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 retetmanu

Dragana Pešić, Irena Melih, Veljko Kolak, Ana Nikitović, Marija Lalović, Ankica Jakovljević

University Business Academy in Novi Sad, Faculty of Stomatology, Pančevo, Serbia

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 retetmanu, neophodno je omogućiti zadovoljavajuće uklanjanje opturacionog materijala i adekvatno debridmanje kanala korena zuba. Cilj ove in vivo studije bio je evaluacija efikasnosti tri sistema rotirajućih instrumenata u uklanjanju gutaperke/AH Plus silera i RealSeal SE sistema tokom retetmana, primenom skeniranje elektronske mikroskopije. Metode. Kanali koreena 72 sveže ekstrahirana donja centralna inciziva su preprijezani pravilnikom iRaCe NiTi instrumenata do veličine #30. Zubi su nasumično podijeljeni 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 tehniku hladne lateralne kondenzacije. U grupama 1 i 4 retetman 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 retetmana zubi su presečeni longitudinalno na polovine a efikasnost metoda retetmana ocenjivana je po mnoštu skenirajuće elektronske mikroskopije. Uprčevanje tri parametra (prisustvo razmaznog sloja, debris od ostataka opturacionog materijala i nesomjerno površine) obavljeno je pomoću prethodno definisane skale vrednosti. Ova tri parametra su ocenjivane u koronalnoj, 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 irregularnosti površine dentine kada je korišten ProTaper sistem u poredenju sa
Introduction

The main goal of nonsurgical root canal retreatment is to reestablish healthy periapical tissues following ineffective root canal treatment, or re-infection. 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. 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. 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.

When taken into account that Resilon has similar sealing ability as GP with the AH Plus sealer, 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.

There are many different techniques for removal of root canal filling material: solvents, hand, rotary and ultrasonic instruments, heat-carrying instruments, or a combination of these techniques. The rotary nickel-titanium (NiTi) systems are preferred in endodontic retreatment because of their safety, efficiency and speed. 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 SA, 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. According to Pirani et al., 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 labial surfaces 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.

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 length 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. 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) and also, ProFile rotary system (Dentsply Maillefer, Ballaigues, Switzerland) as a conventional system.
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. 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 (BAL-TEC, 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 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.

![Representative scanning electron microscopy micrographs of samples from the root middle third showing presence of filling debris:](image)

**Table 1**

| Parameter               | Scale of values assigned to 3 different parameters evaluated |
|-------------------------|---------------------------------------------------------------|
|                         | Scale of values                                               |
| **Smear layer**         |                                                               |
| Absent                  |                                                                 |
| More than 75% visible   | Present in limited areas, less than 75% of tubules uncovered  |
| of smear layer          | and partially opened                                          |
| Present                 | Present, tubules visible in limited areas and partially closed; less than 50% of dentinal tubules visible |
| Homogeneous smear layer | Homogeneous smear layer present above all dentin, dentinal tubules not visible |
| **Filling debris**      |                                                               |
| Absent                  |                                                        |
| Present                 | Partially present                                             |
| Isolated irregularities | 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 |

Pešić D, et al. Vojnosanit Pregl 2019; 76(9): 880–886.
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

| Characteristics/filling material | Retreatment methods |  |  | p  |
|---------------------------------|---------------------|---|---|----|
| Smear layer (mm), mean ± SD     |                     |  |  |    |
| AH Plus/gutta-percha            |                     |  |  |    |
| coronal                         | 1.58 ± 0.90        | 1.08 ± 0.29 | 1.00 ± 0.00 | 0.0454 |
| middle                          | 1.92 ± 1.165       | 1.33 ± 0.49 | 1.25 ± 0.45 | 0.2574 |
| apical                          | 2.33 ± 1.37        | 1.89 ± 0.83 | 1.58 ± 0.67 | 0.4227 |
| p                               | 0.3301             | 0.0232     | 0.0189     |    |
| Real Seal                       |                     |  |  |    |
| coronal                         | 1.00 ± 0 ±         | 1.00 ± 0   | 1.00 ± 0   | 1.00  |
| middle                          | 1.33 ± 0.49        | 1.17 ± 0.39 | 1.25 ± 0.45 | 0.6491 |
| apical                          | 1.67 ± 0.78        | 1.58 ± 0.79 | 1.50 ± 0.52 | 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        | 1.33 ± 0.49 | 1.17 ± 0.39 | 0.1698 |
| middle                          | 2.25 ± 1.05        | 1.50 ± 0.67 | 1.67 ± 0.67 | 0.1216 |
| apical                          | 2.75 ± 0.87        | 1.75 ± 0.62 | 1.67 ± 0.65 | 0.0038 |
| p                               | 0.0271             | 0.2326     | 0.0361     |    |
| Real Seal                       |                     |  |  |    |
| coronal                         | 1.08 ± 0.29        | 1.25 ± 0.45 | 1.00 ± 0.00 | 0.1475 |
| middle                          | 1.42 ± 0.51        | 1.50 ± 0.67 | 1.50 ± 0.52 | 0.9267 |
| apical                          | 2.00 ± 0.60        | 2.08 ± 0.79 | 1.67 ± 0.65 | 0.2995 |
| p                               | 0.0009             | 0.0203     | 0.0065     |    |
| Surface profile, mm, mean ± SD |                     |  |  |    |
| AH Plus/gutta-percha            |                     |  |  |    |
| coronal                         | 1.08 ± 0.29        | 1.00 ± 0.00 | 1.00 ± 0.00 | 0.3679 |
| middle                          | 1.42 ± 0.51        | 1.00 ± 0.00 | 1.17 ± 0.39 | 0.0378 |
| apical                          | 1.67 ± 0.78        | 1.42 ± 0.51 | 1.50 ± 0.52 | 0.7575 |
| p                               | 0.0655             | 0.0035     | 0.0126     |    |
| Real Seal                       |                     |  |  |    |
| coronal                         | 1.00 ± 0.00        | 1.08 ± 0.29 | 1.00 ± 0.00 | 0.3679 |
| middle                          | 1.08 ± 0.29        | 1.08 ± 0.29 | 1.00 ± 0.00 | 0.5977 |
| apical                          | 1.58 ± 0.51        | 1.33 ± 0.49 | 1.42 ± 0.51 | 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.

Pešić D, et al. Vojnosanit Pregl 2019; 76(9): 880–886.
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 efficiency 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. 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. According to Pirani et al., 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.

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, 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 efficiency of each instrumentation technique in removing two different materials, significant differences were 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. Other studies showed that differences in the amount of remaining filling material were not statistically significant regarding to different filling methods. 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. 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.

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. 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. 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. In a Marques et al. 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. As previous studies concluded, the apical instrument 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.

**REFERENCES**

1. Iriboz E, Suzak ÖH. Comparison of ProTaper and Mtwo retreatment systems in the removal of resin-based root canal obturation materials during retreatment. Aust Endod J 2014; 40(1): 6–11.

2. Schirrmeister JF, Wroha K, Meyer KM, Altenburger MJ, Hellwig E. Efficacy of different rotary instruments for gutta-percha removal in root canal retreatment. J Endod 2006; 32(5): 469–72.

3. Shipper G, Orstavik D, Tészina FB, Trop M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 2004; 30(5): 342–7.

4. Camba RY, De Martin AS, Barros PP, Silva FM, Jacinto RC, Bueno CE. In vitro evaluation of the cleansing time and analysis of the amount of gutta-percha or Resilon remnants in the root canal walls after instrumentation for endodontic retreatment. J Endod 2007; 33(12): 1426–8.

5. Melih İ, Jakubović A, Popović M, Pešić D. Comparative evaluation of sealing ability of different obturation materials. Srp Arh Celok Lek 2010; 138(5–6): 287–91. (Serbian)

6. Marfzi K, Merade M, Phátho G, Duran-Sindreu F, Bueno R, Raig M. Efficacy of three different rotary files to remove gutta-percha and Resilon from root canals. Int Endod J 2010; 43(11): 1022–8.

7. Ezzie E, Fleury A, Solomon E, Spears R, He J. Efficacy of retreatment techniques for a resin-based root canal obturation material. J Endod 2006; 32(4): 341–4.

8. Daudrénar P, Inamunshy M, Molehibi P, Mehrshargar P, Vatanpour M. Efficacy of Two Rotary NiTi Instruments in Removal of Resilon/Epiphany Obturants. Iran Endod J 2012; 7(4): 183–8.

9. Oyama KO, Siqueira EL, Santos M. In Vitro Study of Effect of Solvent on Root Canal Retreatment. Braz Dent J 2002; 13(3): 208–11.

10. Horvath SD, Altenburger MJ, Naumann M, Welkowitz M, Schirrmeister JF. Cleanliness of dentinal tubules following gutta-percha removal with and without solvents: A scanning electron microscopic study. Int Endod J 2009; 42(11): 1032–8.

11. Helmizade-Yeti D, Yılmaz A, Kızıltas-Sendur G, Aslan OS, Abbott PV. Efficacy of reciprocating and rotary systems for removing root filling material: A micro-computed tomography study. Scanning 2014; 36: 576–81.

12. Rios Mde A, Villota AM, Cunha RS, Velasco RC, De Martin AS, Katz A, et al. Efficacy of 2 reciprocating systems compared with a rotary retreatment system for gutta-percha removal. J Endod 2014; 40(4): 543–6.

13. de Melo Junior JF, Cunha RS, Bueno CE, Zulo ML. Retreatment efficacy of gutta-percha removal using a clinical microscope and ultrasonic instruments: part I-an ex vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108(1): e59–62.

14. Pirani C, Pelliccioni GA, Marchioni S, Montebugnoli L, Piana G, Prati C. Effectiveness of three different retreatment techniques in canals filled with compacted gutta-percha or Thermafil: a scanning electron microscope study. J Endod 2009; 35(10): 1433–40.

15. Après E, Ershaba A, Takeda A, Takahashi M, Sanaka M, Suda H. Removal of two types of root canal filling material using pulsed Nd: YAG laser irradiation. Photomed Laser Surg 2004; 22(6): 470–6.

16. Kelse A, Arslan H, Kamalak A, Aşkuy M, Sousa-Neto MD, Verti- tian M. Removal of filling materials from oval-shaped canals using laser irradiation: A micro-computed tomographic study. J Endod 2015; 41(2): 219–24.

17. Kelse A, Kamalak A, Keskin C, Aşkuy M, Uçun İ. The efficacy of laser, ultrasound and self-adjustable file in removing smear layer debris from oval root canals following retreatment: A scanning electron microscope study. J Endod 2016; 42(3): 104–11.

18. Rödig T, Hausdörfer T, Konietschke F, Dullin C, Hahn W, Hülsmann M. Efficacy of D-RaCe and ProTaper Universal Retreatment NiTi instruments and hand files in removing gutta-percha from curved root canals - a micro-computed tomography study. Int Endod J 2012; 45(6): 580–9.

19. Bernardes RA, Duarte MA, Viana RR, Alkaidy MP, Vasconcelos BC, Brunento CM. Comparison of three retreatment techniques with ultrasonic activation in flattened canals using micro-computed tomography and scanning electron microscopy. Int Endod J 2015. doi: 10.1111/iej.12522.
20. Rödig T, Reicherts P, Konietzchke F, Dullin G, Hahn W, Hüslmann M. Efficacy of reciprocating and rotary NiTi instruments for retreatment of curved root canals assessed by micro-CT. Int Endod J 2014; 47(10): 942–8.

21. Zuolo AS, Meli JE, Cantba RF, Zuolo ML, Bueno CE. Efficacy of reciprocating and rotary techniques for removing filling material during root canal retreatment. Int Endod J 2013; 46(10): 947–53.

22. Summa F, Cammarota G, Ploitiis G, Grande NM, Panmeijer CH. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. J Endod 2008; 34(4): 466–9.

23. Pešić D, Meli I, Kolak V, Nikitović A, Jakovljević A. Evaluation of apically extruded debris during removal of gutta-percha and resilon using different instrumentation techniques. Vojnosanit Pregl 2018; 75(1): 56–61.

24. Foschi F, Nucci C, Montebugnoli L, Marchionni S, Beschi L, Malagnino VA, et al. SEM evaluation of canal wall dentine following use of Mrwo and ProTaper NiTi rotary instruments. Int Endod J 2004; 37(12): 832–9.

25. Prati C, Foschi F, Nucci C, Montebugnoli L, Marchionni S. Appearance of the root canal walls after preparation with NiTi rotary instruments: A comparative SEM investigation. Clin Oral Invest 2004; 8(2): 102–10.

26. Simsek N, Almogigü F, Koets A, Budet ET, Er K. 3D analysis of D-RaCe and self-adjusting file in removing filling material from curved root canals instrumented and filled with different techniques. ScientificWorldJournal 2014; 2014: 836513.

27. Torabinejad M, Handsides R, Khadem A-A, Bakland LK. Clinical implications of the smear layer in endodontics: A review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002; 94(6): 658–66.

28. Ferrell G, Mehls GD, Pérez F. The efficacy of R-Endo rotary NiTi and stainless-steel hand instruments to remove gutta-percha and Resilon. Int Endod J 2010; 43(2): 135–41.

29. Zarei M, Shadrani F, Vatanpour M. Comparison between gutta-percha and Resilon retreatment. J Oral Sci 2009; 51(2): 181–5.

30. Nair PN, Sjögren U, Key G, Sundqvist G. Therapy-resistant foreign body giant cell granuloma at the periphery of a root-filled human tooth. J Endod 1990; 16(12): 589–95.

31. Marques SB, Baratto-Filho F, Leonardi DP, Henrique BA, Volpato L, Branco BF. Effectiveness of ProTaper, D-RaCe, and Mrwo retreatment files with and without supplementary instruments in the removal of root canal filling material. Int Endod J 2012; 45(10): 927–32.

32. Bramante CM, Fidelis NS, Assumpção TS, Bernardinho N, Garcia RB, Bramante AS, et al. Heat release, time required, and cleaning ability of MTwo R and ProTaper universal retreatment systems in the removal of filling material. J Endod 2010; 36(11): 1870–3.

33. Mickel AK, Chogle S, Liddle J, Hoffaker K, Jones JF. The role of apical size determination and enlargement in the reduction of intracanal bacteria. J Endod 2007; 33(1): 21–3.

Received on September 25, 2017. Revised on December 4, 2017. Accepted on December 11, 2017. Online First December, 2017.