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Efficacy of several rotary systems in removal of two different obturation materials during endodontic retreatment

Efikasnost različitih rotirajućih sistema u uklanjanju dva opturaciona materijala pri endodontskom retretmanu

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Abstract

Background/Aim. In order to achieve good results in endodontic retreatment, satisfactory removal of filling material and adequate debridement of the root canal is necessary. The aim of this *in vitro* study was to evaluate the efficacy of three rotary systems in removing gutta-percha/AH Plus and RealSeal SE obturation materials during retreatment using scanning electron microscopy. **Methods.** A total of 72 freshly extracted mandibular first incisors were enlarged to a size #30 using iRaCe NiTi instruments. Teeth were randomly divided into 6 groups of 12 specimens each. 36 teeth (groups 1, 2 and 3) were filled with AH Plus®/gutta-percha and another 36 (groups 4, 5 and 6) with Resilon (RealSeal SE system), both using lateral condensation technique. In groups 1 and 4, the retreatment was performed using the ProFile System, in groups 2 and 5 using the ProTaper Universal Retreatment System and in groups 3 and 6 using the D-RaCe system. After retreatment the teeth were split vertically into halves and efficacy of retreatment techniques was evaluated by scanning electron microscopy. The assessment and comparisons of 3 parameters: smear layer, filling debris and surface profile irregularities were made using a predefined scale. These 3 parameters were evaluated in the coronal, middle and apical thirds of the root. Statistical analysis was performed using the Kruskal-Wallis test with the Bonferroni post-hoc test. **Results.** In the AH Plus/gutta-percha samples filling debris removal was significantly better when the D-RaCe and ProTaper System were used compared to the ProFile in the apical third. Less dentin irregularities were observed when the ProTaper was used compared to the ProFile system ($p = 0.0139$). In the RealSeal samples, no significant differences were found between the retreatment methods. **Conclusion.** None of the instrumentation technique completely removed filling material from the root canal, which implies the need for more research in this field. The apical third of the root canal was the most complicated area in terms of complete smear layer and filling debris removal and presence of surface profile irregularities regardless the filling materials.

Key words:
gutta-percha; microscopy, electron, scanning; root canal filling materials; root canal therapy; treatment outcome.

Apstrakt

Uvod/Cilj. U cilju postizanja dobrih rezultata u endodontskom retretmanu, neophodno je omogućiti zadovoljavajuće uklanjanje opturacionog materijala i adekvatan debridman kanala korena zuba. Cilj ove *in vitro* studije bio je evaluacija efikasnosti tri sistema rotirajućih instrumenata u uklanjanju gutaperke/AH Plus silera i RealSeal SE sistema tokom retretmana, primenom skenirajuće elektronske mikroskopije. **Metode.** Kanali korenova 72 sveže ekstrahirana donja centralna inciziva su preparisani primenom rotirajućih iRaCe NiTi instrumenata do veličine #30. Zubi su nasumično podeljeni u 6 grupa od po 12 uzoraka. Ukupno 36 zuba (grupe 1, 2 i 3) opturisani su gutaperkom sa AH Plus silerom, a preostalih 36 zuba (grupe 4, 5 i 6) RealSeal SE sistemom, primenom tehnike hladne lateralne kondenzacije. U grupama 1 i 4 retretman je obavljen primenom ProFile Sistema, u grupama 2 i 5 primenom ProTaper Universal Retreatment sistema, a u grupama 3 i 6 primenom D-RaCe Sistema. Posle retretmana zubi su presečeni longitudinalno na polovine a efikasnost metoda retretmana ocenjivana je pomoću skenirajuće elektronske mikroskopije. Upoređivanje tri parametra (prisustvo razmaznog sloja, debris od ostataka opturacionog materiajala i iregularnost površine) obavljeno je pomoću prethodno definisane skale vrednosti. Ova tri parametra su ocenjivana u koronarnoj, srednjoj i apikalnoj trećini korena zuba. Statistička analiza je obavljena primenom Kruskal-Wallis testa sa Bonferroni *post-hoc* testom. **Rezultati.** U uzorcima opturisanim AH Plus/gutaperkom uklanjanje debrisa bilo je statistički značajno bolje primenom D-RaCe i ProTaper sistema u odnosu na ProFile sistem u apikalnoj trećini ($p < 0.05$). Utvrđeno je manje iregularnosti površine dentina kada je korišćen ProTaper system u poređenju sa

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ProFile sistemom ($p = 0.0139$). Kod uzoraka opturisanih RealSeal SE sistemom nisu utvrđene statistički značajne razlike između ispitivanih metoda retretmana. **Zaključak.** Ni jedna od tehnika instrumentacije nije omogućila kompletno uklanjanje opturacionog materijala iz kanala korena zuba. Sve ispitivane tehnike retretmana su bile manje efikasne u apikalnoj trećini kanala korena, nezavisno od vrste opturacionog materijala.

Ključne reči:
gutaperka; mikroskopija, elektronska, skenirajuća; zub, materijali za punjenje korenskog kanala; lečenje, ishod.

Introduction

The main goal of nonsurgical root canal retreatment is to reestablish healthy periapical tissues following ineffective root canal treatment, or reinfection [1]. Removal of as much filling material as possible from the inadequately prepared and filled root canal systems would appear to be essential to uncover remaining necrotic tissue or bacteria that may be responsible for periapical inflammation and persistent disease [2]. Thus, in order to achieve good results, it is necessary to perform the adequate debridement of the root canal after the satisfactory removal of previous filling material.

Gutta-percha (GP) is certainly the most commonly used filling material in endodontics. Resilon (Pentron Corp., Wallingford, CT, USA) was introduced relatively recently as a synthetic polymer-based alternative to GP [3]. A polycaprolactone thermoplastic material with bioactive glass, bismuth, and barium salts as fillers has handling properties similar to GP. This material induces a chemical interaction that leads to the formation of a single resin block, which adheres to the root canal walls [4].

When taken into account that Resilon has similar sealing ability as GP with the AH Plus sealer [5], it could be expected that this material can be removed in similar ways as GP. Beside numerous studies concerning its physical, chemical and biological properties, removal of Resilon from root canal has also been investigated [1, 4, 6–8].

There are many different techniques for removal of root canal filling material: solvents [9, 10], hand, rotary [6, 8, 11, 12] and ultrasonic instruments [13, 14], heat-carrying instruments, laser [15, 16] , or a combination of these techniques [17]. The rotary nickel–titanium (NiTi) systems are preferred in endodontic retreatment because of their safety, efficiency and speed [18–21]. In order to improve endodontic retreatment procedure, especially designed the NiTi rotary instruments were developed. In this study, the instruments especially developed for retreatment were used, such as the D-RaCe System (FKG Dentaire, La Chaux-de-Fonds, Switzerland) and ProTaper Universal Retreatment System (PTUS) (Dentsply, Maillefer, Ballaigues, Switzerland) and also, ProFile rotary system (Dentsply Maillefer, Ballaigues, Switzerland) as a conventional system.

Scanning electron microscopy (SEM) was proved to be the adequate method of evaluation of dentin walls after root canal retreatment [1, 4, 14, 19, 22]. According to Pirani et al. [14], SEM observation is the only technique available to observe the smear layer and organic and filling debris in a retreated root canal.

The aim of this study was to evaluate the effectiveness of 3 different rotary instruments (ProFile, PTUS and D-RaCe System) in removing GP/AH Plus, or Resilon filling material from the previously *in vitro* filled root canals using SEM.

Methods

This study was conducted *in vitro* on 72 freshly extracted human lower first incisors, extracted for orthodontic reasons, or due to periodontal disease. The teeth with immature apices, the presence of external resorption, or any root damage were excluded from the experiment, as well as teeth with two canals or calcifications.

The soft tissue and calculus were removed mechanically from the root surfaces. Two longitudinal grooves of 1-mm depth were prepared with a diamond bur on the lingual and labialsurfaces of each root to facilitate vertical splitting for the SEM analysis after retreatment. After preparation of access cavity, working length was determined by a size 10 K-file (FKG, La Chaux-de-Fonds, Switzerland) 1 mm shorter than its appearance at the apical foramen.

An initial endodontic treatment was performed using the iRaCe rotary NiTi instruments (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), R1 15/.06, R2 25/.04 and R3 30/.04, using a crown-down sequence, according to the manufacturer recommendations. The irrigation protocol, maintaining patency of the root canals and use of the rotary engine motor were as described in study by Pešić et al. [23].

Before obturation, the samples were randomly divided into 6 groups of 12 specimens each. Thirty-six teeth (groups 1, 2 and 3) were filled with the GP cones (VDW, Munich, Germany) and the AH Plus® sealer (Dentsply DeTrey, Konstanz, Germany), and another 36 (groups 4, 5 and 6) with the Resilon filling material, RealSeal SE system (SybronEndo, Orange, CA, USA), both using the lateral condensation technique. The coronal surface of Resilon groups was light cured for 40 s.

A high-speed hand-piece with water cooling was used for cutting the crowns of the teeth, 14 mm apically from the working lenght to equalize the volume of the filling material in the samples as much as possible. The roots were sealed with GC Fuji II (GC Corporation, Tokyo, Japan). The quality of root canal filling was assessed using the digital radiographs taken in two different directions. The samples were stored for 21 days at 37 C and 100% humidity in an incubator (INCUCELL, MMM Group, Germany) to allow the complete setting of the sealer, as described by Pešić et al. [23]. For the purpose of objectivity, the initial treatment and retreatment procedures were performed by a single operator.

Three different rotary systems were used for retreatment: ProFile rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) in groups 1 and 4; ProTaper Universal Retreatment System (PTUS) (Dentsply Maillefer, Ballaigues,

Switzerland) in groups 2 and 5 and D-RaCe rotary system (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) in groups 3 and 6.

The protocol for each tested retreatment techniques, including the irrigation protocol and rotary engine motor handling procedure, were as described in Pešić et al. [23] study. Apical enlargement during retreatment was up to size 40 for all of these three techniques. The parameters for completion the retreatment were: no more filling material visible on the instruments, or root canal walls and smoothness of root canal walls.

Scanning electron microscopy evaluation method

After retreatment, the samples were sectioned in half using a chisel. Random halves were dehydrated in graded alcohol concentrations, dried, and then gold-sputtered (BALTEC, SCD 005 SPUTTER COATER) and observed by SEM (JEOL JSM 6460 LV with EDS device Oxford Instruments INCA; JEOL, Tokyo, Japan).

After a general survey of the root canal walls, the SEM photos of each third of the root canal were taken: at magnification of ×1000 to score the smear layer and inorganic debris at the coronal, middle, and apical thirds (Figure 1), and at ×200 to evaluate the surface profile. The images were saved digitally and individually scored blind by 2 trained operators.

In the selected SEM pictures, the absence, or presence of smear layer and filling debris was rated and scored using a predefined scale [24, 25] by an independent observer. The dentin surface profile was assessed by evaluating the presence of grooves, pits, and predentin areas, also using the predefined scale (Table 1). Each root canal was divided into 3 portions (coronal, middle, apical), and each portion was evaluated independently.

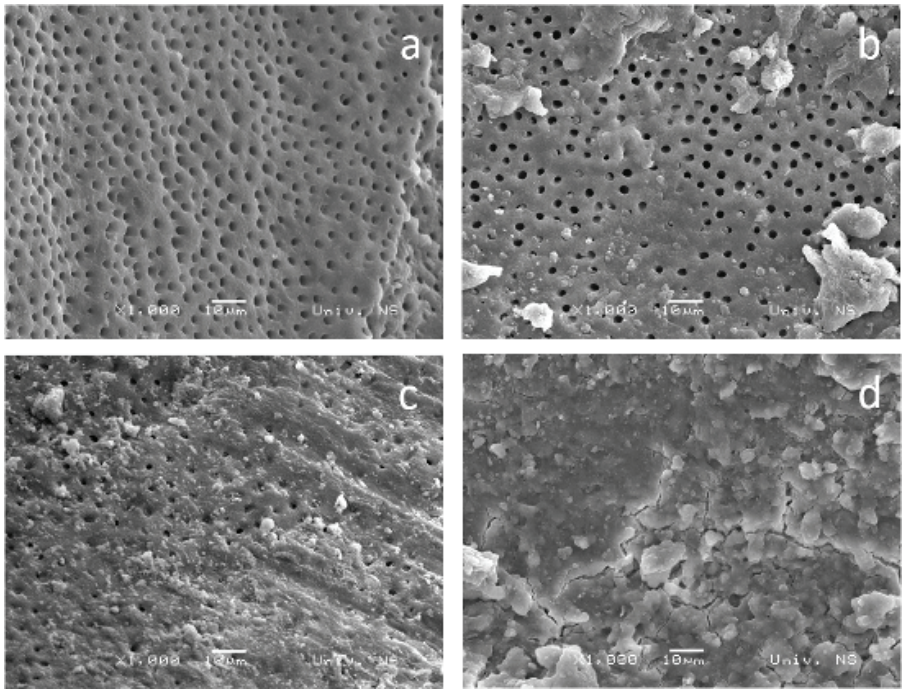

Fig. 1 – Representative scanning electron microscopy micrographs of samples from the root middle third showing presence of filling debris: a) absent filling debris, b) minimal presence of debris with less than 25% of the area, c) debris often present, d) debris present everywhere and covering dentin surface (Original magnification ×1000).

Table 1

Scale of values assigned to 3 different parameters evaluated

Parameter	Scale of values			
	1	2	3	4
Smear layer	Smear layer absent, more than 75% of tubules exposed and free from smear layer	Present in limited areas, less than 75% of tubules uncovere; tubules partially opened	Present, tubules visible in limited areas and partially closed; less than 50% of dentinal tubules visible	Homogeneous smear layer present above all dentin, dentinal tubules not visible.
Filling debris	Absent	Minimal presence (less than 25% of the area)	Often present	Present everywhere and covering dentin surface
Surface profile	Absence of irregularities	Isolated irregularities and grooves	Partially irregular, with limited non-instrumented areas	Irregular with grooves, areas of non-instrumented dentin

Statistical analysis

The Kruskal-Wallis test was used to evaluate differences between the mean values of smear layer, filling debris and surface profile of the 3 retreatment methods in the 3 different root canal portions. The level of significance was set at $p < 0.05$. Also, the pairwise comparison tests (Kruskal-Wallis) were done for each pair of retreatment methods and each pair of root canal portions, and significances were adjusted with the Bonferroni correction for multiple comparisons; a level of significance was established at $p < 0.05$.

Results

Smear layer

In the AH Plus/GP groups, the smear layer was observed in several portions of dentin root walls in all the retreatment techniques. The statistical differences ($p = 0.0454$) were found between the 3 retreatment methods only in the coronal third (Table 2). The following pairwise comparison tests, adjusted with the Bonferroni corrections, showed no significant differences between the retreatment methods (Table 2).

In the RealSeal groups, similar amounts of smear layer were observed in the groups 4, 5 and 6. No significant differences ($p > 0.05$) were found between the 3 retreatment methods (Table 2).

In all groups, the smear layer islands were found especially in the apical thirds. When comparing the presence of smear layer in the coronal, middle and apical thirds, the significant differences were found in almost every retreatment technique (Table 2), regardless of the material that was removed from the root canal. The apical third was the one with the most smear layer and the coronal one with the least.

Filling debris

In the AH Plus/GP samples, the filling debris was observed in all the retreatment groups. The greatest amount of remaining filling material was found in the apical thirds. A statistical difference ($p = 0.0038$) was found between the 3 retreatment methods only in the apical thirds (Table 2). The ProFile instruments were the least efficient in removing the obturation material. The following pairwise comparison tests adjusted with the Bonferroni corrections showed a significant difference between D-RaCe and ProFile instruments, and between PTUS and ProFile (Table 2).

Table 2

Efficacy of three different retreatment techniques in removing of two obturation materials in each third of the root

Characteristics/filling waterial	Retreatment methods			*p*
	ProFile	PTUS	D-RaCe	
Smear layer (mm), mean ± SD				
AH Plus/gutta-percha				
coronal	$1.58 \pm 0.90^{a,1}$	$1.08 \pm 0.29^{a,1}$	$1.00 \pm 0.00^{a,1}$	0.0454
middle	$1.92 \pm 1.165^{a,1}$	$1.33 \pm 0.49^{a,1,2}$	$1.25 \pm 0.451^{a,1,2}$	0.2574
apical	$2.33 \pm 1.37^{a,1}$	$1.89 \pm 0.83^{a,2}$	$1.58 \pm 0.67^{a,2}$	0.4227
p	0.3301	0.0232	0.0189	
Real Seal				
coronal	$1.00 \pm 0^{a,1}$	$1.00 \pm 0^{a,1}$	$1.00 \pm 0^{a,1}$	1.00
midlle	$1.33 \pm 0.49^{a,1,2}$	$1.17 \pm 0.39^{a,1,2}$	$1.25 \pm 0.45^{a,1,2}$	0.6491
apical	$1.67 \pm 0.78^{a,2}$	$1.58 \pm 0.79^{a,2}$	$1.50 \pm 0.52^{a,2}$	0.9186
p	0.0202	0.0327	0.0205	
Presence of filling debris, mm, mean ± SD				
AH Plus/gutta-percha				
coronal	1.67 ± 0.78^{1}	1.33 ± 0.49^{1}	1.17 ± 0.39	0.1698
midlle	$2.25 \pm 1.05^{1,2}$	1.50 ± 0.67^{1}	1.67 ± 0.49^{2}	0.1216
apical	$2.75 \pm 0.87^{a,2}$	$1.75 \pm 0.62^{bc,1}$	$1.67 \pm 065^{c,1,2}$	0.0038
p	0.0271	0.2326	0.0361	
Real Seal				
coronal	1.08 ± 0.29^{1}	1.25 ± 0.45^{1}	1.00 ± 0.00^{1}	0.1475
midlle	$1.42 \pm 0.51^{1,2}$	$1.50 \pm 0.67^{1,2}$	1.50 ± 0.52^{2}	0.9267
apical	2.00 ± 060^{2}	2.08 ± 0.79^{2}	$1.67 \pm 0.65^{2,3}$	0.2995
p	0.0009	0.0203	0.0065	
Surfice profile, mm, mean ± SD				
AH Plus/gutta-percha				
coronal	1.08 ± 0.29	1.00 ± 0.00^{1}	1.00 ± 0.00^{1}	0.3679
midlle	$1.42 \pm 0.51^{a,1}$	$1.00 \pm 0.00^{b,1,2}$	$1.17 \pm 0.39^{ab,1,2}$	0.0378
apical	1.67 ± 0.78^{1}	1.42 ± 0.51^{3}	1.50 ± 0.52^{2}	0.7575
p	0.0655	0.0035	0.0126	
Real Seal				
coronal	1.00 ± 0.00^{1}	1.08 ± 0.29^{1}	1.00 ± 0.00^{1}	0.3679
midlle	$1.08 \pm 0.29^{1,2}$	1.08 ± 0.29^{1}	$1.00 \pm 0.00^{1,2}$	0.5977
apical	1.58 ± 0.51^{3}	1.33 ± 0.49^{1}	1.42 ± 0.51^{3}	0.4650
p	0.0012	0.1738	0.0035	

Horizontally: different superscript letters indicate a significant difference between the groups in each anatomical third of the root; Vertically: different superscript number indicate a significant difference between the thirds in each instrument group. PTUS – proTAper Universal Retreatment System; SD – standard devitaion.

In the RealSeal groups, the similar amounts of filling debris were observed in the groups 4, 5 and 6. No statistical differences were found between the 3 retreatment methods (Table 2).

When comparing the presence of filling debris in different portions of the root, the apical third was the area with significantly more filling debris ($p < 0.05$) regardless of the method used for removal, except when the PTUS system was used for the removal of GP/AH Plus sealer (Table 2).

Surface profile

Concerning the tested instrumentation techniques, in the AH Plus/GP samples, the significant differences in the surface profile appearance were found in the middle thirds (Table 2). The following pairwise comparison tests adjusted with the Bonferroni corrections showed less dentin irregularities when the PTUS system was used compared to the ProFile system ($p = 0.0139$).

The 3 retreatment groups showed similar canal morphology in the samples filled with the RealSeal material, without a significant differences (Table 2).

Comparing the samples filled with the AH Plus/GP and RealSeal for each retreatment method, a significant difference was found only when the ProFile system was used, concerning the smear layer and filling debris evaluation (Table 3). In terms of surface profile irregularities, significant differences were not found. Significantly more smear layer was observed in the AH Plus/GP samples compared to the RealSeal samples in the coronal third (Table 3).

Significantly less amount of filling debris was found in the RealSeal group in the coronal, middle and apical third of the root canal, after retreatment using the ProFile system (Table 3). No significant differences were found when efficacy of other tested instrumentation techniques were compared in two tested filling materials.

Table 3
Comparison between two filling materials (RealSeal vs. AH Plus/gutta-percha) in the ProFile retreatment groups

Characteristics	*p*
Smear layer	
coronal	0.0325
middle	0.2385
apical	0.2688
Filling debris	
coronal	0.0248
middle	0.0412
apical	0.0217

Discussion

Removing all root fillings is a prerequisite of nonsurgical retreatment in order to uncover the remnants of necrotic tissue, or bacteria that might have caused the previous failure of the treatment [26]. Therefore, one of the expected root canal filling material good properties is to be easily removable.

In this study, the SEM evaluation was used because it allows the observation of smear layer morphology, presence of debris inside dentinal tubules and root canal orifices and morphology of intertubular dentin [27]. According to Pirani et al. [14], all other possible techniques (including microcomputed tomography) are insufficient to detect these features. Although the SEM evaluation may seem to have no clinical significance, it gives opportunity to detect and compare efficacy of different instruments in endodontic retreatment. The results of this study showed that all of the instrumentation techniques left filling residue inside the root canals, which is in accordance with other studies [4, 7, 8, 14, 22, 28].

The use of rotary instrumentation in removing the root canal filling material is expected to be more efficient compared to hand files. Also, the rotary instrumentation is proved to be safer compared to hand instruments concerning the amount of apically extruded debris [23], which certainly may be the cause of endodontic failure. In the present study, the PTUS and D-RaCe systems, which have been specially developed for retreatment, were used, and their efficacy was evaluated and compared to each other and to the ProFile System, which is commonly used in an initial endodontic treatment as well as in retreatment.

Comparing efficiancy of each instrumentation technique in removing two different materials, significant difference was found only when the ProFile system was used. No significant differences regarding the removal of RealSeal system, compared to AH Plus/GP were found when other tested techniques were used. This result indicates that techniques used for GP removal can also be applied to the Resilon-filled teeth.

In some studies that used SEM as a method of evaluation, the amount of remaining filling material was less in the teeth obturated with Resilon comparing to the GP/sealer [1, 4, 7]. Other studies showed that differences in the amount of remaining filling material were not statistically significant regarding to different filling methods [28]. It is questionable, however, whether all these studies are comparable with this one, because of different retreatment methods used in these investigations.

In this study, the SEM evaluation showed remnants of the filling material in all 3 analyzed root thirds, which is in accordance with other studies [4, 8, 10]. This investigation showed that the absence of filling materials on the instruments and smoothness of root canal walls was not a valid criteria to demonstrate complete removal of the filling material from the canal walls, as explained by Zarei et al. [29].

In the samples obturated with AH Plus and GP there was no significant differences between the tested instruments in smear layer removal. In terms of filling debris, the removal instruments specially designed for retreatment were more efficient than ProFile in the apical thirds of the roots. This result can be very important clinically since the microorganisms remained in the apical portion of the root canal have been considered to be the main cause of the endodontic treatment failure [30]. The fact that the PTUS and D-RaCe systems were more efficient than ProFile in the apical third of the root canal in terms of GP removal indicates that the espe-

cially designed instruments should be used in the retreatment cases. Also, specific design characteristics of the instruments may affect their efficiency during retreatment [31, 32]. The results of these studies may be related to the convex triangular cross-section of the PTUS and D-Race instruments that renders their internal mass larger than the internal mass of the ProFile instruments.

In this study, additional instruments were used during retreatment, which was proven to result in a statistically significant improvement in the root canal wall cleanliness [31]. In a Marques et al. [31] study, there was no significant difference when D-RaCe and PTUS with use of additional instruments were compared which is similar to this investigation.

In the samples obturated with the RealSeal system, all retreatment techniques showed similar performances in terms of the smear layer morphology, amount of debris and surface profile. It is in compliance with results of other studies [7, 8, 28].

The apical third of the root was the area with the greatest amount of smear layer, filling residual debris and surface profile irregularities, with grooves and zones of non-instrumented dentin regardless the filling materials, which was in accordance with other studies [7, 22]. As previous studies concluded [14, 33], the apical instrumentation with a no. 40 instrument is probably insufficient for the complete removal of the filling debris plugs present in all dentinal tubules, which was also a result of this investigation.

Conclusion

The SEM evaluation proved to be very efficient method for observing the root canal walls morphology after endodontic retreatment. None of the instrumentation technique completely removed filling material from the root canal, which implies the need for more research in this field. The apical third of the root canal was the most complicated area in terms of complete smear layer and filling debris removal and presence of surface profile irregularities regardless the filling materials. Further research should be directed towards finding solutions for better apical debridement. In the apical thirds, the instruments especially developed for retreatment were significantly more efficient in removal of AH Plus/GP than the ProFile instruments, which should be considered when performing endodontic retreatment.

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