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Ex vivo study of the efficacy of two irrigation systems in retreatment of root canals filled with bioceramic sealers

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Abstract

AIM. To evaluate the presence of residual filling material in the root canal walls after retreatment and final irrigation using scanning electron microscopy (SEM).

MATERIALS AND METHODS. Fifty-two mandibular oval premolars were instrumented with ProTaper Next X1–X3 and divided into 2 groups: Group BC, filled with Bio-C Sealer and Group AH, filled with AH Plus. The experimental groups were retreated with a ProTaper Next X4 file and received different irrigation protocols (n = 13): Group BC-PUI: agitation with ultrasound; Group BC-EC: agitation with Easy Clean; Group AH-PUI: agitation with ultrasound; and Group AH-EC: agitation with Easy Clean. The remaining filling material in the dentinal tubules was evaluated in scanning electron microscope images by three evaluators who scored the samples. The Kappa test was performed to check interexaminer agreement. Pearson's chi-square test with a significance level < of 5% was performed to compare the groups.

RESULTS. It was found that the BC-EC group showed better results in the apical and middle thirds. In the coronal third, the BC-PUI group also performed well. AH Plus showed the lower results in all situations.

CONCLUSIONS. In the apical third, the BC-EC group showed better performance, in the middle third, the AH-PUI group had the worst performance, and in the coronal third, the BC-PUI group stood out in terms of cleaning. This manuscript provides the importance of thorough cleaning, especially in difficult areas such as the apical third, is emphasized to improve the overall outcome of treatment.

Keywords: retreatment, ultrasound, scanning electron microscopy

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Экспериментальное ex vivo исследование эффективности двух ирригационных систем при повторной обработке корневых каналов, обтурированных биокерамическими силерами

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Резюме

ЦЕЛЬ. Оценить наличие остаточного пломбировочного материала на стенках корневого канала после повторной обработки и финальной ирригации с использованием сканирующей электронной микроскопии (СЭМ).

МАТЕРИАЛЫ И МЕТОДЫ. Пятьдесят два овальных нижнечелюстных премоляра были инструментированы системой ProTaper Next X1–X3 и разделены на две группы: группа BC – обтурация биокерамическим силером Bio-C Sealer, группа AH – обтурация AH Plus. Экспериментальные группы подвергались повторной обработке инструментом ProTaper Next X4 и различным протоколам ирригации (n = 13): BC-PUI – активация ирриганта ультразвуком; BC-EC – активация с помощью Easy Clean; AH-PUI – активация ультразвуком; AH-EC – активация с помощью Easy Clean.

Остаточный пломбировочный материал в дентинных канальцах оценивался в сканирующем электронном микроскопе тремя независимыми экспертами по бальной системе. Для оценки согласованности между экспертами применялся коэффициент Каппа. Для статистического сравнения между группами использовался χ^2-критерий Пирсона при уровне значимости <5%.

РЕЗУЛЬТАТЫ. Группа BC-EC продемонстрировала лучшие результаты в апикальной и средней трети. В коронковой трети наилучшие показатели были зафиксированы в группе BC-PUI. Наихудшие результаты во всех зонах показала группа с силером AH Plus.

ВЫВОДЫ. В апикальной трети группа BC-EC обеспечила наилучшую очистку, в средней трети наихудшие показатели зафиксированы в группе AH-PUI, а в коронковой трети лучшую очистку обеспечила группа BC-PUI. Настоящее исследование подчеркивает важность тщательной очистки корневого канала, особенно в труднодоступных зонах, таких как апикальная треть, для повышения эффективности эндодонтического лечения.

Ключевые слова: повторная обработка, ультразвук, сканирующая электронная микроскопия

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INTRODUCTION

The root canal system has ramifications and isthmic areas, which makes the disinfection process a real challenge. The presence of microorganisms in the root canals is the main cause of failure of endodontic treatment [1].

Conventional retreatment is the first treatment option in case of endodontic treatment failure. Effective removal of obturation material is an extremely important step to allow better cleaning and disinfection of the root canal system, so that irrigants and instruments can act along the entire canal [2].

Irrigation solution activation [3] has been used to improve the cleaning process and promote smear layer removal, facilitating root canal system disinfection [4]. The Easy Clean (EC) plastic instrument (Bassi / Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) has the shape of an “airplane wing” and can be used in

a rotary or reciprocal motion to move the irrigation solution, which promotes a mechanical action, thus improving the cleaning of the canal walls [5; 6].

The epoxy resin-based sealer AH Plus (Dentsply/Maillefer, Bailagues, Switzerland) is considered the gold standard sealer due to its high bond strength to dentin [7–9]. Bioceramic sealers are increasingly used in endodontic practice due to their physicochemical and biological properties [10]. They are biocompatible materials that are stable and non-toxic in the biological environment [11].

Several studies have used SEM to verify the amount of remaining filling material in the dentinal tubules [12–14]. However, few studies have investigated irrigation methods in the removal of bioceramics [3; 15].

The aim of this study was to use SEM to evaluate the efficacy of retreatment with two different rinsing systems in teeth previously filled with resin sealer or bioceramics. The null hypotheses tested were that the amount of residual filling material after retreatment would be the same between (*i*) the two endodontic sealers and (*ii*) the irrigation systems.

MATERIALS AND METHODS

The present study was submitted to and approved by the local research ethics committee under number 3.090.544. The sample was calculated based on a previous study [12] using the statistical test ANOVA, with a minimum difference between treatment means of 4, a test power of 0.80, and an alpha of 0.05. Fifty-two extracted oval human mandibular premolars (bucco-lingual diameter twice the mesio-distal diameter along the first two-thirds of the canal) were selected and kept in 0.1% thymol solution until the start of the study. Teeth with single canal roots, complete rhizogenesis, and a curvature angle between 0° and 10° according to the method of Schneider [16] were included in the study.

All roots with an angle of curvature greater than 10°, with incomplete rhizogenesis, root fractures and/or perforations, and previously treated canals or whose patency was not achieved were excluded.

Teeth were standardized to 15 mm by leveling their occlusal surfaces with a 223 Carboril disk (Dentorium, New York, USA). The working length (WL) was determined by inserting a #10 K-file into the canal using a magnifying glass at 3.5x magnification until its tip appeared at the apical end of the root, subtracting 1 mm.

Preparation of the specimen

The canals were instrumented with ProTaper Next X1–X3 rotary files (Dentsply Sirona, Charlotte, USA) driven by an X Smart Plus motor (Dentsply/Maillefer) in a rotary motion with a torque of 2.0 Ncm and a speed of 300 rpm, with in and out movements and brushing of the canal walls.

The irrigant used was 2.5% sodium hypochlorite (NaOCl) in a 5 mL luer syringe (Descarpack, São Paulo, Brazil) and a 27G Endo-Eze needle (Ultradent, Indaiatuba, Brazil) 3 mm from the apex. Irrigation was performed with 5 mL of solution for each file removal, for a total of 15 mL of irrigation fluid. The final irrigation protocol was performed with 3 cycles of 20 seconds of 17% EDTA and 3 cycles of 20 seconds of NaOCl [4], irrigated with EC and finally rinsed with saline. The canal was dried with ProTaper Nxt X3 absorbent paper tips (Dentsply Sirona, Ballaigues, Switzerland).

Teeth were randomly divided into 2 groups (n = 26): Group AH, filled with AH Plus (Dentsply Sirona, Charlotte, USA) and Group BC, filled with Bio-C Sealer Bioceramic (Angelus, Londrina, Brazil). Both sealers were manipulated according to the manufacturers' recommendations and placed in the canal through a preselected gutta-percha cone (ProTaper Next X3 (Dentsply Sirona, Charlotte, USA). The single cone technique was used to perform the root canal filling.

The roots were radiographed in the buccal-lingual and mesio-distal directions to assess the quality of the filling. The access cavities were filled with Cavit temporary filling material (3M ESPE, Saint Paul, USA). All roots were stored in an oven at 37°C and 100% humidity for 2 weeks to allow the sealers to cure.

For canal initial retreatment Gates-Glidden (Dentsply Sirona, Ballaigues, Switzerland) drills Nos. 2 and 3 were used in the cervical third and ProTaper Next X4 (40.06) rotating files coupled to an X Smart Plus motor and rotating at a speed of 300 rpm and a torque of 2.0 Ncm were used in the middle and apical thirds. Each instrument was used on three teeth and discarded. Rinsing was performed with 15 mL of NaOCl. As a criterion for assessing clearance, the canal walls should be smooth, and the instrument used should not contain any visible obturation material under a magnifying glass with 3.5x magnification.

According to the clearance procedures, the specimens were divided into 4 subgroups (n = 13) according to the irrigation system used:

– AH + PUI: Teeth were filled with AH Plus and ultrasonic activation was performed with an Irrisonic tip (Helse, Santa Rosa do Viterbo, São Paulo) in a Gnatus ultrasonic device with 10% power 1 mm below the WL;

– AH + EC: Teeth were filled with AH Plus, and irrigation fluid was moved 1 mm below the WL in a reciprocal motion in WaveOne all mode using EC in an X Smart Plus motor;

– BC + PUI: Teeth filled with Bio-C Sealer + agitation of the irrigant with PUI. The procedures were the same as for AH + PUI;

– BC + EC: Teeth filled with Bio-C Sealer + agitation of irrigation solution with EC. The procedures were the same as for AH + EC.

The rinsing protocol for all groups was the same as for endodontic treatment. After the final irrigation, the specimens were dried with paper points and a gutta-percha cone was inserted to WL. Using the 1190 FF drill (KG Sorensen, Cotia, Barsil), two grooves were made to near the root canal on the buccal and lingual walls along the entire length of the root longitudinally without connection to the main canal. The specimens were washed under running water to remove debris. A No. 24 spatula was used to apply a vertical force that caused the separation of the root halves [17].

The most intact half of each root was selected. Horizontal slits were drilled with a drill 1190 FF (KG Soresen, Serra, Brazil) at 3, 6 and 9 mm from the anatomical apex to determine the thirds examined: apical, middle, and coronal.

After drying, specimens were mounted on stubs with double-sided tape, coated with gold in the metallizer (Denton Vacuum, Moorestown, USA), andassessed by SEM (JSM-6390LV, JEOL, Tokyo, Japan) for the root canal walls evaluation. Stepwise magnifications of 10, 100, and up to 2000x were performed until the delineated areas (3, 6, and 9 mm from the apex) were visible, and three photographs were taken at each mark.

Statistical analysis

The images were sent in slide format in the Microsoft Office PowerPoint program to three calibrated examiners for evaluation. A score (Fig. 1) was assigned for each image based on the study by Pirani et al. [18].

For inter-rater analysis, the Kappa test was performed. After applying the Kolmorogov-Smirnov test, association analysis was performed using Pearson's chi-square test and Student's t test, both with a significance level of 5%. The Minitab version 17 program was used.

RESULTS

A total of 156 images were obtained and evaluated by 3 calibrated examiners. Interexaminer agreement was calculated for each of the thirds. Then, 4 experimental groups were compared in each third. In the apical third, the BC + EC group showed better results (Table 1).

In the middle third, there was similar behavior between the AH + EC / BC + PUI and BC + EC groups compared with the AH + PUI group (Table 2). The AH + PUI group showed the worst results, with a statistical difference compared with AH + EC (p = 0.01). There was also a statistical difference between the BC + PUI and BC + EC groups (p < 0.00) (Table 2).

In the coronal third, the BC + PUI group had the best performance compared with all others, followed by AH + PUI and AH + EC, with no statistical difference between them, followed by the control group and BC + EC (Table 3).

When comparing the individual groups, a statistical difference was found between the groups AH + PUI (p = 0.01); AH + EC (p < 0.00) and BC + PUI (p < 0.00). Performance was similar for the other groups (Table 4).

In summary, in the apical and middle mm third, the BC + EC group performed better overall, and in the coronal third, the BC + PUI group performed better.

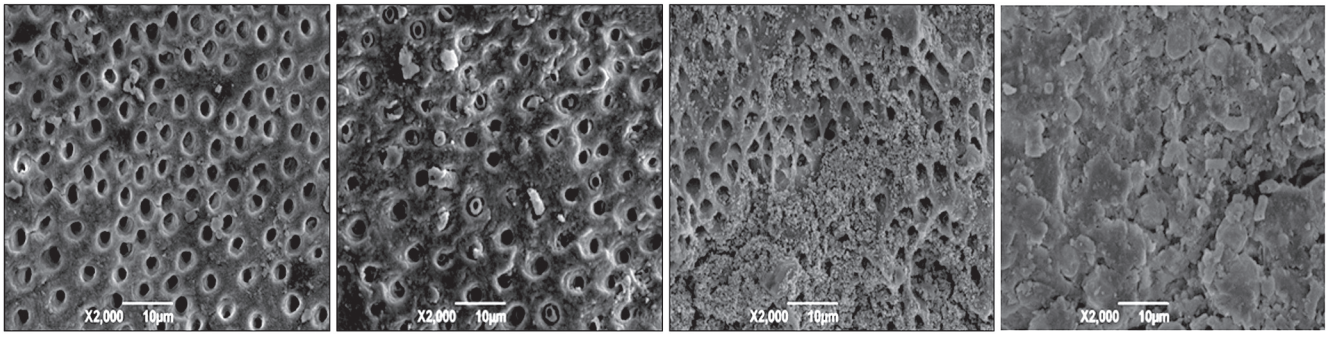

Fig. 1. SEM imagens of the evaluated areas: *A* – Score 1: smear layer/debris not present, more than 75% of tubules open; *B* – Score 2: less than 75% of tubules open; *C* – Score 3: tubules visible in limited areas, less than 50% of tubules visible; *D* – Score 4: homogeneous smear layer/debris, tubules not visible

Рис. 1. СЭМ-изображения оцененных участков: *A* – балл 1: смазанный слой/дебрис отсутствует, более 75% дентинных канальцев открыты; *B* – балл 2: открыто менее 75% канальцев; *C* – балл 3: канальцы видны лишь на отдельных участках, открыто менее 50% канальцев; *D* – балл 4: однородный смазанный слой / дебрис, канальцы не визуализируются

Table 1. Percentage of the score by groups in the apical third

Таблица 1. Процентное распределение баллов по группам в апикальной трети

Group / escore	Controle	AH + PUI	AH + EC	BC + PUI	BC + EC*	*p*-value*
1	5.13	–	–	–	20.51	–
2	20.51	23.08	2.56	–	23.08	< 0.01
3	20.51	23.08	35.90	30.77	33.33	–
4	53.85	53.84	61.54	69.23	23.08	–

Note: * Difference between the BC + EC group compared to all other groups

Примечания: * Различия между группой BC + EC и всеми другими группами

Table 2. Percentage of the score by groups in the middle third

Таблица 2. Процентное распределение баллов по группам в средней трети

Group / escore	Controle[a]	AH + PUI[b]	AH + EC[a, b]	BC + IUP[a, b]	BC + EC[a, b]
1	7.69	–	7.69	20.51	2.56
2	35.90	30.77	48.72	28.21	43.59
3	25.64	64.10	20.51	43.59	46.15
4	30.77	5.13	23.08	7.69	7.69

Note: a – control X BC + PUI / BC + EC – $p < 0.00$; *b* – AH + PUI X AH + EC / BC + EC / BC + PUI – $p = 0.037$

Примечания: a – контроль X BC + PUI / BC + EC – $p < 0.00$; *b* – AH + PUI X AH + EC / BC + EC / BC + PUI – $p = 0.037$

Table 3. Percentage of a score by groups in the coronal third

Таблица 3. Процентное распределение баллов по группам в коронковой трети

Group / escore	Controle[a]	AH + PUI[b]	AH + EC[b]	BC + PUI[c]	BC + EC[a]	*p*-value*
1	23.08	17.95	28.21	53.85	20.51	
2	17.95	43.59	53.85	35.90	10.26	< 0.00
3	35.90	30.77	10.26	10.26	53.85	–
4	23.08	7.69	7.69	–	15.38	–

Note: * Difference between the BC + PUI group and all others; *a* – AH + PUI / AH + EC x control – $p = 0{,}023$

Примечания: * Различия между группой BC + PUI и всеми остальными группами; *a* – AH + PUI / AH + EC по сравнению с контролем: $p = 0{,}023$

Table 4. *p*-value of the difference in proportion between the experimental groups in each third*

Таблица 4. *p*-значения различий в пропорциях между экспериментальными группами в каждой трети*

Group	Apical	Middle	Coronal
AH + PUI x AH + EC	0.59	0.01	0.87
AH + PUI x BC + PUI	0.27	0.35	0.14
AH + PUI x BC + EC	0.01	0.20	0.01
AH + EC x BC + PUI	0.35	0.02	0.23
AH + EC x BC + EC	< 0.00	0.25	0.02
BC + PUI x BC + EC	< 0.00	0.03	< 0.00

Note: * Chi-square test with a significance level of 95%

Примечания: * Критерий χ^2 при уровне значимости 95%

DISCUSSION

This study investigated the presence of residual filling material in the root canal wall after retreatment and final irrigation using SEM. The null hypotheses tested were rejected because there were differences in both the sealers and the irrigant agitation methods employed.

The removal of filling material is a challenge during the endodontic treatment. To address this, several methods were investigated, including manual, rotary, and reciprocating instrumentation, as well as additional irrigant agitation methods. However, none of the methods has been shown to completely remove the filling material on the dentinal tubules [2; 5; 19].

Mandibular premolars present challenges for both treatment [20] and retreatment [21] due to their oval anatomy, which can potentially lead to a large percentage of unprepared root canal walls. In this study, the ProTaper Next system was used for instrumentation and retreatment [19], with a larger instrument tip for retreatment compared to treatment [22].

The manufacturer of Irrisonic recommends using using 2 mm short of the WL, while EC can be used at the WL, but the two instruments used to agitate the solutions were used 1 mm below the WL as a way of standardization for this study.

The evaluation of the samples was conducted using SEM, a standard technique for observing smear layer morphology, the presence of debris within the dentinal tubules, and intratubular dentin morphology [13; 14; 18; 23; 24]. A disadvantage of using SEM is the lack of standardization of the site to be evaluated. In this study, this factor was circumvented by previously delineating the areas to be studied.

In the present study, the quality of cleaning of the dentinal tubules of the coronal, middle, and apical thirds was evaluated, and it was found that there were significant differences between the methods of agitation of the irrigants with respect to these regions. EC was more effective in the apical and middle thirds, while in the coronal third PUI showed better results, which corresponds with a previous study [17] that showed that EC was more effective than PUI in removing the smear layer in the apical third of the canals. However, other studies [5; 25; 26] found no significant differences in cleaning the root canal thirds after endodontic retreatment. PUI performed well in retreatment of maxillary premolars filled with Bio-C Sealer [27]. A possible explanation for the better performance of EC in the apical third is its design: it lacks a cutting blade, is made of plastic, and therefore does not damage the canal walls, whereas ultrasound requires a larger space to achieve better results, which is not the case in the apical third.

Our results corroborate the assertion that sealers penetration depth is directly related to the diameter of tubules, which are more numerous and large in the middle and cervical thirds [28]. Both AH Plus sealer and bioceramics have sufficient fluidity to penetrate the dentin recesses and tubules of the canal, making complete removal of these materials virtually impossible [12]. The bioceramic sealer tested was easier to remove, leaving the tubules freer of debris and consequently contributing to a higher rate of treatment success, possibly related to the solubility of this cement [29].

This study had some limitations, including the absence of information regarding the age and sex of the tooth donors, which could affect the interpretation of the results. In addition, the presence of tubular sclerosis poses a challenge to the standardization of the samples used in this study because they were sourced from a dental bank [23]. Also, the method by which the teeth were sectioned may influence the outcomes and lead to debris and [30], displacement of the remaining obturator material [22].

It is important to note that the study was conducted on straight canals and further studies should investigated using canals with more complex anatomy. In addition to anatomy, different methods, and instruments as well as the type of obturator material may influence the outcomes.

CONCLUSION

It is concluded that in the apical third, the BC-EC group performed better, in the middle third, the AH-PUI group had the worst performance, and in the coronal third, the BC-PUI group excelled in terms of cleaning, however, none of the methods were able to completely remove the filling material.

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