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Effects of two post space preparation methods and three cleaning techniques on post space cleanliness: A micro-CT evaluation

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Purpose: The aim of this study was to evaluate the cleanliness of post space walls after using two different post space preparation (PSP) and three different root canal wall cleaning techniques.

Methods: A total of 104 mandibular premolars were selected. After root canal preparation, specimens were divided into two groups (n = 52) for PSP treatment: conventional post space preparation (CPSP) and modified post space preparation (MPSP). Four subgroups (n = 13) were defined based on the cleaning method: control, self-adjusting-file (SAF), passive ultrasonic irrigation (PUI), and photon-induced photoacoustic streaming (PIPS). Micro-computed tomography (μ-CT) scans of the teeth were performed before and after the post space cleaning techniques. The remaining residue volumes were measured to calculate cleaning percentages (%).

Results: After the first μ-CT scan, there was a significant difference between CPSP and MPSP ($p< 0.05$). A higher residue volume was generated on post space walls following the MPSP technique compared with the CPSP technique ($p< 0.05$). In both PSP techniques, significant differences were observed among the irrigation procedures ($p< 0.05$). Cleaning efficiency was highest for SAF in group CPSP and PIPS in group MPSP ($p< 0.05$). Pairwise comparisons revealed a residue volume similarity between the same cleaning techniques of the PSP groups ($p> 0.05$), except for the PIPS technique ($p< 0.05$).

Conclusion: CPSP can be preferred over the MPSP in clinical practice because it removes more residues. PIPS and SAF are more effective than PUI.

Keywords: Laser, micro-CT, root canal irrigation, self-adjusting file, ultrasonic.

Introduction

Fiber posts are used to restore endodontically treated teeth with coronal loss because of caries, coronal fractures, and failed restorations (1). For resin to penetrate the dentinal tubules, the dentinal wall of the fiber post space must be cleaned effectively before fiber post cementation (2). Residues remaining after post space preparation (PSP) can block the dentin tubules and lead to leakage and debonding of the fiber post (2,3). Although several studies have evaluated the debridement of post space canal walls using different cleaning techniques, residues are routinely found on the dentinal surface (3–6). Therefore, new techniques and approaches are required for post space cleaning.

The self-adjusting-file (SAF) system (ReDent Nova, Ra'anana, Israel) can adapt to root canal configuration,

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providing root canal surface debridement with the scraping motion and continuous and simultaneous irrigation flow (7,8). Within this framework, its effectiveness in post space cleaning should be investigated. Passive ultrasonic irrigation (PUI) relies on the transmission of acoustic energy from a vibrating instrument (i.e., a file or straight wire) to the root canal irrigant (9). However, attempts to improve the push-out bond strength of fiber posts by post space cleaning using PUI do not achieve complete cleaning (10,11). Photon-induced photoacoustic streaming (PIPS) uses an Er:YAG laser (LightWalker DT, Fotona, Ljubljana, Slovenia) with a radial firing ended tapered tip (Fotona) to create acoustic shock waves that generate a secondary cavitation effect in the irrigation solution, promoting canal irrigation (12). This technique improves the efficiency of final irrigants after PSP (10).

To the best of our knowledge, no studies have compared the effectiveness of the SAF, PUI, and PIPS irrigation systems on post space cleaning by micro-computed tomography (μ-CT) imaging. Therefore, in this study, we investigated the effect of two different PSP regimes and three distinct post space cleaning techniques on removing the canal filling residues from the post space walls. Two null hypotheses were proposed:

1. There is no difference in the effectiveness of the PSP techniques in removing root canal filling residues from the post space walls.
2. There is no significant difference in the efficiencies of the irrigation cleaning protocols.

Materials and Methods

The minimum sample size was calculated by power analysis (power: 0.85, α error: 0.05, effect size: 0.36) using MINITAB software (Minitab, Inc., State College, PA, USA). The sample number obtained was 100.

Teeth Selection and Preparation

To provide numerically equal subgroups, 104 human mandibular premolar teeth were collected. The selected teeth were extracted only for periodontal or orthodontic reasons. The teeth had a single root and a canal, mature apices, root curvature between 0° and 10°, similar root lengths (21.4 ± 0.6 mm), and no cracks or fractures. In addition, selected root canals had a long to short canal diameter ratio of less than 1.5, measured at 5 mm from the apex (13); therefore, the root canals were considered round. Tissue residues and dental calculus were debrided with a periodontal curette, and the teeth were then stored in 0.1% thymol solution until experimental procedures were performed. All teeth were decoronated at the cementoenamel junction using a low-speed diamond bur under continuous water irrigation. The working length was determined by insertion of a #10-K file (Antaeos, VDW GmbH, Munich, Germany) into the canal until the file tip was just visible at the apical foramen when observed under 4× magnification, and subsequently 1 mm was subtracted from the measured length. Each root canal was instrumented with #25.06 and #40.06 Revo-S Ni–Ti rotary files (Micro-Mega, Besançon, France) driven by an X-Smart Plus endodontic motor (Dentsply Maillefer, Ballaigues, Switzerland). During the instrumentation, 2.5 mL of 5.25% sodium hypochlorite (NaOCl) was applied between each endodontic file. A 30-gauge irrigation needle (Max-i-Probe, Dentsply Sirona) was used to deliver the irrigation solutions.

After preparing and irrigating the root canals, the teeth were randomly divided into two main groups (n = 52) for PSP using different techniques: the conventional post space preparation (CPSP) technique and the modified post space preparation (MPSP) technique.

CPSP Technique

A 30-gauge irrigation needle (Max-i-Probe, Dentsply Sirona) was used to irrigate the root canals of group CPSP with 2.5 mL of 5.25% NaOCl, 2.5 mL of 17% EDTA for 1 min, and then 2.5 mL distilled water. After drying with paper point cones, all canals were filled with β-phase gutta-percha cones (DiaDent, Cheongju, Korea) and AH Plus root canal sealer (Dentsply Detrey GmbH, Konstanz, Germany) by the lateral compaction technique. Teeth were stored at 37°C and 95% humidity for 72 h. Afterward, the post spaces were prepared using a size #3 Largo drill (Angelus, Londrina, PR, Brazil), leaving 4 mm of the intact root canal filling in the apical thirds of the root canals.

MPSP Technique

In group MPSP, apart from the 4-mm apical part of the root canal, post spaces were prepared using a size #3 Largo drill (Angelus) after the root canal preparations. The canals were irrigated as described for group CPSP. After drying the canals with paper point cones, the apical 4-mm of each canal was filled with a #40.06 α-phase gutta-percha cone (VDW Dental, Munich, Germany) and AH Plus canal sealer according to the single cone technique. The gutta-percha was cut at 0.5 mm above the base level of the post space using a Dia-Pen device (DiaDent) and slightly compacted vertically into the apical root canal with the tip of the Dia-Pen. Thus, a 4-mm healthy root canal filling was obtained in the apical thirds of the root canals. The

teeth were stored at 37°C and 95% humidity for 72 h to allow complete setting of the sealer.

The First µ-CT Scan

All 104 teeth were embedded in acrylic resin. Scanning was conducted using a µ-CT device (SkyScan 1272, Brüker, Kontich, Belgium) under the following settings: 10 µm isotropic resolution (image pixel size), 80 kV X-ray tube voltages, 125 µA anode current, 180° rotation around the vertical axis, and 0.6° step rotation. Images were transferred to CTAn software (SkyScan, Aartselaar, Belgium) for densitometric and morphometric measurements, allowing calculation of the volume (mm^3) of the residues remaining along the post space walls.

Post Space Cleaning Techniques

In both PSP groups, four subgroups (n = 13) were defined by the cleaning technique used: Control, SAF, PUI, and PIPS. A single operator performed all root canal preparations, filling steps, PSPs, and post space cleaning. A total of 15 mL irrigation solution was used in all subgroups.

Control: Created post spaces were manually irrigated with 15 mL distilled water using a 30-gauge irrigation needle placed in the post space and moved ~3 mm with up-and-down motion in the root canal.

SAF: The size 2.0 mm SAF instrument (ReDent Nova) was used at 5000 vibrations per minute with an amplitude of 0.4 mm at the full length of post space. For simultaneous irrigation, the VATEA peristaltic irrigation pump (ReDent Nova) was connected to the SAF instrument, and the irrigant flow rate was set to 5 mL/min. Post spaces were cleaned with 5 mL of 5.25% NaOCl for 1 min and then 5 mL of 17% EDTA for 1 min. Finally, post spaces were irrigated with 5 mL distilled water using a 30-gauge irrigation needle (Max-i-Probe, Dentsply Sirona) placed in the post space and moved ~3 mm with up-and-down motion in the root canal.

PUI: Post spaces were irrigated with 5 mL of 5.25% NaOCl for 1 min and then with 5 mL of 17% EDTA for 1 min using a PUI tip (ESI Endo Soft Instruments, EMS, Le Sentier, Switzerland) connected to the ultrasonic device (EMS) at 40-kHz power setting. The PUI tip was placed into the post space and used without touching the post space walls. Finally, post spaces were irrigated with 5 mL distilled water as described for the SAF system.

PIPS: Post spaces were irrigated with 5 mL of 5.25% NaOCl for 1 min and then with 5 mL of 17% EDTA for 1 min using the quartz PIPS tip (Fotona) connected to the Er:YAG laser device (Fotona). The PIPS tip of diameter 600 µm and length 9 mm was placed 2 mm coronally into the root canal without water/air spray. The Er:YAG laser device was adjusted to 0.3 W, 15 Hz, and 20 mJ/pulse, as recommended by the manufacturer. Finally, post spaces were irrigated with 5 mL distilled water as described for the SAF system.

The Second µ-CT Scan

Groups CPSP and MPSP were scanned for a second time with the µ-CT device under otherwise identical conditions. The volume (mm^3) of root canal filling residues was recorded. This value was used to calculate and compare the cleaning percentage of each irrigation method in both PSP techniques:

Cleaning percentage=(Volume of residues at first scan -Volume of residues at second scan)/(Volume of residues at first scan) ×100.

Statistical Analysis

The data were analyzed ($\alpha = 0.05$) using IBM SPSS software (ver. 22.0; SPSS, Inc., Chicago, IL, USA). Nonparametric tests were used as follows because the data were not normally distributed (Shapiro–Wilk, $p< 0.05$):

The Mann–Whitney U test was used to compare the root canal filling residue volumes (mm^3) between the CPSP and MPSP groups after the first µ-CT scan.

The Kruskal–Wallis test was used to compare the cleaning efficacies of the irrigation techniques within the CPSP and MPSP groups. The Student–Newman–Keuls test was pre-

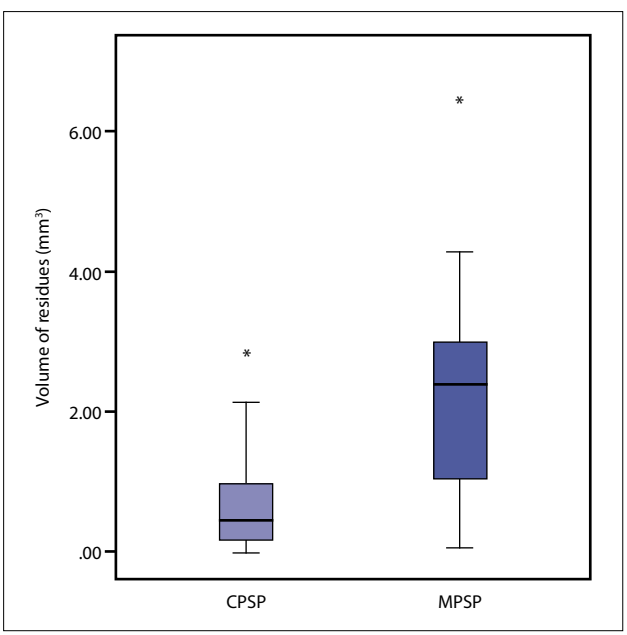

Fig. 1. Box plot graph of the volume of root canal filling residues created by CPSP and MPSP techniques.

ferred for post hoc assessments in each PSP group.

The Mann–Whitney U test was used for pairwise comparisons of the same irrigation techniques between the CPSP and MPSP groups.

Results

None of the irrigation techniques used could completely remove the root canal filling residues. The first µ-CT scan revealed that a higher residue volume (mm^3) was generated on post space walls following the MPSP technique compared with the CPSP technique ($p< 0.05$) (Fig. 1).

There were significant differences among the irrigation subgroups in both PSP techniques ($p< 0.05$). SAF showed the highest cleaning efficiency in group CPSP and PIPS in group MPSP ($p< 0.05$) (Fig. 2).

Pairwise comparisons between the same irrigation protocols of the PSP groups indicated no significant differences between the irrigation protocols ($p> 0.05$), except for the PIPS technique, which showed a higher cleaning efficiency in the MPSP group ($p< 0.05$) (Fig. 3). All descriptive statistics and significant differences are shown in Table 1.

Three-dimensional µ-CT reconstructions of one representative sample from the experimental group before and after post space cleaning are shown in Fig. 4.

Discussion

The root canal dentinal walls should be cleaned to allow the resin to penetrate the dentinal tubules (2,3,14). Therefore, in this study, we assessed whether an alternative way of creating a post space could lead to improved cleanliness of the post space dentin surfaces. In the modified technique (MPSP), it was aimed that the post space walls would not be touched by the clinician and no root canal filling residues would remain on the post space walls.

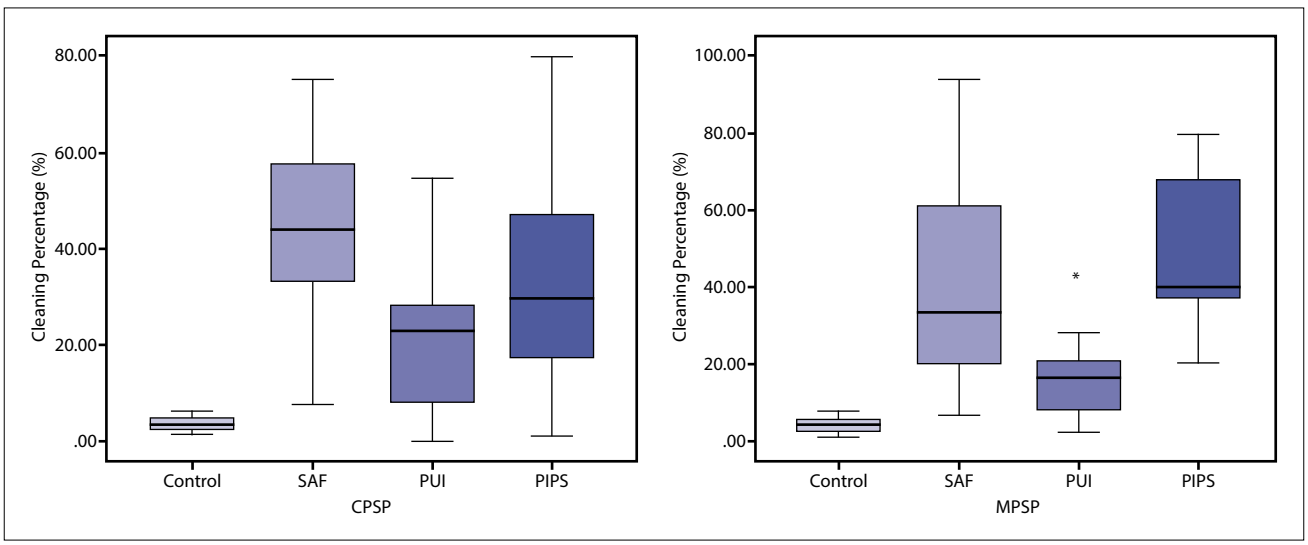

Fig. 2. Box plot graph of the effectiveness of the cleaning techniques tested in CPSP and MPSP groups.

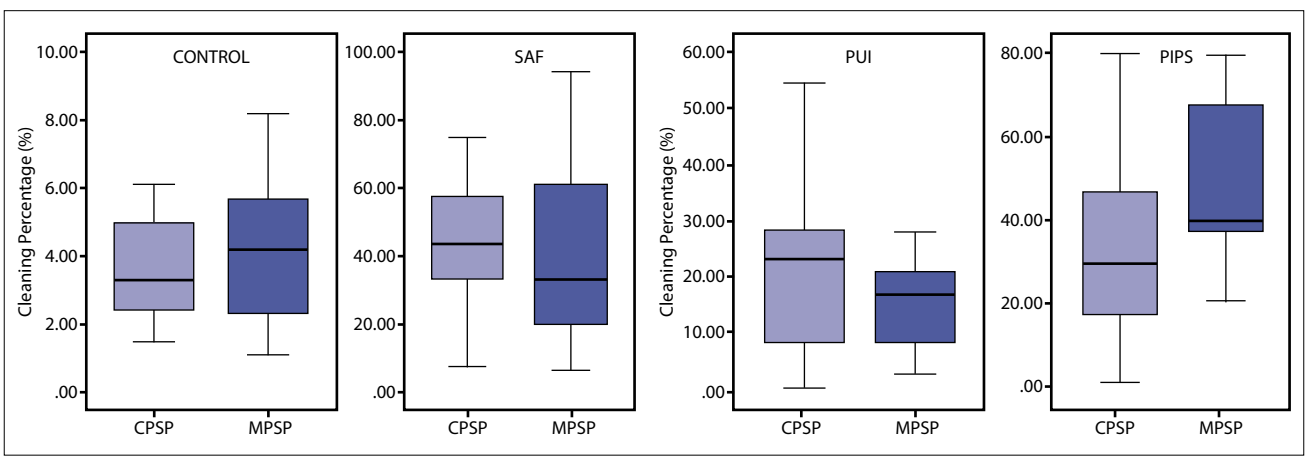

Fig. 3. Box plot graph of the pairwise comparisons between the same irrigation protocols of PSP groups.

Table 1. Median and 25%–75% quartiles of the groups and subgroups

	n	Median	25%–75% quartiles	Statistical significance (p)
CPSP (%)				
Control[a]	13	3.30	2.35–5.05	<0.05
SAF[b]	13	43.90	32.17–59.65	
PUI[c]	13	23.00	7.625–28.65	
PIPS[d]	13	29.40	15.67–47.82	
MPSP (%)				
Control[a]	13	4.20	2.10–5.87	<0.05
SAF[b]	13	33.20	19.35–61.725	
PUI[c]	13	16.60	7.12–22.02	
PIPS[e]	13	39.90	35.57–67.82	
After the first μ-CT scan (mm^3)				
CPSP[x]	52	0.46	0.17–0.99	<0.05
MPSP[t]	52	2.41	1.04–3.01	

The comparison of the first μ-CT scan values (in mm^3) is also shown. *Significantly different groups are shown with different superscript letters. CPSP: Conventional post space preparation; MPSP: Modified post space preparation.

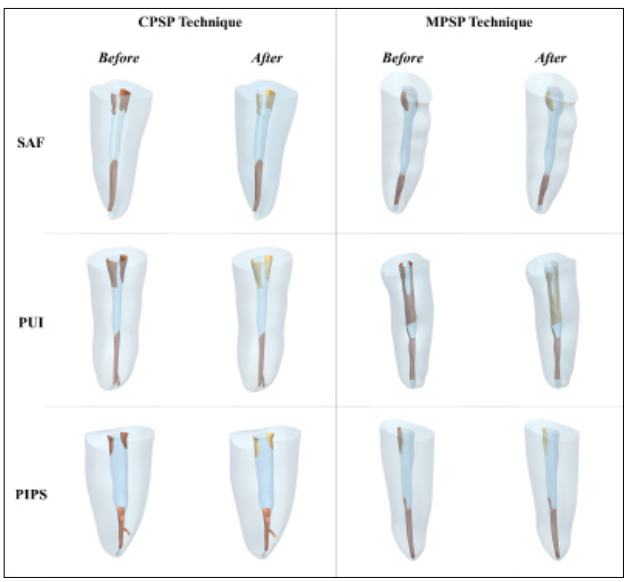

Fig. 4. Reconstructed three-dimensional μ-CT images of representative samples from each experimental group before and after post space cleaning procedures. In the prepared post spaces, the residues observed before the cleaning process are visualized in a darker color, and the residues observed after the cleaning process are visualized in a lighter color

Such a PSP technique has not been found in the literature previously; its use in this study is the first in the literature. However, the MPSP technique caused a significantly higher residue volume on the dentinal walls than CPSP. Thus, the first null hypothesis was rejected because there was a notable difference in the root canal filling residue amounts between the two PSP techniques.

PSP was performed using Largo drills (also known as Peeso reamers), which are the post drills of the Angelus Reforpost glass fiber post system. The parallel-shaped post spaces fit with the anatomical shape of these Reforpost retainers. The diameter of the size #3 Largo drill (1.10 mm) is greater than that of the finishing rotary file (#40.06) used in canal preparation in this study. It could thus be expected that PSP might effectively remove the canal filling residues in group CPSP. The Largo drill was reported to remove the root canal filling materials effectively (3). From the results, it can be interpreted that in the MPSP technique, root canal sealer-covered gutta-percha may contaminate the post space walls in an uncontrolled way during the insertion of the gutta-percha into the apical root canal third. It is also possible that some root canal sealer was transferred from the apical root canal to the post space during truncation and compaction of gutta-percha with the Dia-Pen. Furthermore, softened α-phase gutta-percha may have adhered to the canal walls.

The irrigation methods used in this study were unable to remove the residues completely. This finding is in line with previous studies (3–5,15). The SAF system demonstrated the most successful cleaning efficiency among the subgroups of the CPSP technique. SAF is often used after rotary instruments as an effective supplementary stage of root canal retreatment (16–18). Voet et al. (18) demonstrated that the supplementary use of SAF effectively decreased the residual gutta-percha-occupied areas in root canals after retreatment with rotary files. More gutta-percha residues might remain in the dentinal walls following the CPSP technique than the MPSP technique because of the lack of gutta-percha canal filling in MPSP, apart from the apical third. The scraping motion of the SAF system occurs with continuous and simultaneous NaOCl irrigation through the instrument. This mode of action might have cleaned those gutta-percha residues better than the other root canal cleaning systems. Moreover, the SAF system has two different instrument width options (1.5 and 2.0 mm). In this study, we used the SAF instrument with a 2.0 mm diameter rather than a 1.5 mm diameter for post space cleaning because it had shown greater effectiveness in large canals (17).

The PIPS technique showed the most successful cleaning efficiency among the subgroups of the MPSP technique. When Ekim and Erdemir compared the effect of various final irrigant activation protocols on the push-out bond strength of fiber posts, the highest bond strength was obtained in the PIPS laser-activated irrigation group (10). In addition, the Er:YAG laser is reported to have photothermal and photoablation mechanisms (19) and promote composite resin ablation (20). In the MPSP technique,

relatively more root canal sealer residues might remain on the post space walls due to the lack of gutta-percha canal filling, except for the apical third. Thus, it can be predicted that the Er:YAG laser caused partial melting and evaporation of the resin-based sealer used. As a result, the combination of the MPSP technique and PIPS system might have demonstrated better cleaning efficiency than the other irrigation protocols.

Microbubble formation and cavitation effects occur in the PUI technique, resulting in a continuous movement of the irrigation solution and causing shear forces that break down the root canal residues (21). There have been conflicting studies regarding the effectiveness of ultrasonic use on post space cleaning. In one study, the presence of ultrasonic activation increased the cleansing efficacy of irrigation solutions in post space walls (6), whereas in another study, no improvement was observed following additional ultrasonic irrigation with EDTA or NaOCl (2). In the current study, while the PUI system showed greater cleaning efficiency than the control groups, it had limited inşuence on the post space dentin surface than the SAF and PIPS systems in both PSP techniques. This difference may be due to the different working principles of the tested irrigation techniques. PUI acts by means of the effect of cavitation created in the liquid. PIPS produces both acoustic streaming and cavitation effects, besides chemical changes to the dentin surface, and the SAF system exerts mechanical forces and provides some root canal preparation.

Pairwise comparisons between the control subgroups of CPSP and MPSP indicated no significant difference. The fact that the control groups showed very low median values in both PSP groups (4.20% in MPSP, 3.30% in CPSP) indicates the failure of distilled water to remove root canal filling residues. This finding is consistent with the literature (3,10). Although the median values of the cleaning percentages of SAF and PUI systems were higher in group CPSP (43.90% for SAF and 23.00% for PUI) than in group MPSP (33.20% for SAF and 16.60% for PUI) in pairwise comparisons, the differences were not significant. However, the PIPS system showed a significantly higher cleaning percentage in group MPSP than in group CPSP. As mentioned earlier, the MPSP technique could result in an increased percentage of sealer residue, and a more effective cleaning has been achieved as a result of the chemical effect of the Er:YAG laser on resin-based canal sealers when compared with the other irrigation systems.

µ-CT scanning has been used to distinguish the root canal filling material from the canal walls (22). Combined with the use of three-dimensional analysis programs, µ-CT scanning permits an accurate mathematical calculation of the volume of filling residues remaining on root canal walls (16). However, it is impossible to determine the gutta-percha-to-sealer ratio of the residues by µ-CT scanning, which may be a limitation of our study.

In this study, the cleaning percentages were statistically compared, not the remaining residue volumes. The reason for this is to determine the residue cleaning efficacy of each technique. As an exception, only the volumes (in mm^3) obtained after the first µ-CT scans were used to compare the amount of residue after conventional and modified PSPs.

Conclusion

Under the conditions of this study, the CPSP technique outperformed the MPSP technique. Thus, the CPSP technique can be preferred in clinical practice. PIPS and SAF irrigation systems were more efficient than PUI. Combining CPSP with PIPS or SAF is recommended for removing post space residues.

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Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Erciyes University Clinical Research Ethics Commitee (date: 10.11.2017, protocol no: 2017/515).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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