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Is SWEEPS (Laser assisted irrigation) better than Passive Ultrasonic Irrigation and XP-Endo Finisher?-An in vitro study

Yelda Erdem Hepşenoğlu,[1] Sertan Fındıkçı,[1] Şeyda Erşahan,[1] Mete Üngör,[1] Ali Keleş,[2] Mustafa Gündoğar,[1] Melis Oya Ateş,[2] Celalettin Topbaş[3]

[1]*Department of Endodontics, İstanbul Medipol University Faculty of Dentistry, İstanbul, Türkiye*
[2]*Department of Endodontics, Bolu Abant İzzet Baysal University Faculty of Dentistry, Bolu, Türkiye*
[3]*Department of Endodontics, Sağlık Bilimleri University Faculty of Dentistry, İstanbul, Türkiye*

Purpose: The study's objective was to evaluate the efficiency of various irrigation activation methods for removing gutta-percha and sealer using Micro-CT and SEM after retreatment with rotary files.

Methods: Twenty-one permanent single-rooted teeth that were extracted and had a single canal were decoronated to a length of 16 mm. AH Plus sealer was used for obturating the root canals. Following obturation, Micro-CT scanning was carried out (S1). Another Micro-CT scan was performed following the elimination of the original filling material using ProTaper Universal retreatment files (S2). Next, each of the 21 samples was divided into three groups ($n = 7$): Group 1: XP-Endo Finisher (XPF); Group 2: Passive Ultrasonic Irrigation (PUI); Group 3: SWEEPS. Subsequent irrigation activation technique by one of each system was followed by the final Micro-CT scanning (S3). After calculating the remnant volume of the filling material, a single specimen was examined under a scanning electron microscope for every group. Statistical evaluation was accomplished utilizing the Kruskal-Wallis and Shapiro-Wilk tests.

Results: After analyzing the samples, S1 and S2 scanning results revealed no statistically significant differences among the three groups ($p > 0.05$). Furthermore, no significant difference in the final volume of residual filling material (S3) between the three groups was found statistically.

Conclusion: In summary, XPF, PUI, and SWEEPS techniques are equally efficient at removing remnant filling materials after conventional retreatments.

Keywords: Laser activated irrigation; micro-CT; passive ultrasonic irrigation; root canal retreatment; SWEEPS; XP-Endo finisher.

Introduction

Persistent microorganisms in the canal, insufficient root canal filling, and inadequate made restorations can be shown as reasons for root canal treatment (RCT) failure (1). Endodontic retreatment is seen as a successful treatment option when the RCT is unsuccessful (2). The aim of endodontic retreatment is the complete removal of gutta-percha and sealer from the canals; however, completely

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Correspondence: Sertan Fındıkçı. İstanbul Medipol University Faculty of Dentistry, İstanbul, Türkiye
Tel: +90 212 – 453 48 48 e-mail: yerdem@medipol.edu.tr
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eliminating the obturation materials from the root canal is one of the main challenges in retreatment (3). A study has shown that all methods used in endodontic retreatment leave residues on the canal walls, especially in the apical third (4). Retreatment of a tooth with complex anatomy is more difficult (5). Root canal instruments are more effective in removing material from straight, rounded canals. However, instruments may not be able to reach certain areas in oval-shaped canals (6).

Irrigation activation systems were recently utilized to overcome the difficulties encountered during root canal filling removal. One of these systems is passive ultrasonic irrigation (PUI), which comprises the ultrasonic activation of irrigation solutions. PUI transmits acoustic energy from an oscillating file to a root canal irrigant; it ensures a larger stream flow in the irrigating solution and thus greater penetration into the tubules of the canal wall (7). It can be used to remove dentinal debris, organic tissues, and calcium hydroxide from the canal (8). It is also effective in eliminating the previous root canal filling throughout the root canal retreatment (9) and removing the filling in oval canals (10). Another system is a heat-treated NiTi rotary instrument known as the XP-Endo Finisher (XPF; FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), recommended for use after root canal shaping as a final approach (FKG Dentaire 2016). During rotation, the XPF may expand its diameter up to 6 mm and is consistent with files that have a diameter of at least 25 mm. It was suggested that this instrument has a variable cross-section in order to improve its ability to touch more areas of the root canal wall and eliminate any residual bacteria following biomechanical preparation (11). According to a study, the XPF helps enhance the dispersion of irrigant in the root canal (12). Additionally, the XPF can also enhance the elimination of organic tissue, debris, smear layer, intracanal germs, and former obturation materials (13,14).

A novel laser-induced erbium: yttrium aluminum garnet (Er:YAG) mode known as Shock Wave-Enhanced Emission Photoacoustic Streaming (SWEEPS) has been developed recently. In order to enhance the cleaning and disinfection effectiveness of the Photon Induced Photoacoustic Streaming (PIPS) technique, SWEEPS was created. Its effectiveness stems from the application of two ultrashort pulses (25 µs) with low energy levels (25 mJ) into an irrigant within the root canal (15,16). Powerful shock waves and photoacoustic streams are produced by the sequence of bubbles that are timed to emerge in the irrigant as a result of the laser-liquid interaction. The secondary bubbles eventually cause the initial bubbles that are already there to collapse (16). It has been demonstrated that the SWEEPS mode has a promising future for retreating the root canal and removing smear layers and debris from complicated areas (17). In a study comparing SWEEPS and PUI, SWEEPS was found more effective in curved root canal retreatments (18). To our knowledge, no research has been conducted on how SWEEPS contributes to the root canal retreatment in oval canals. Thus, this clinical study's objective was to assess the impact of the PUI, XPF, and SWEEPS on the retreatment procedures utilizing Microcomputed tomography (Micro-CT). The null hypothesis is that SWEEPS is superior to other methods in removing remnant gutta-percha and sealer in oval canals.

Materials and Methods

The study was approved by the Institutional Ethical Committee (#E-10840098-772.02-6159). Twenty-one human teeth, newly extracted for periodontal reasons and possessing a single straight, oval-shaped root canal with an apical curvature of less than 10 degrees conforming to the standardized Vertucci type I classification, were stored in a 0.1% thymol solution. Teeth that had undergone endodontic treatment, calcification, or crack lines were not involved in the study.

Root Canal Instrumentation and Filling Procedures The selected teeth were decoronated to achieve a 16 mm length. A stainless steel #10 K-file (Dentsply Sirona Inc, Charlotte, NC) was used until the tip extruded from the apex. The indicated working length (WL) was determined to be 0.5 mm less than the mentioned length. All canals were shaped by ProTaper Universal NiTi rotary instruments (Dentsply Sirona Inc, Charlotte, NC) according to the guidelines provided by the manufacturer. Canal shaping was completed with an F3 ProTaper file. Canals were irrigated with 2 mL of 5.25% sodium hypochlorite solution (NaOCl) using a 30-gauge blunt-tip needle every time a file was changed. After finishing canal preparation, all canals were irrigated with 6 mL of 17% ethylenediaminetetraacetic acid (EDTA), followed by 6 mL saline. With sterilized paper points (Dentsply Sirona Inc, Charlotte, NC), the canals were dried. Using the lateral condensation technique, all instrumented teeth were obturated with F3 gutta-percha and AH Plus sealer (Dentsply Sirona, Charlotte, NC). Then, the cavities were sealed with Cavit G (3M ESPE, St Paul, MN). All specimens were preserved for one month in phosphate-buffered saline (PBS) to guarantee that the sealer had completely set. The samples were subsequently submitted for Micro-CT scanning (stage 1- S1).

Micro-CT Analysis Following obturation, Micro-CT scanning was carried out using a SkyScan 1172 (Bruker-Micro-CT, Kontich, Belgium). It scanned all specimens at 100 kV, 100 µA, 180° rotations with a step of 0.6°, and an exposure time of 2200 ms. Using an 11 MP camera, slices with a resolution of 2,000 × 1,330 and a pixel size of 9 µm were generated. Following the alignment of the pulp chamber floor perpendicular to each specimen's long axis, data reconstruction was carried out using DataViewer v.1.5.4.0 software (Bruker-Micro-CT). NRecon software (v.1.10.6, Bruker-Micro-CT) was used with a beam-hardening correction of 45%, smoothing of 2, and an attenuation coefficient range of 0 and 0.06. By using this method, an image of each filling was created from the grayscale, and any voids or dentin were reduced to a simple black and white pixel composition. Regions of interest were selected for each slice to determine the filling and void volume (in mm3). Using CTAn v.1.12 software (Bruker-Micro-CT), polygonal surface representations of dentin, filling, and voids were created. They were then qualitatively evaluated using CTVol v.2.2.1 software (Bruker-Micro-CT). From the Micro-CT scans, it was not possible to distinguish between spreader tracts, gaps, and voids. As a result, any part of the root canal cavity that did not contain a filling after obturation was considered empty. Lateral canals or accessory canals were not considered. Samples were scanned at 100 kV, 100 µA, and 13.7 µm isotropic pixel size, yielding transverse cross-sections of 900–1200 per sample.

Root Canal Retreatment and Final Irrigation Protocols

Gates-Glidden drills (Dentsply Sirona Inc, Charlotte, NC) were employed to extract previous root canal fillings in the absence of chemical solvents. The gutta-percha and sealer were then removed using ProTaper Universal retreatment files (Dentsply Sirona Inc, Charlotte, NC). The D1 (ISO 30, 0.09 taper), D2 (ISO 25, 0.08 taper), and D3 (ISO 20, 0.07 taper) files were utilized at 300 rpm by torque 2. 2 mL of 5.25% NaOCl was used for irrigation after each instrument, and 5 mL of 17% EDTA solution was used for the last irrigation. The final irrigation solution had to be clear of any visible debris, the last file D3 had to reach the full WL, and no filling material could be seen covering the file flutes. These were the requirements for the completion of mechanical retreatment. After that, the samples were split into three groups of seven teeth each at random so that they could be processed. Each specimen was kept in phosphate-buffered saline until it was time for scanning.

Following the use of the retreatment files (stage 2 – S2), Micro-CT scanning was carried out. To calculate the total volume of filling material left (mm3), all specimens were scanned and divided into three sections: the coronal, middle, and apical third. After being calculated using Dolphin software (Chatsworth, California), all 21 specimens had almost equal amounts of filling material left. These samples were then randomly split into three experimental groups (n = 7) and instructed to remove the leftover filling material in accordance with their group protocol (Fig. 1, 2).

Using Additional Irrigant Activation Systems for the Final Removal of Filling Material

Group 1: PUI group

An ultrasonic device (VDW Ultra; VDW, Munich, Germany) with a frequency of 30 KHz was used to drive a non-cutting stainless steel irrisafe file (#20) (Satelec Acteon group in Merignac, France). The ultrasonic activation protocol is a 20-second activation with 2 mL of 5.25% NaOCl for each canal, 2 mm less than the working length. Total activation time was sixty seconds. For EDTA, the identical protocols were used. After that, 5 mL of saline was used. Group 2: XPF group: The XP-Endo Finisher (FKG Dentaire, size #25, taper .00) was cooled down (Endo-

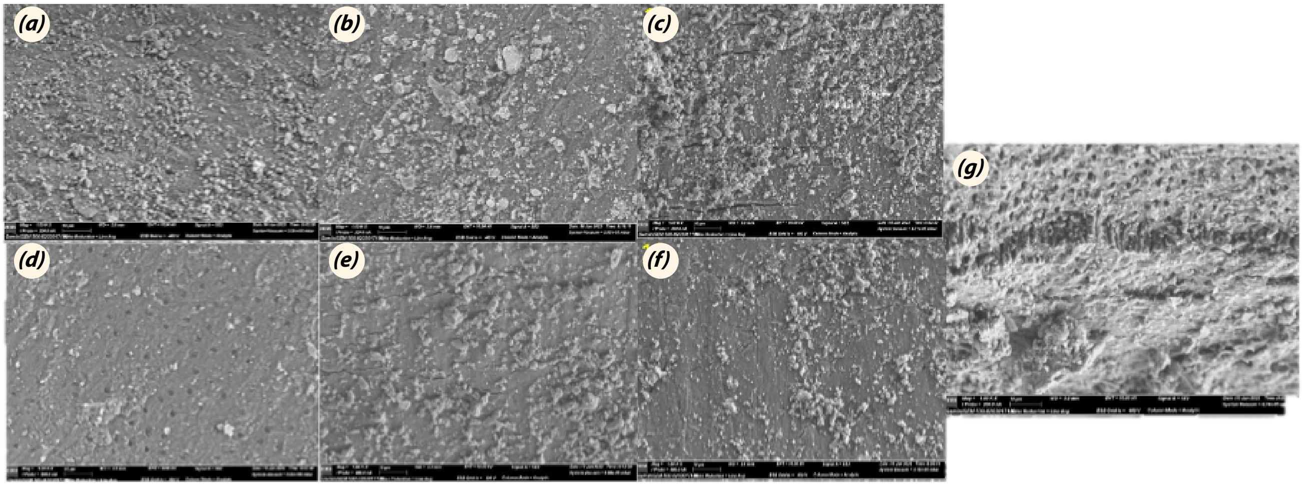

Fig. 1. Scanning electron microscopic micrographs of samples. Remnants of sealer are observable on the dentin surfaces of apical third, respectively for XPF, PUI and SWEEPS **(a, b, c)**. Remnants of sealer are less visible on the dentin surfaces of coronal third, respectively for XPF, PUI and SWEEPS **(d, e, f)**. A representative removal of sealer and open dentin tubules were visible **(g)**.

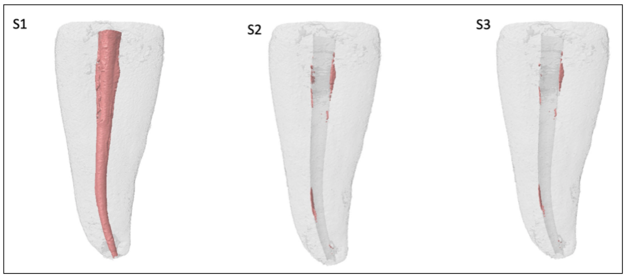

Fig. 2. Schematic diagram of the procedures done at S1, S2 and S3 steps.

Frost; Roeko, Langenau, Germany) to maintain WL. The manufacturer's instructions were followed in flushing the canals with 2.5 mL 2.5% NaOCl for 30 seconds. Then, an XPF instrument was inserted into the canal up to 1 mm short of the WL and powered by the motor at 800 rpm (1 N-cm torque) for 30 seconds (up-and-down motion in continuous rotation with 7 mm amplitude). After cleaning the canals with 2.5 mL of 2.5% NaOCl, the solution was activated using the XPF instrument for 30 seconds with the same protocol (2 × 30 seconds). Another XPF was utilized for each canal. Two milliliters of 17% EDTA was then introduced into each canal, and the XPF was again activated for 1 minute (2 × 30 seconds). Group 3: SWEEPS group: Using a 27-G irrigation needle, 0.5 mL of 1% NaOCl was injected into the canal. SWEEPS and its fiber tip (SWEEPS 600, Fotona) were used at 2940 nm wavelength (Er: YAG laser at 0.3 W, 15 Hz and 20 mJ per pulse). Both the air and water closed. The SWEEPS tip was inserted into the cavity for 3 x 30 seconds. The amount of NaOCl solution was replenished as it decreased in the cavity. For 90 seconds, the identical protocols were used with EDTA (2 mL of total irrigant volume; 3 × 30 seconds).

After the completion of the final retreatment, the process of Micro-CT imaging was carried out using three distinct experimental systems (Stage 3 – S3).

SEM Evaluation Upon Micro-CT scanning, all specimens were prepared longitudinally using a high-speed diamond bur. Also, a bone hammer was used to break root canals in half. Ethanol concentrations were used to dehydrate the samples; they were dried to the critical point. Special care was given to avoid contacting samples during this process. Lastly, the samples were sputter-coated with gold and prepared for SEM analysis. By a scanning electron microscope (SEM) (Jeol JSM 6360 LV; Jeol Technic Co, Tokyo, Japan), the amount of sealer residue in the apical, coronal, and middle thirds of each sample was assessed. One specimen was submitted to SEM evaluation for every group.

Power Analysis

As a result of the power analysis using the G*Power program (version 3.1.9.7), the minimum sample size for each group was determined to be n=5, with an alpha error of 0.05, a power of 0.80, and an effect size (d) of 0.9697.

Statistical Analysis

Continuous variables (mean, standard deviation, minimum, median, maximum) were described using descriptive statistics. The Shapiro-Wilk test was used to determine whether the data were normally distributed. The Kruskal-Wallis test was used to check for differences between more than two continuous variables that did not fit a normal distribution. A threshold of 0.05 was established for statistical significance. MedCalc® Statistical Software version 19.7.2 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2021) was used to conduct the analyses.

Results

The results of the statistical analysis conducted on the Micro-CT data indicated that no statistically significant change was observed in the total volume of both Stage 1 (representing the volume of initial obturation material) (p

Table 1. The mean, standard deviation, and p values of the amount of removed dentin thickness in experimental groups (%)

	Stage 2	Stage 3	Difference between S2 and S3
XP			
Mean+SD	18.2±15.2	16.2±13.9	-2±7.7
PUI			
Mean+SD	17.1±10	17.8±10.7	0.7±2
SWEEPS			
Mean+SD	28.6±15.1	31.5±17.8	2.9±4.1
Total			
Mean+SD	20.9+13.8	21.3+15.1	0.4+5.3
p	0.236	0.115	

*Kruskal-Wallis Test.

= 0.22) and Stage 2 (representing the volume of remaining initial filling material) phases (p = 0.236). The initial obturated surface area and initial remaining filling volume following mechanical file retreatment were found to be similar in all samples.

The mean percentage of the residual filling material after utilizing various irrigation methods was determined to be 16.2 ± 13.9 for XPF, 17.8 ± 10.7 for PUI, and 31.5 ± 17.8 for SWEEPS. No statistically significant difference was observed in the final remaining filling quantities when comparing different irrigation methods (p = 0.115). The analysis of the ultimate volume of residual filling material indicates that XPF, PUI, and SWEEPS exhibit similar volumes of remaining filling material (Table 1, p = 0.155).

Discussion

In this study, utilizing Micro-CT imaging, the effectiveness of XPF, PUI, and SWEEPS was compared with respect to the elimination of remnants throughout the retreatment of teeth with oval root canals. Conventional irrigation using a syringe and needle may have limited penetration into the dentinal tubules (19). Consequently, the irrigation activation methods were chosen with the notion that a flushing action is necessary for eliminating remnants from the root canal system. The utilization of irrigation activation systems has proven widely successful in the context of retreatment and the activation of irrigants. SWEEPS (Shock Wave-Enhanced Emission Photoacoustic Streaming), which became available in 2021, uses dual laser pulses to generate a continuous flow of bubbles, producing powerful shock waves that increase acoustic streaming (20). This technique facilitates the elimination of infectious substances from hard-to-reach parts of the canal through the occurrence of shock waves and amplified light-activated acoustic streaming (21). The findings suggest that the utilization of SWEEPS can potentially enhance the efficacy of endodontic treatments by diminishing the microorganism count (22). However, more investigation is required on this topic. The goal of this research was to compare the SWEEPS procedure to XPF and PUI for removing residual filling materials. Teeth exhibiting oval-shaped canals were chosen due to the inherent challenge associated with the elimination of filling materials from such canals with retreatment files that possess round cross-sections (23-26). Because retreatment methods for removing obturation material are incapable of properly cleaning the root canal walls, mostly in the apical third, irrigant activation devices are necessary. In this investigation, ProTaper Universal retreatment files were utilized since previous researches have demonstrated that this technique removes the majority of filling material (23,27,28). The study's findings revealed that all irrigation systems (S3) lowered the volume of filling material compared to S2. After conducting a comparative analysis of various techniques for irrigation, it was found that there was no statistically important difference in the mean volume of the residual filling material among all three procedures (p = 0.155). The findings of our investigation demonstrated that the additional usage of all activation systems resulted in enhanced elimination of remaining obturation material in the coronal, middle, and apical regions. The results were comparable to those of previous studies regarding the elimination of root canal sealer. The irrigation effect of XPF-activated NaOCl was found to be superior to traditional needle irrigation. This increased effect of the XPF file may be owing to its spoon-shaped form during activation in conjunction with NaOCl irrigation that produced irrigant streaming potent enough to eliminate microorganisms from the root canal biofilm (29).

Upon evaluating the efficacy of PUI activation in retreatment, it was determined that PUI was more successful than needle irrigation and it improved the complete debridement of the root canals during retreatment in oval canals. This may be owing to its efficient acoustic streaming (30). As we found no significant difference between SWEEPS and other activation methods in the present study, we reject our null hypothesis. In addition, recent studies have found no difference in the efficacy of PUI and SWEEPS systems. However, Er:YAG laser-activated irrigation demonstrated superior outcomes compared to PUI and SWEEPS (31). In contrast, a different study evaluating the bioceramic sealer cleaning capacity of two activation systems revealed that the SWEEPS technique performed better than the PUI technique (32).

The inconsistency between the study mentioned before and our findings can be caused by the use of different sealers. In the present investigation, we utilized AH Plus resin-based sealer, which is regarded as the gold standard material (33,34). SWEEPS was more efficient than PUI in the elimination of filling residues from curved root canals, according to another study (18). This analysis included oval-shaped root canals, which may clarify the differing results.

In other studies, the removal of the canal filling is mostly examined using SEM, radiographic imaging, metallographic optical microscope, and Micro-CT (35-37). In our study, we preferred Micro-CT because it is a fast, precise, and non-invasive technique used for three-dimensional assessment of the effectiveness of endodontic retreatment. The primary benefit of employing Micro-CT imaging lies in its ability to perform multiple scans of a single sample at various points during the retreatment process (38). Nonetheless, the utilization of Micro-CT may result in artifacts within the reconstructed images, such as beam-hardening, which can add complexity to the interpretation of the visual representation (39). On the other hand, in some samples, we combined Micro-CT with SEM. Commonly, SEM is employed to analyze dentinal tubules in terms of the existence of filling substances (40,41). However, this method does not allow for obtaining a complete three-dimensional perspective of the entire root canal system (42).

Despite our efforts to replicate clinical situations, our investigation was carried out in an in vitro setting, utilizing extracted teeth that possessed straight oval root canals. The generalizability of the findings from this study to teeth with root canal curvatures is limited since the effectiveness of irrigating devices is influenced by root curvature. As the process of decoronation is not feasible in regular practice, an important note to take into consideration is that the findings of the current study may not be generalizable. Micro-CT scans are limited to the examination of diminutive specimens, hence confining their application to the analysis of compact entities of reduced dimensions. One of our limitations was not using Nano-CT imaging which is an emerging, high-resolution cross-sectional imaging technique and represents a technical advancement of the established micro-CT technology. Further clinical investigations in this area are essential.

Conclusion

Consequently, the XPF, PUI, and SWEEPS approaches showed comparable efficacy in the removal of residual filling residues during conventional retreatment procedures. However, these techniques were unable to achieve complete removal of such remains from root canals with an oval-shaped configuration. Thus, the null hypothesis was rejected.

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Ethical Approval: The study protocol was approved by the İstanbul Medipol University Ethics Commitee (date: 13.10.2022, protocol no: E-10840098-772.02-6159).

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

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