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ORIGINAL ARTICLE

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Radiographic and scanning electron microscopic assessment of root canal filling remnants after endodontic re-instrumentation

Avaliação radiográfica e em microscopica eletrônica de varredura de remanescentes de obturação após a re-instrumentação endodôntica

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ABSTRACT

Objective: Failures in endodontic treatment may occur by several reasons. Endodontic retreatment is an interesting alternative to manage this clinical problem. However, it is not possible to completely remove the root canal filling by any current retreatment technique. The aim of this study was to evaluate the presence of residual root canal filling materials after endodontic re-instrumentation. **Material and Methods:** Sixty extracted anterior human teeth were prepared by step-back technique with Flexofiles, K-files and Gates-Glidden (GG) burs. Between the use of each file or bur, root canals were irrigated with sodium hypochlorite (NaOCl). Smear layer was removed by irrigation with ethylenediaminetetraacetic acid and NaOCl. After drying with paper points the root canals were randomly divided into 5 groups (n = 12), according to filling material: Resilon cones/Real Seal sealer or gutta-percha cones and Endofill, Sealapex, AH Plus or MTA Fillapex sealers. After one week, root canal fillings were removed using Eucaliptol and K-files. Root canals were re-instrumented with K-files and GG burs sized larger than the first ones. The removal of root canal filling material was analyzed by radiography and scanning electron microscopy (SEM). Statistical analysis was performed using Binary Logistic Regression test ($P < 0.05$). **Results:** Radiographic and SEM analysis showed that material from the MTA Fillapex group was better removed than that from Endofill, Sealapex, AH Plus and Real Seal groups. **Conclusion:** After re-instrumentation,

RESUMO

Objetivo: Falhas no tratamento endodôntico podem ocorrer por várias razões. O retratamento endodôntico é uma alternativa interessante para tratar esse problema clínico. No entanto, não é possível remover completamente o material obturador do canal radicular por qualquer das técnicas atuais de retratamento. O objetivo deste estudo foi avaliar a presença de resíduos de material obturador após a re-instrumentação endodôntica. **Material e Métodos:** Sessenta dentes anteriores humanos foram preparados pela técnica escalonada com Flexofiles, limas K e brocas Gates-Glidden (GG). Entre o uso de cada instrumento ou broca, os canais radiculares foram irrigados com hipoclorito de sódio (NaOCl). A lama dentinária foi removida por irrigação com ácido etilenodiaminotetraacético e NaOCl. Após secagem com pontas de papel, os canais radiculares foram divididos aleatoriamente em 5 grupos (n = 12), de acordo com o material obturador: cones Resilon/cimento Real Seal ou cones de guta-percha e cimento Endofill, Sealapex, AH Plus ou MTA Fillapex. Após uma semana, o material obturador foi removido usando Eucaliptol e K-files. Os canais radiculares foram re-instrumentados com limas K e brocas GG de tamanhos maiores do que as anteriormente usadas. A presença de remanescente de material obturador no canal radicular foi analisada por radiografia e microscopia eletrônica de varredura (MEV). A análise estatística foi realizada pelo teste de Regressão Logística Binária ($P < 0,05$). **Resultados:** As análises radiográfica e por MEV mostraram que o material do grupo MTA Fillapex foi melhor removido do que o dos grupos Endofill, Sealapex, AH Plus e Real Seal. **Conclusão:** Após a re-instrumentação, o grupo MTA

MTA Fillapex group showed less remnants into the root canals than Endofill, Sealapex, AH Plus and Real Seal groups. Residual material was most often found in the apical third.

KEYWORDS

Dental radiography; Endodontic retreatment; Root canal filling materials; Scanning electron microscopy.

Fillapex apresentou menos remanescentes nos canais radiculares que os grupos Endofill, Sealapex, AH Plus e Real Seal. O material residual foi encontrado mais frequentemente no terço apical.

PALAVRAS-CHAVE

Microscopia eletrônica de varredura; Obturação do canal radicular; Radiografia dental; Retratamento.

INTRODUCTION

Despite advances in the regenerative endodontic field, conventional endodontic treatment remains the most employed approach to manage dental pulp diseases. However, failures in these conventional treatments may occur by several reasons, such as professional inability, failures in root canal filling or coronal sealing as well as inappropriate disinfection of the root canal system [1]. When the access to the root canal is feasible, endodontic retreatment is an interesting alternative to manage endodontic failures [2,3]. Root canal retreatment intends to completely remove existing filling material in order to regain access to the apical foramen, allowing new cleaning and shaping of the entire root canal [3-5] as well as make possible the filling of the root canal system.

Several techniques have been suggested to remove different root canal filling materials, including the use of manual files [6], rotary files [7-9], manual associated to rotary files [4,10-12] and the use of heat or solvents [13,14] to soften gutta-percha and facilitate root canal filling removal. However, studies indicate that it is not possible to completely remove the existing root canal filling material by any current retreatment protocol [12,15-17].

Recently, hydroxyl ions diffusion through radicular dentine before root canal filling with different materials and after re-instrumentation has been studied [18]. It was verified that, except to the Sealapex group, the pH means after re-instrumentation were higher than those reached before root canal filling. It was suggested that a possible greater intratubular penetration of Sealapex hampered the removal of sealer and hence the recovery of the dentin permeability. Using the same teeth that were previously used [18], the aim of this study was to assess, through radiography and scanning electron microscopy (SEM), the presence of residual root canal filling materials after endodontic re-instrumentation. The null hypothesis was that the nature of filling material has influence on its removal from root canal.

MATERIAL AND METHODS

Research protocol nº 976/FR369069 was approved by the local Ethics Committee for Research with Human Beings.

Tooth selection and root canal preparation

Sixty extracted anterior human teeth with single, straight or slightly curved and completely formed roots were used. Teeth were extracted for reasons unrelated to this research and, after donation and informed consent obtained from the patient; they were collected from the University Oral and Maxillofacial Surgery Clinics. After endodontic access, the length of each tooth was measured by introducing an ISO #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) in the root canal until its tip was visible at the apical foramen. Working length was established at 1 mm shorter than the tooth length. Root canals were prepared using a standardized step-back technique with ISO Flexofile and K-files (Dentsply Maillefer). The apical stop was created by applying three files in the working

length; the first file used was the one that best adjusted to the anatomical diameter. Teeth in which the anatomical diameter was smaller than #20 or larger than #25 were excluded. Afterwards, additional two files, larger than the first one used, were employed in each root canal in order to create a surgical diameter. In the sequence, three or four more instruments were employed; stepping back 1 mm at each file change. Preparation was completed using numbers 1, 2 and 3 Gates-Glidden (GG) burs (Dentsply Maillefer), stepping back 2 mm at each change. Between the use of each file or bur, root canals were irrigated with 2 mL of 1% sodium hypochlorite (NaOCl) (Asfer, São Caetano do Sul, SP, Brazil). After preparation, root canals were irrigated with 3 mL of 17% ethylenediaminetetraacetic acid (EDTA) (Merck, Darmstadt, Hesse, Germany) followed by 3 mL of 1% NaOCl to remove smear layer [19], and were dried with absorbent paper points.

Root canal filling

Teeth were randomly divided into 5 groups (n = 12) regarding the filling material used: Resilon cones/Real Seal sealer (Pentron Clinical Technologies, Wallingford, CT, USA) or gutta-percha cones and Endofill (Dentsply, Petropolis, RJ, Brazil), Sealapex (Kerr-Sybron, Orange, CA, USA), AH Plus (Dentsply) or MTA Fillapex (Angelus Dental Solutions, Londrina, PR, Brazil) sealers. All root canals were filled using cold lateral compaction technique as following: for each root canal a master cone was selected according to the apical stop diameter. The master cone was coated with the appropriate sealer and inserted into the root canal. Afterward, cold lateral compaction with accessory cones was performed. Finally, a heat source removed the excess of filling material from pulp chamber. The quality of the root canal fillings was verified by radiography (Figure 1). After coronal sealing with Citodur (Dorident, Viena, Viena, Austria), teeth were stored for 1 week at 37°C and 100% humidity to allow complete setting of the sealers.

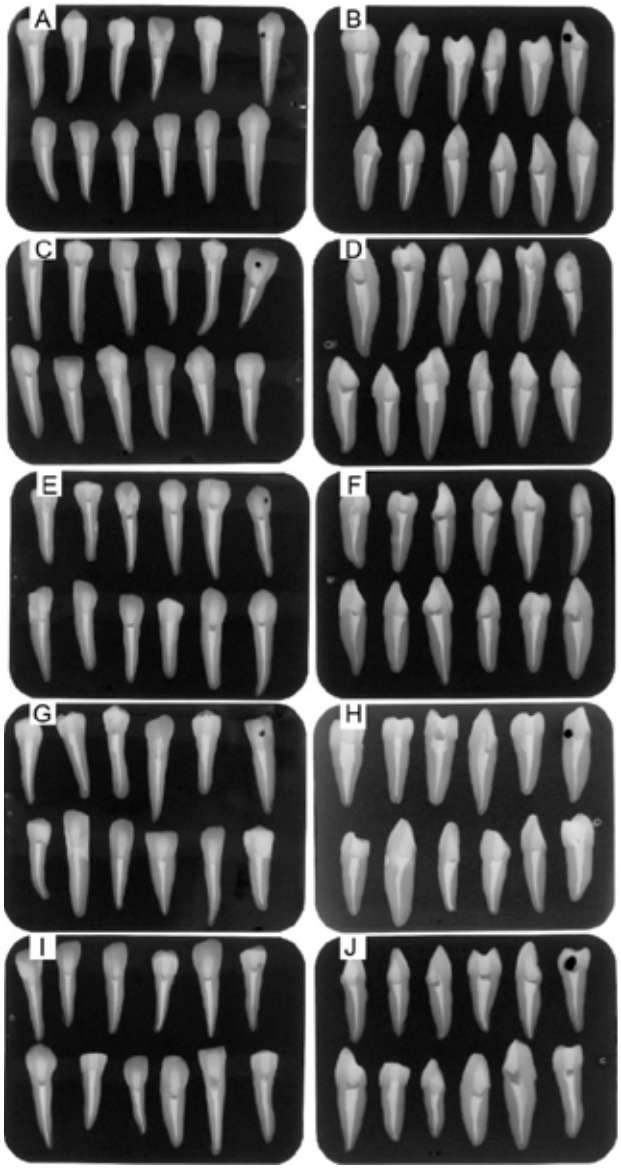


Figure 1 - Radiographs for access the quality of the root canal filling in the groups (A, B) Real Seal, (C, D) Endofill, (E, F) Sealapex, (G, H) AH Plus, and (I, J) MTA Fillapex, taken in buccal/palatal and medial/distal directions, respectively.

Root canal filling removal

Filling materials were removed in a crown-down direction using K-files and eucalyptol (SS White, Rio de Janeiro, RJ, Brazil) as solvent. Root canals were re-instrumented through the use of two files larger than the last one used to prepare each apical stop. Numbers 4, 5 and 6 GG burs were used in the middle and cervical thirds.

Radiographic assessment

To evaluate the quality of root canal filling removal, teeth were radiographed in the buccal/palatal (BP) and medial/distal (MD) directions. Radiographic analysis was performed by 2 independent examiners, using a negatoscope, under 4.5 magnifying lens. Remnants of root canal filling material on cervical, middle and apical thirds were classified as absent (No) or present (Yes). Examiners discussed any disagreement situation until consensus.

SEM assessment

Additionally to the radiographic analysis, 6 teeth from each group were randomly chosen and processed to evaluate, under SEM, the presence of residual filling material. Using carborundum discs, tooth crown and apical third were removed, and deep grooves were made on the buccal and palatal surfaces of the roots, without perforating the root canal. Roots were then split using a chisel and a hammer. One half of each root was selected and prepared for SEM examination. After assembly on coded stubs, specimens were placed in a vacuum chamber and sputter-coated with 300-Å-gold layer (Bal-Tec CD 005; Bal-Tec Co., Balzers, Liechtenstein). Root fragments were then analyzed using a JEOL SEM (JEOL JSM-6390LV) operated at 15 kV. Dentinal walls of the cervical and the middle thirds were observed at 3,000 x magnification by the same examiners, in a blind manner. Photomicrographs, representative of the predominant condition of each root third, were taken to compare with the image of the same thirds in the radiographies. The specific goal of this analysis was to verify whether the clinical view, represented by radiographic image, matched with the microscopic findings.

Statistical Analysis

Binary Logistic Regression test was used to compare the number of thirds with residual filling material per group and verify in which third the materials remained most often, in the radiographic assessment. This test was also applied to compare the findings between both methods of assessment (radiography and SEM). Significance level was set at 5%.

RESULTS

Radiographic assessment

Figure 2 shows the number of root thirds in each group with or without remaining filling material. Table I expresses, per group, the percentages of root canal thirds with residual filling material and odds ratio with its confidence interval. Remnants of filling material were observed in all groups. In root canals filled with MTA Fillapex a significantly minor percentage of thirds showed remaining filling material in comparison with those filled with AH Plus and Resilon/Real Seal. Root canals filled with AH Plus showed 5.16 times greater probability to present remaining material than those filled with MTA Fillapex. For Resilon/Real Seal group this probability raised to 7.95 times (Table I). Considering all root thirds, there was no difference in the percentage of thirds with presence of remaining filling material among MTA Fillapex, Endofill, Sealapex groups and among Resilon/Real Seal, AH Plus and Sealapex groups. However, a difference was found when those three first groups were compared to the last three ones (Table I).

Regardless the material, the presence of residual filling was significantly greater ($P < 0.001$) in the apical third (65%) than in the cervical (45%) and middle thirds (16.66%).

Considering only the cervical thirds with residual filling material from different groups, less root canals filled with MTA Fillapex or Endofill presented remnants than those from Sealapex, AH Plus and Real Seal groups ($P = 0.01$). Regarding to middle and apical thirds no significant difference was found among materials (Table II).

Radiographic and SEM assessment comparison

Comparison between radiographic and microscopic assessment found no significant difference ($P = 1.00$), independently of the root canal filling material evaluated (Figure 3).

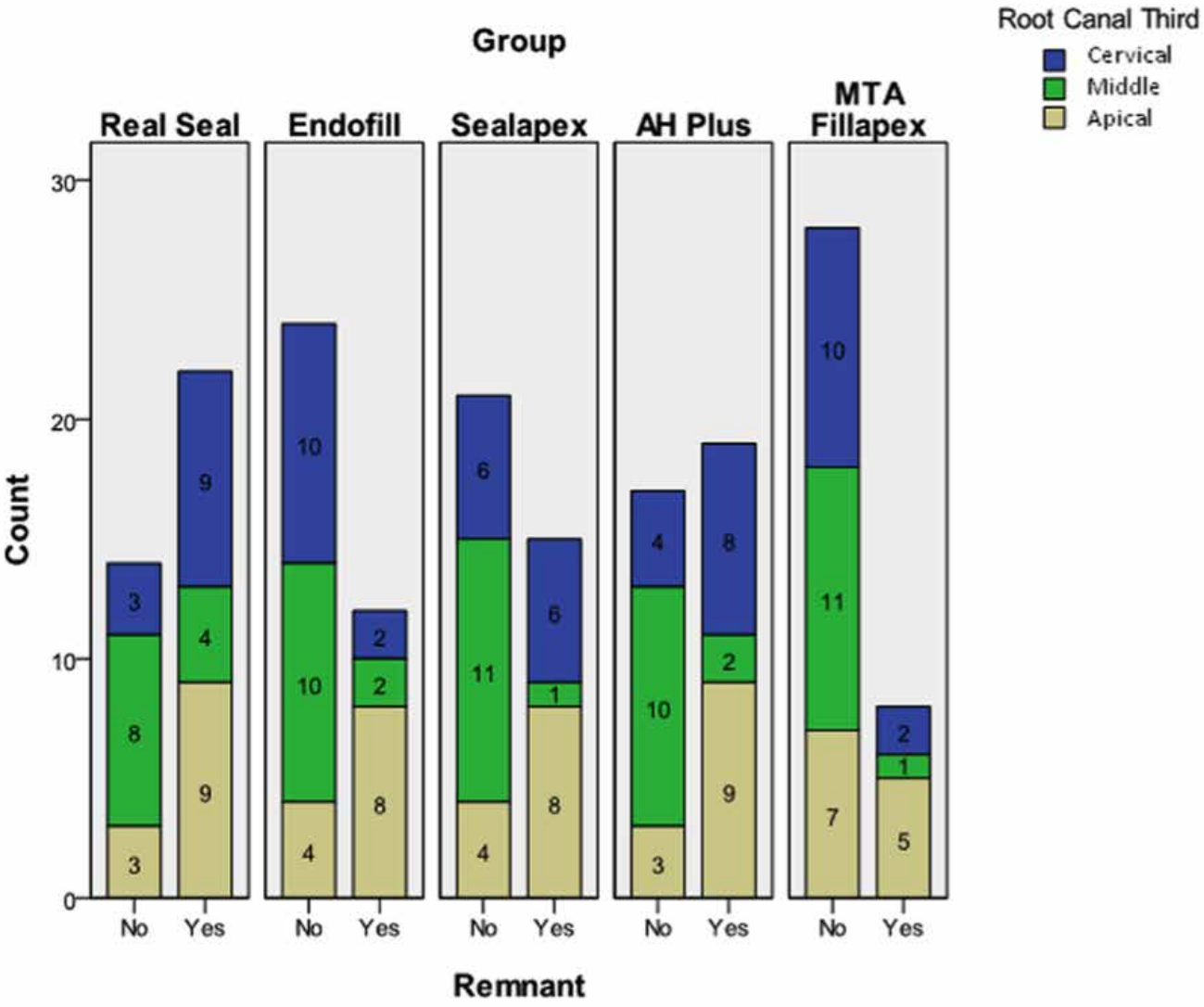


Figure 2 - Number of radicular thirds, in each group, with (yes) or without (no) remaining root canal filing material.

Table I - Percentages of radicular thirds with residual root canal filling material per group

GROUP	TRFM (%)	OR (CI)§
Real Seal	61.11[a]	7.95 (2.50 / 25.22)
AH Plus	52.77[a]	5.16 (1.67 / 15.99)
Sealapex	41.66[ab]	2.95 (0.96 / 9.05)
Endofill	33.33[b]	1.91 (0.61 / 5.93)
MTA Fillapex	22.22[b]	1

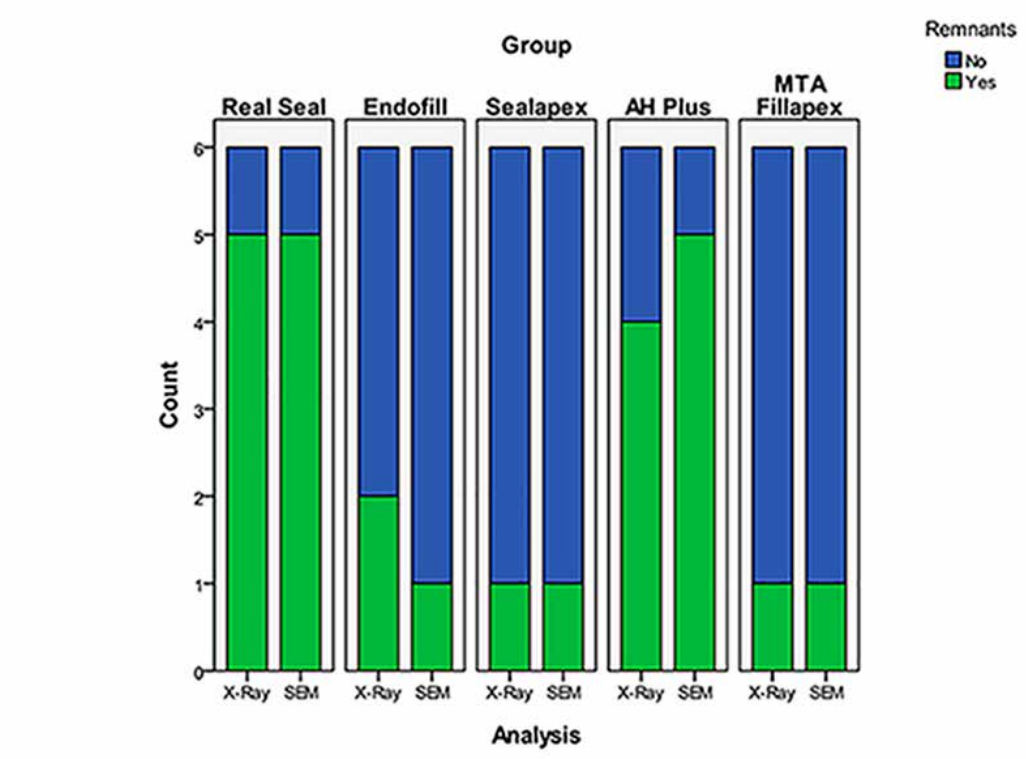
P = 0.014. TRFM: thirds with residual filling material. §Odds ratio (OR), with its confidence interval (CI), in the comparison of MTA Fillapex with the other materials. Equal letters indicate statistic equivalence.

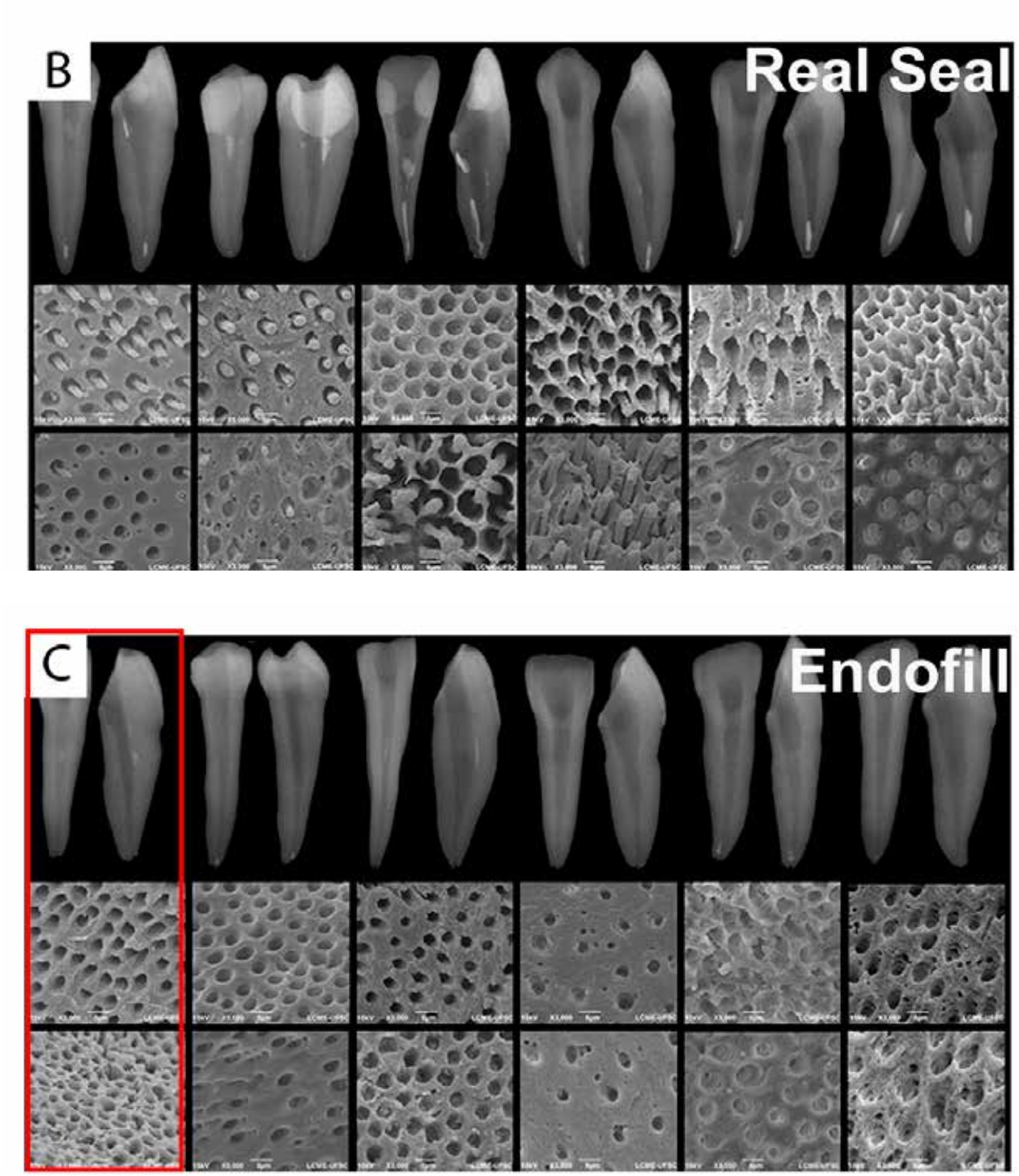
Table II - Percentages of root thirds with remaining filling regarding the radicular third and the root canal filling material

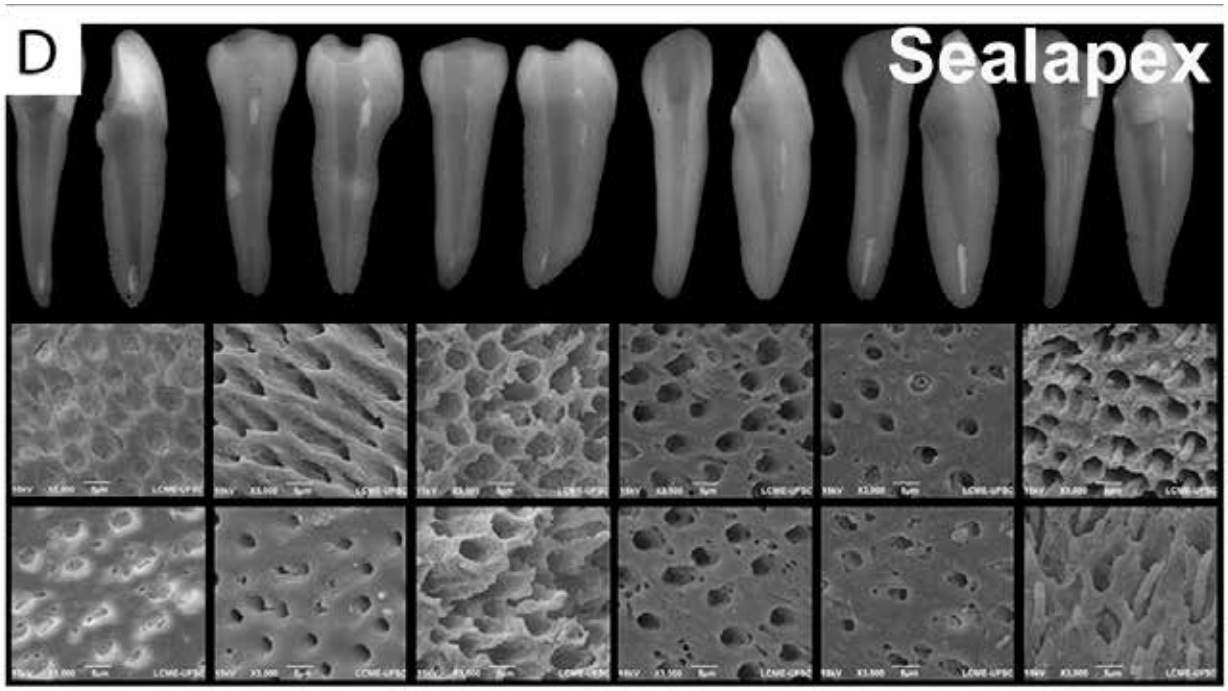
	MATERIAL	%	OR (IC)§
Cervical P = 0.01	Real Seal	33.33[b]	15 (2.02 / 111.17)
	AH Plus	29.62[b]	10 (1.44 / 69.26)
	Sealapex	22.22[b]	5 (0.75 / 33.21)
	Endofill	7.40[a]	1 (0.11 / 8.55)
	MTA Fillapex	7.40[a]	1
Middle P = 0.51	Real Seal	40[a]	5.50 (0.51 / 59.01)
	AH Plus	20[a]	2.20 (0.17 / 28.13)
	Endofill	20[a]	2.20 (0.17 / 28.13)
	Sealapex	10[a]	1 (0.05 / 18.08)
	MTA Fillapex	10[a]	1
Apical P = 0.44	Real Seal	23.07[a]	4.20 (0.73 / 23.90)
	AH Plus	23.07[a]	4.20 (0.73 / 23.90)
	Endofill	20.51[a]	2.80 (0.53 / 14.73)
	Sealapex	20.51[a]	2.80 (0.53 / 14.73)
	MTA Fillapex	12.82[a]	1

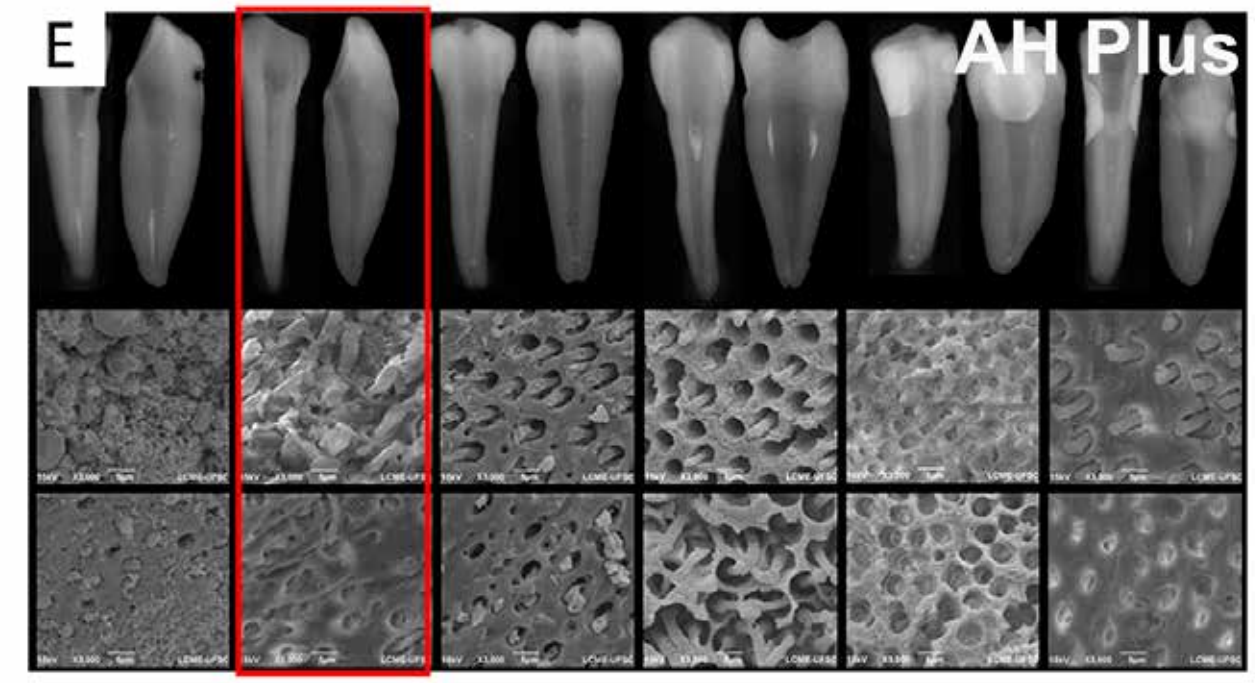
§Odds ratio (OR), with its confidence interval (CI), in the comparison of MTA Fillapex with the other materials. Equal letters indicate statistic equivalence.

A




B
Real Seal
C
Endofill


D
Sealapex


E
AH Plus

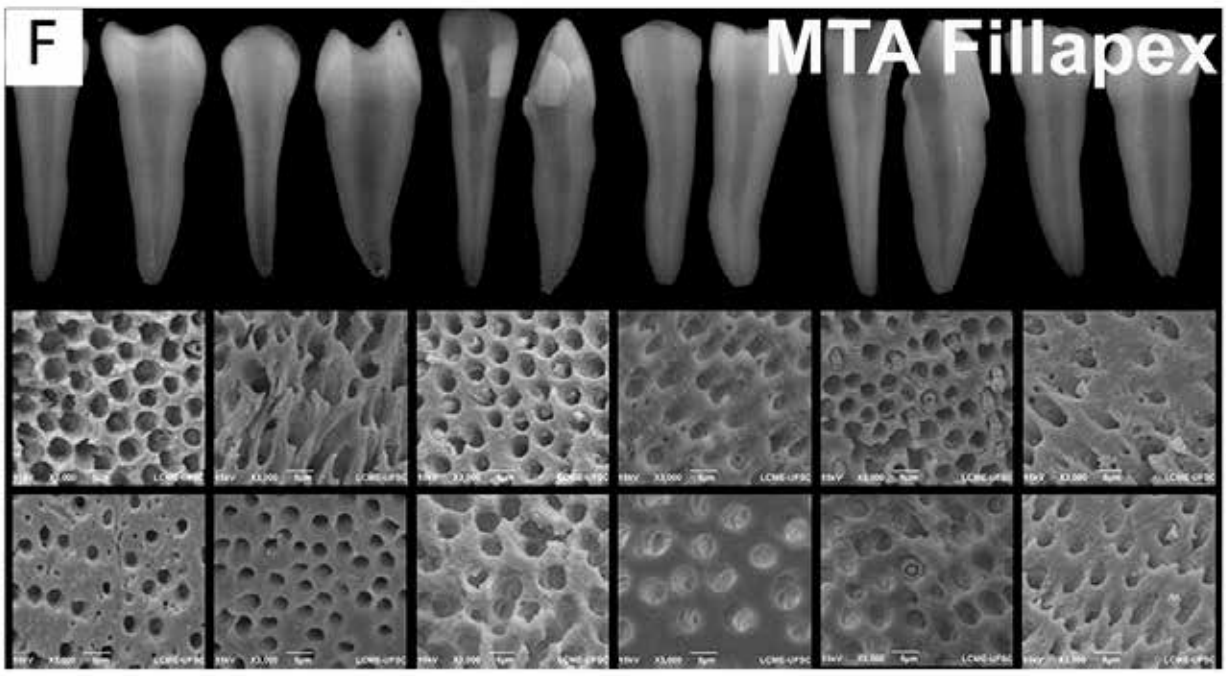


Figure 3 - Comparison between radiographic and scanning electron microscopic (SEM) analyses. (A) Graphic demonstrating the findings of each assessment method per group. (B, C, D, E, F) Radiographs taken in buccal/palatal and medial/distal directions, and photomicrographs from the 6 teeth of each group analyzed by both methods. In red boxes are highlighted the specimens with no matching between the methods of assessment.

DISCUSSION

When initial endodontic treatment fails, root canal retreatment must be considered as therapeutic approach [20]. However, it is only indicated if the removal of the root canal filling material is possible [4,5], since retreatment success is related to the complete filling material removal [6], as its remnants act as a physical barrier that could hamper the activity of the root canal disinfectant products [21].

One of the issues that influence the emptying procedure during the endodontic retreatment is the technique employed to fill the root canals [12]. Greater amount of material remains into root canals filled through thermoplastic techniques than in those filled through lateral compaction technique [15]. The latter was chosen for this study because it is the most employed technique worldwide.

Several materials have been used to fill root canals. Gutta-percha, associated to a range of sealers, has been the most usual material [5,6,8,13]. In this study, gutta-percha was used with zinc oxide and eugenol (Endofill), epoxy resin (AH Plus) and calcium hydroxide (Sealapex) based sealers because these materials are frequently used in clinical practice. Furthermore, MTA based sealer (MTA Fillapex) was used because it brought new conceptions to root canal filling. According to the manufacturer, MTA Fillapex has long term sealing capacity, promotes the deposition of hard tissue at the root apex and perforation sites and can be removed through conventional techniques used for the removal of other filling materials.

Since the gutta-percha is not able to adhere to dentine walls, new root canal filling systems have been developed in order to replace this material [4,6,13]. In the last few years, root canal filling systems based on thermoplastic polymers have been introduced, such as Resilon/Real Seal, which was used in this study. These materials chemically bind to dentine walls

through intratubular tags, creating a cohesive unit among dentine, sealer and resin points, named "monoblock" [5,6,8,22]. Its manufacturer (Sybrondental Specialties Inc., Anaheim, CA, USA) states that when endodontic retreatment is necessary, Real Seal can be removed through conventional techniques.

Heat or solvents can be used to soften gutta-percha and help files to remove root canal filling material [6,13,14]. Chloroform was used for this; however, its toxicity and its potential to alter the chemical composition of the dentine surface, inducing to root canal transportation during retreatment procedures [23], compelled the search of alternatives. Thus, orange oil, xylol and eucalyptol, which was employed in this study, have been used to replace chloroform [24].

Although it is possible to remove root canal filling through several techniques, [4,6-12] authors are unanimous in stating that none of them are able to completely remove root canal filling, specially resin based materials [12,15,16]. In the present study, it was found remaining root canal filling material in all groups, regardless the material used. Moreover, remnants of filling materials were most often located in the apical third than in the cervical and middle thirds; which was also observed in other studies [4,8,11,13].

Different physical-chemical properties of sealers, such as adherence to the dentinal walls and flowability, could influence intratubular penetration and affect its removal from the root canal. In this study, the null hypothesis was accepted, since root canals filled with resin based materials were hardest to empty. For Resilon/Real Seal group, probably this was due to sealer intratubular penetration and the monoblock formation. According Versiani et al. [25], AH Plus has flowability similar to Real Seal, which might have hampered its removal from the root canal. In addition, Tedesco et al. [26] found that AH Plus was superior to Endofill, Sealapex, and MTA Fillapex sealers regarding both bond strength and quality of interface formation, which also might have hampered the removal of this sealer [9]. In our previous study [18], we had suggested that the reason for the equilavence between pH means before and after re-instrumentation to the Sealapex group was its deeper intratubular penetration. However, in the present study this was not confirmed, since there was no difference in the number of radicular thirds with residual material on dentinal walls in Sealapex group compared to the other groups. Further studies are required to completely clarify this issue.

The anatomy of the root canal system is an important aspect to be considered in endodontic filling removal. According to Ma et al. [27], the complex anatomy of oval shaped root canals may be a big challenge during retreatment procedures. Wu et al. [28] found from 50% to 92% oval shaped root canals in the apical third. Therefore, this shape could make the removal of the filling material more difficult in this region. In the cervical and middle thirds, the use of files more robust than those used apically makes the removal of the root canal filling less difficult, because larger files are more resistant and allow using much strength in removal movements. In the present study, the use of thin files may have prevented the emptying in the apical third, especially in the root canals filled with Resilon/ Real seal.

Considering radiographic assessment, it was noted that remaining filling materials were easily detected in radiographies taken in MD direction, which indicated that remnants were most often located in buccal and lingual aspects. However, this is not a clinical fact, since dental radiographs are taken in a BP direction; thereby false-positive emptying evaluation might occur.

When SEM photomicrographs from the cervical and middle thirds were assessed, it was found that, in all groups, there were specimens presenting remnants of root canal filling material. This SEM analysis was useful to evaluate the ability to identify residual

filling material through radiography. It was found a consistency between both assessment methods, which demonstrates the effectiveness of radiographic assessment to verify filling material remnants within the root canal after an emptying approach, without taking into account the direction of the radiography. In this comparison, only two specimens from the total sampling were no equivalent concerning those assessment methods.

CONCLUSION

Root canals filled with MTA Fillapex presented less remnants on dentinal walls, after endodontic re-instrumentation, than those filled with Endofill, Sealapex, AH Plus or Resilon/Real Seal. Independently of the material, residual filling was most often found in the apical third. Radiographic assessment is effective to identify remnants of root canal filling material after an emptying approach for retreatment.

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