the obturating cements into the dentinal tubules [6], reduce adherence to dentin and negatively affect the sealing capacity of obturating materials [7]. In addition, it may react chemically with these other materials and affect their physical properties [8]. The most frequent method to remove CH is the use of a hand file of a size compatible with that of the master apical file used for cleaning and shaping, together with abundant irrigation [9,10], however, other devices and techniques can be used to improve the reach of chemical substances, which can be used to remove CH from root canals.

Passive ultrasonic irrigation (PUI), which consists of the agitation of an irrigant using an ultrasonic insert inside the root canal, is used for the same purpose and has been widely studied [11]. EasyClean (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil), a very flexible #25.04 file made of acrylonitrile butadiene styrene, produces vigorous intracanal fluid agitation [12,13]. XP-Endo Finisher (FKG Dentaire, La Chaux-de-Fonds, Switzerland) is a file with an asymmetric structure, which increases the efficacy of cleaning and shaping and the removal of debris and biofilm. This file has a small core (# 25/00), and its exclusive NiTi alloy (MaxWire® - Martensite-Austenite Electropolish-fleX) grants the file good flexibility and the capacity to expand sideways. Because of this expansion, the file may touch and clean concave and deeper areas of the dentin walls, thus preserving the original anatomic shape of the internal root canal. The mechanical activity of this file, combined with irrigant agitation, seems to increase the efficiency of cleaning the main canal and the dentinal tubules [14] with less debris, similarly to PUI [15]. However, no study has evaluated the combined use of PUI and XP as an additional irrigation protocol to remove CH from internal resorptions of root canals.

Most studies that evaluated CH removal from root canals with internal resorptions used split-tooth models and image analysis [16-20]. However, these study models provide only two-dimensional analyses, do not measure the amount of HC remaining in the resorption cavity accurately and cannot be used for an accurate standardization of the samples [16-20].

Micro-computed tomography (micro-CT) is a non-destructive study method that may be used for a three-dimensional analysis of the samples, providing accurate information about sample volume, area and surface [21]. This study evaluated the removal of CH from root canals with simulated internal resorptions and compared different methods of removal. The null hypothesis was that the irrigant solution activation would not affect the removal of CH from root canals with simulated internal resorptions.

MATERIAL AND METHODS

Root canal model and sample preparation

Sixty acrylic resin blocks (IM do Brasil, São Paulo, Brazil) with simulated canals and an internal resorption were prepared for this study. The simulated canals had a #30 apical diameter, .08 taper and an oval-shaped resorption in the middle third measuring 5 mm in diameter.

Sample size, calculated using the GraphPad Prism software, was based on data of a pilot study. A bilateral test for associated samples, at a level of significance of 0.05% and test power of 0.85, indicated a size of 60 samples.

All procedures were carried out by an endodontic specialist with more than 7 years of clinical experience. Working length was determined using #10 hand K-files (Dentsply Maillefer, Ballaigues, Switzerland) until the tip was visualized at the apical foramen. Real working length (WL) was set at 1mm short of the apical foramen. The foramina of simulated canals were sealed with a cyanoacrylate adhesive (Superbonder, Henkel, Düsseldorf, Germany) e filled with a CH intracanal medicament (Ultracal; Ultradent, South Jordan, UT) delivered using a 30-gauge NaviTip cannula (Ultradent, South Jordan, UT) to 2 mm short of the working length.

The blocks were kept in sealed containers for 21 days [22] and, after that, scanned using an X-ray micro-CT scanner (SkyScan 1172; Bruker, Kontich, Belgium). Immediately after that, the blocks were divided into five test groups (n=12) according to the method used for CH removal: hand files (HF), as a control group; Easy Clean (EC); passive ultrasonic irrigation (PUI); XP-Endo Finisher (XP); and XP-Endo Finisher and PUI (XP+PUI).

Calcium hydroxide removal

The simulated canals were covered with opaque tape, and the Reciproc R25 file (VDW, GmbH, Munich, Germany) was first used to RWL in all groups to start removing CH. The irrigants were inserted into all canals using a 5-mL syringe (UltraDent, Salt Lake City, UT) and a 27-g needle (Endo-Eze; UltraDent, Salt Lake City, UT) inserted to 3 mm short of RWL using back and forth movements.

All procedures were conducted using irrigants warmed to 37 °C in a warmer (Qtamp80, Quanta, Ciudad del Este, Paraguay) containing distilled water at 37 °C. Water temperature in the warmer was checked every five minutes using an infrared thermometer (HM-88C, HighMed, São Paulo, Brazil).

The activation time and volume of irrigants used were based on the study by Freire et al. [23]. Activation protocols are described below:

HF: the canals were first irrigated with 2 mL of 2.5% NaOCl (Fórmula & Ação, São Paulo, Brazil). After that, a #25 K-file was inserted into the root canal and agitated for 30 seconds. The root canal was then irrigated with 2 mL of 17% EDTA and maintained in the canal for 3 minutes (Fórmula & Ação, São Paulo, Brazil), and the #25 K-file was inserted in the root canal again and agitated for another 30 seconds. Finally, the canals were irrigated with 10 mL of 2.5% NaOCl.

EC: after initial irrigation with 2 mL of 2.5% NaOCl, the EC file, powered by a VDW Silver motor (VDW, Munich, Germany) set at RECIPROC ALL, was moved in reciprocating movements for 30 seconds. After that, the canals were irrigated with 2 mL of 17% EDTA and maintained in the canal for 3 minutes, after that EC was used again for 30 seconds. Finally, 10 mL of 2.5% NaOCl were used for the final irrigation.

PUI: the canals were first irrigated with 2 mL of 2.5% NaOCl. After that, an ultrasonic insert (Irrisonic, Helse Corp., Santa Rosa do Viterbo, Brazil) coupled to an ultrasound device (Suprasson P5; Satelec Acteongroup, Merignac, France) at 20% power was inserted in the root canal to RWL and kept there for 30 seconds. After that, the canals were irrigated with 2 mL of 17% EDTA for three minutes and maintained in the canal for 3 minutes, after that the ultrasonic insert was activated for another 30 seconds. Finally, the canals were irrigated with 10 mL of 2.5% NaOCl.

XP: first, 2 mL of 2.5% NaOCl was placed into the root canals. The XP-Endo Finisher was used according to the manufacturer's instructions at 800 rpm, with in and out movements up to RWL, for 30 seconds. After that, the canals were irrigated with 2 mL of 17% EDTA and maintained in the canal for 3 minutes, and the XP-Endo Finisher was activated again for 30 seconds. Finally, the canals were irrigated with 10 mL of 2.5% NaOCl. Each XP file was used in only three canals.

XP+PUI: first, the canals were irrigated with 2 mL of 2.5% NaOCl while XP was activated according to the manufacturer's instructions at 800 rpm and within and out movements up to RWL for 30 seconds. Immediately after that, 2 mL of 17% EDTA was placed into the root canals and maintained in the canal for 3 minutes, and the ultrasonic Irrisonic insert was activated for 30 seconds, as previously described. Finally, the canals were irrigated with 10 mL of 2.5% NaOCl.

After the application of the CH removal protocols, the blocks were scanned again using micro-CT.

Microcomputed tomography

A SkyScan 1172 scanner was used for the acquisition of micro-CT images at 90 kV, 278 mA, 360° rotation, 0.5° rotation stepsize, and voxel size of 17.42 mm. The 1-mm-thick filter used was made of copper.

The 700 2D images acquired for each specimen were stored in TIFF files and saved in an external HD.

The NRecon 1.6.10.4 software reconstructed the 2D images at different angles using a modified Feldkamp cone-beam reconstruction algorithm implemented on a computer cluster. Reconstruction parameters were adjusted for noise suppression using the following fine-tuning function: Gaussian smoothing filter (kernel = 2), beam hardening correction of 40%, post-alignment of 0.50 to compensate possible misalignment during acquisition, and ring artifacts correction of 10.

Image Analysis

DataViewer 1.5.1 (Bruker-microCT) was used to record 3D image data acquired before and after labeling in software packages of the x, y and z axes. CTan 1.16.4.1 and CTvol 2.3.2.0 (Bruker-microCT) were used to create and visualize 3D models and to measure CH volume. The gray scale necessary to recognize each object in the study was determined using a density histogram and a global thresholding method. Original and segmented scans were compared to ensure segmentation accuracy. A customized processing tool and task lists based on arithmetic and logical operations were used to create binary images of CH. The volume of CH that was removed was calculated by subtracting CH volume after use of the devices from initial total CH volume. The percentage of CH removed was calculated using the following formula:

(remaining CH volume x 100)/(total CH volume)

Statistical analysis

The Origin Pro 2017 software was used for statistical analyses, and the level of significance was set at $p<0.05$. Parametric ANOVA was used for the analysis of volume of CH removal because of variance homogeneity and data normality.

RESULTS

No method under study removed CH from inside the root canals completely. Regardless of method, the cervical third had better removal percentages than the other thirds, with a statistically significant difference in the HF, EC and XP groups ($P<0.05$). In the P and XP+PUI groups, CH removal in the cervical third was similar to that found in the apical third ($P>0.05$). In the cervical third, mean variation of CH removal was 95.2% and 99.9%, with no statistically significant difference between groups ($P>0.05$). In the apical third, mean variation of CH removal between groups ranged from 57.3% to 92.4% ($P<0.05$), and the PUI and XP+PUI groups had the lowest percentages of remaining CH ($P>0.05$). Table I shows the mean percentages of CH removal in the groups.

The removal from oval-shaped resorptions was significantly better in XP+PUI than in the other groups ($P<0.05$).

In general, the percentage of total CH removal along the whole canal was significantly greater in XP+PUI ($p<0.05$) than in the other groups (Figure 1). Figure 2 shows the 3D models of the different activation groups before and after CH removal from the simulated canals.

DISCUSSION

This study compared the effectiveness of different CH removal methods – HF, EC, XP and XP + PUI - from simulated canals with internal resorptions. The combined use of XP+PUI was significantly more effective in removing CH form the apical third, the oval-shaped area of the resorption and the whole of the canals, and the null hypothesis was, thus, rejected.

Intracanal medicaments containing CH have been indicated in cases of internal root resorption [2]. The CH was manteined inside the simulated root canals per 21 days, as the average time to reach maximum pH can vary from 8 to 24 days for the use of CH with aqueous vehicles [22]. However, such medicaments have to be completely removed from the root canal before obturation, because remaining

Table I - Mean (± standard deviation) percentage of calcium hydroxide removed from simulated canals with internal resorptions after use of different irrigation methods: HF – hand file, EC –EasyClean, PUI – passive ultrasonic irrigation, XP – XP-Endo Finisher, XP+PUI – combined XP and PUI

	Cervical Third		Apical Third		Oval-shaped area		Total	
	Mean (%)	Standard deviation	Mean	Standard deviation	Mean (%)	Standard deviation	Mean (%)	Standard deviation
HF	95.2^{Aa}	10.4	57.9^{Bb}	25.5	11.2^{Cb}	15.4	22.7^{b}	13.0
PUI	99.7^{Aa}	0.5	89.2^{Aac}	10.2	13.9^{Bb}	8.5	27.6^{b}	9.1
XP	97.3^{Aa}	8.2	67.6^{Bbc}	19.7	14.1^{Cb}	8.8	25.8^{b}	10.5
EC	95.3^{Aa}	4.9	57.3^{Bb}	20.1	5.7^{Cb}	3.9	18.8^{b}	4.9
XP+PUI	99.9^{Aa}	0.3	92.4^{Aa}	17.2	30.2^{Ba}	8.6	58.4^{a}	12.1

Different uppercase letters indicate statistically significant differences (P<0.05) in the comparison between thirds when the same CH removal method was used. Different lowercase letters indicate statistically significant differences (P<0.05) in the comparisons of the same canal third between groups.

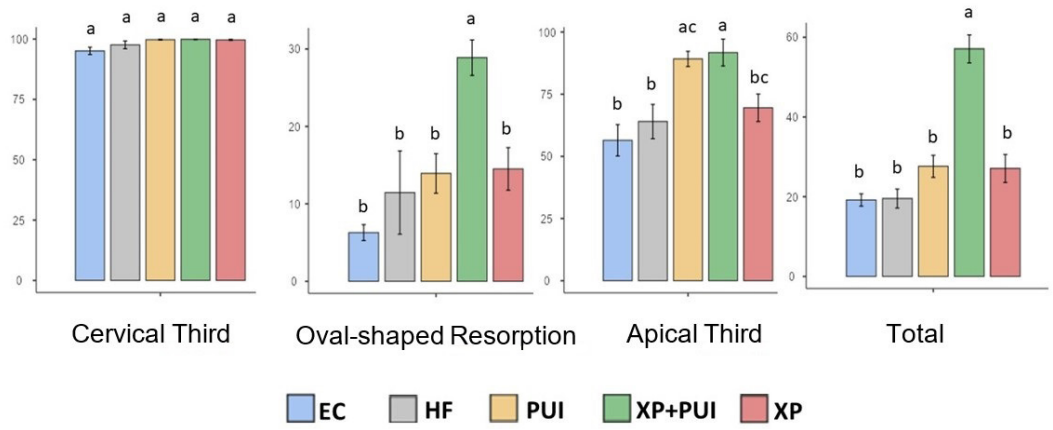

Figure 1 - Mean percentage of calcium hydroxide removal from simulated canals with internal resorptions after the use of different irrigation methods: HF – hand file, EC –EasyClean, PUI – passive ultrasonic irrigation, XP – XP-Endo Finisher, XP + PUI – combined XP and PUI. Different lowercase letters indicate statistically significant differences (P<0.05) in the comparisons of the same canal third between groups.

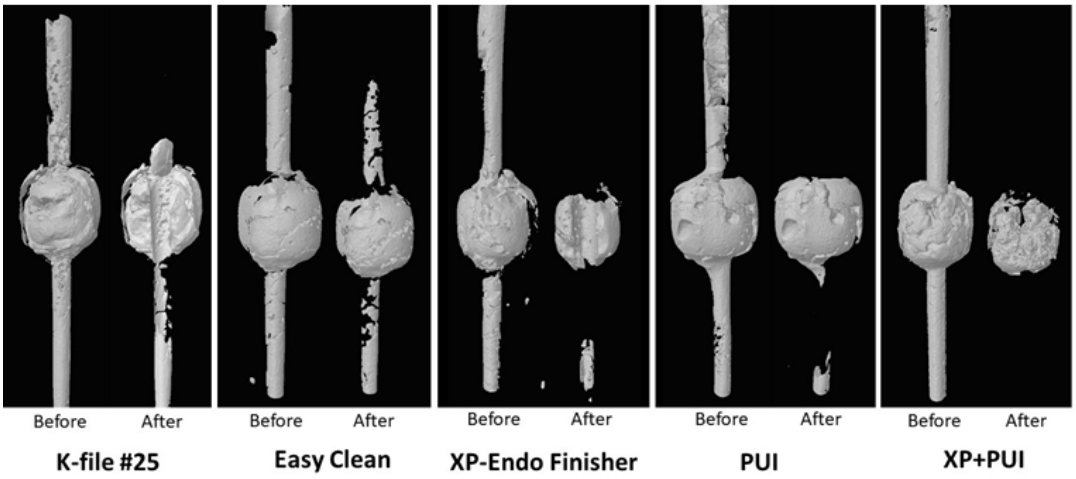

Figure 2 - 3D models of different activation methods before and after CH removal from simulated canals.

CH may negatively affect the quality of the obturation [5-7]. No method used in this study removed CH completely from inside the root canal, particularly from the oval-shaped area of the resorption, which confirms findings of other studies [11,17,18,20,24-27].

The HF, EC, PUI and XP groups had similar results in the cervical third and in the oval-shaped area of resorptions. XP+PUI had results similar to those of PUI alone in the cervical and apical thirds, but results of CH removal from the oval-shaped area of resorptions and the whole

of the canal were not significantly greater. The combination of the XP file and PUI had significantly better results than those of the other groups. Denna et al. [19] found similar results in a recent study, but they studied only canals with no morphological changes.

A possible explanation for this result may be associated with the mechanical action of the XP file and its capacity to expand sideways to a diameter of up to 6 mm, increasing its area of contact with the dentin walls [28]. As it touches the root canal walls, the XP file displaces CH from the oval-shaped area of resorptions and from other difficult-to-reach areas. The subsequent supplemental acoustic streaming and cavitation transmitted by the ultrasonic insert are responsible for cleaning and final removal of the medicament that remained as a suspension inside the canal.

The HF group was a control group, as this type of file does not touch canal walls and has no additional vibration effect [29,30]. The results in this group did not indicate any advantage in CH removal from the area of resorption. In some studies, EC was found to be an alternative for root canal cleaning after cleaning and shaping. However, its efficacy was not good enough to justify its use in CH removal in cases of internal resorption in this study. The agitation of the irrigant used with EC did not result in adequate cleaning of the apical third or the oval-shaped area of resorption, and results were similar to those found for HF. Some authors, however, found that this method removed debris efficaciously from the apical region and isthmuses, especially when rotary movements were used [31]. Maybe the low efficacy of EC resulted from its use with reciprocating movements, as this type of movement, although recommended by manufacturers [11,31], has had worse results than when EC is used with rotary movements [31]. No study, however, has found statistic differences between EC and PUI in CH removal from oval canals [32], or in debris removal [31].

Keskin et al. [16] and Arora et al. [26] did not find any differences between PUI and XP, which is in agreement with the findings in this study. Marques-da-Silva et al. [18], in contrast, found that XP removed significantly more CH than PUI in extracted teeth with simulated cavities. In canals with no morphological anomalies, PUI AND XP were similarly efficacious in removing CH and debris [19,33]. In this study, the separate comparison of the parts of the canal with no anomalies – cervical and apical thirds – did not reveal any difference between activations using PUI or XP.

In this study, the volume of remaining CH was measured using micro-CT. CH volume before and after the use of different methods of removal was calculated using the CTan software, and accurate values were obtained for statistical analyses. Studies in the literature have evaluated other CH removal methods in simulated internal resorptions of extracted teeth that were split longitudinally [16,18,26]. The main studies used radiographs and light microscopy [16,18,26,34]. Micro-CT ensured a very accurate measurement of the volume of CH removed without destroying the specimen. Moreover, a resin block was used with a simulated canal and scanned using a 3D printer, which standardized all the volumes of the specimens, thus avoiding errors in the preparation of simulated cavities, as described in other studies [15,16,35]. Another advantage was the fact that it was not necessary to use human teeth, which have great variations [35,36].

This study demonstrated that, in teeth with internal resorptions, the combination of complementary techniques to activate irrigants is extremely important to potentiate the removal of intracanal medicaments, such as CH. Further studies should be conducted to improve this endodontic treatment procedure, which should result in better root canal sealing.

CONCLUSIONS

The use of XP+PUI was the most efficacious method in the removal of CH medicaments from root canals with simulated internal resorptions. No method in this study removed CH medicaments completely.

Author's Contributions

HCP, AMLB: Conceptualization, Methodology, Formal Analysis, Project Administration. GTMC, LRP, EFI, LGFG: Conceptualization, Methodology, Formal Analysis, Project Administration, Supervision. GG: Formal Analysis, Project Administration, Supervision.

Conflict of Interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Regulatory Statement

Nothing to declare.

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Hermano Camelo Paiva
(Corresponding address)
Universidade de São Paulo, Faculdade de Odontologia, Departamento de Odontologia Restauradora, São Paulo, SP, Brazil.
Email: hermanopaiva@usp.br

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