

## Efficacy of laser-activated irrigation with the SWEEPS modality in removing calcium hydroxide from simulated internal resorption cavities

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### Abstract

**Aim:** To compare the efficacy of shockwave-enhanced emission photoacoustic streaming (SWEEPS), sonic activation with EDDY, and passive ultrasonic irrigation (PUI) in the removal of calcium hydroxide medicaments from artificial internal resorption cavities.

**Methodology:** Ninety mandibular premolars with single oval canals were prepared to size 50/0.04 and split longitudinally. Standardized cavities were prepared in the apical third of the root canal and filled with calcium hydroxide. The root halves were reassembled and divided into three groups (n = 30) according to the removal methods used. The amount of residual calcium hydroxide was evaluated using a four-grade scoring system. The differences between the groups were analyzed using the Kruskal-Wallis H test ( $p < 0.05$ ).

**Results:** SWEEPS removed significantly more calcium hydroxide than PUI ( $p < 0.003$ ) and EDDY ( $p < 0.035$ ). There was no significant difference between the EDDY and PUI groups ( $p = 1.000$ ).

**Conclusion:** None of the systems tested were able to completely remove the calcium hydroxide paste from the simulated internal resorption cavities; however, SWEEPS removed more calcium hydroxide than the EDDY and PUI techniques.

**Keywords:** Laser-activated irrigation, SWEEPS, internal resorption, calcium hydroxide, sonic activation, passive ultrasonic irrigation

## Introduction

Internal root resorption (IRR) is the progressive loss of intraradicular dentin and dentinal tubules through the activity of clastic cells triggered by the inflammatory reactions of the pulp in response to trauma or infection. Due to its slow progression, IRR is usually asymptomatic, and the affected tooth responds normally to pulp sensitivity tests and is detected during a routine dental examination (1). Orthograde root canal treatment of IRR often provides a good prognosis when the size of the IRR is limited within the dentin without any perforation (2). However, the anatomy of lesions may present difficulties during root canal preparation since root canal instruments cannot touch all walls. Therefore, it is important to explore new methods for irrigation agitation that can reach all walls of the IRR cavities and assist in the removal of granulation tissue (3, 4).

In clinical cases of IRR, calcium hydroxide is applied to root canals between appointments to maximize disinfection, stop bleeding, and necrotize remaining tissue (2, 5). The complete removal of calcium hydroxide is important since residual material impairs the accuracy and adaptability of electronic apex locators and the physical properties of root canal sealers (6-8). However, it is difficult to remove calcium hydroxide, especially in irregular root canals with IRR (6). Therefore, various methods have been presented to maximize the efficacy of calcium hydroxide removal from the root canal system.

Various activation methods are used to increase the efficacy of irrigation solutions used in root canal treatment. Passive ultrasonic irrigation (PUI) is an irrigation technique in which the irrigant is passively agitated in the canal via an ultrasonic tip inserted into the canal and passively moved up and down to the working length (WL). Previous studies have reported that PUI is more effective in removing debris from the canal surface compared to the use of a conventional irrigation syringe (9, 10). The EDDY tip (VDW GmbH, Munich, Germany) is made of a size 25.04 flexible polyamide to prevent it from cutting into the dentin and altering root canal morphology during sonic activation at high frequency (6,000 Hz). According to the manufacturer, it allows for the effective cleaning of complex root canal systems without the limitations of ultrasonic activation-activated devices (11). Previous studies have also shown that EDDY is effective in removing calcium hydroxide from root canals (3, 12, 13). However, more recently, the erbium-doped yttrium aluminum garnet (Er:YAG) laser (LightWalker AT, Fotona, Ljubljana, Slovenia) and the shockwave-enhanced emission photoacoustic streaming (SWEEPS®) novel protocol have been recommended for this purpose, and they have been suggested to have higher efficacy than the sonic, ultrasonic, and photon-induced acoustic streaming of irrigants (14). The specificity of SWEEPS is the delivery of pairs of ultrashort pulses (25  $\mu$ s) into the disinfectant liquid (15), resulting in the formation of a series of bubbles that are timed to appear in such a way that secondary bubbles lead to the

collapse of existing bubbles, producing extremely powerful shock waves and photoacoustic streaming (16). The increased cleaning efficacy with the laser activation of the irrigant is attributed to the formation of small bubbles and waves with the high absorption of erbium laser pulses into water (14). SWEEPS works similarly to photon-initiated photoacoustic streaming (PIPS), however the method of action is different in that SWEEPS sends pulse pairs into the liquid. SWEEPS amplification of pressure waves was stronger than typical PIPS irrigation, which generated a single Er:YAG pulse (15). A fiberglass tip is placed in the access cavity to create vapor bubbles that progress into the root canal without causing any changes to the canal architecture. Cavitation and photoacoustic streaming of the irrigant result from their collapse (15). There are only a few studies comparing the efficacy of SWEEPS to different irrigation activation techniques in the removal of calcium hydroxide from root canals, and their results suggest that SWEEPS is more effective (17, 18).

To the best of our knowledge, there are no reports comparing the efficacy of the SWEEPS technology and the EDDY tip in removing calcium hydroxide from simulated IRR cavities. Therefore, this study aimed to compare the efficacy of the SWEEPS, EDDY, and PUI techniques used in irrigation activation for the removal of calcium hydroxide from simulated IRR cavities. The null hypothesis was that there was no difference between the irrigation activation techniques in terms of their efficacy in removing calcium hydroxide from simulated IRR cavities.

## Materials and Methods

This study was approved by the Medipol University Institutional Ethics Committee (Date: 21.03.2023, approval number: 250). A power calculation was made based on a previous study (19) (G\*Power 3.1.7 software, Heinrich Heine University, Düsseldorf, Germany) and revealed that a total of 12 samples were required per group at 95% confidence (1- $\alpha$ ), 99.1% test power (1- $\beta$ ), and  $f = 0.819$  effect size. Therefore, a total of 90 mandibular premolar teeth (30 per group) were included in the study.

The crowns of the teeth were removed with a diamond saw (Isomet; Buehler, Düsseldorf, Germany) under water cooling to standardize the root length to  $13 \pm 1$  mm. The canals were instrumented with a #10 K-file to ensure foraminal patency, and the WLs were measured by subtracting 1 mm from this measurement by inserting a #15 K-file (Dentsply-Maillefer, Ballaigues, Switzerland) until visible in the apical foramen. Root canals were prepared with a Reciproc R50 instrument (VDW GmbH, Munich, Germany) under copious irrigation with a 5.25% NaOCl solution administered using a 30-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA). After the mechanical preparation was completed, the root canals were rinsed with 2 mL of distilled water,

2.5 mL of 17% EDTA solution, and 2 mL of distilled water in that order, and dried with paper points.

All samples were fixed in Eppendorf tubes by modifying them with impression silicone (Optosil, Hanau, Germany) according to a previously described methodology (4). After the removal of the samples from the impression material, grooves were made on the buccal and lingual surfaces using a water-cooled diamond bur, and the teeth were separated along their long axes in the buccolingual direction using a hammer and a small chisel. The root length was determined, and the middle third area was limited to ensure simulation of resorption in the same region in both tooth segments. Then, standard artificial internal resorption cavities (0.8 mm in depth and 1.6 mm in diameter) were prepared using a round bur in the root canal dentin of the two halves of each tooth, 5 mm above the root apex. After 37% phosphoric acid (Dia-Etch; DiaDent, Seoul, Korea) was applied to the cavity surfaces for 30 seconds, they were washed with distilled water and dried (20). The bisected teeth were bonded using a small amount of cyanoacrylate gel adhesive (Scotch Super Glue gel; 3M, St Paul, MN, USA) and placed back in Eppendorf tubes. The root canals were filled with a paste made of calcium hydroxide powder (Kalsin; Spot Dis Deposu Inc., Istanbul, Turkey) mixed with a saline solution. Calcium hydroxide paste was placed in the canals, 2 mm from the WL, using a size 25 of Lentulo Spiral Paste Carrier (Dentsply-Maillefer, Ballaigues, Switzerland).

Two radiographs (in the mesiodistal and buccolingual directions) were taken to confirm the complete filling of the canals with the calcium hydroxide paste. The access cavities were sealed with temporary filling material (Cavit, 3M ESPE, Seefeld, Germany), and the samples were stored at 37 °C and 100% relative humidity for two weeks.

At the end of the two-week period, two layers of colored nail polish were applied to the samples, including the apical foramen, to prevent leakage of the irrigant. These procedures were performed to create a closed system, simulating the vapor lock effect (21). The samples (n = 90) were then allocated to three groups according to the irrigation protocol performed. Irrigation was undertaken using the Navitip 30-gauge syringe and needle as follows: Irrigation was performed with 2.5 mL of 5% sodium hypochlorite (NaOCl) and agitation for 20 s, with the repetition of the cycle twice more (a total of 7.5 mL of NaOCl was used). Subsequently, 2.5 mL of 17% EDTA was used for irrigation, followed by agitation for 20 s, and this cycle was also repeated twice (a total of 7.5 mL of EDTA was used). Lastly, a final wash with 5 mL of distilled water was undertaken.

Irrigant agitation performed in each group is described below.

### SWEEPS activation

The SWEEPS fiber tip (25  $\mu$ s ultra-short dual pulse mode- Auto SWEEPS mode) was inserted into the Er:YAG laser (LightWalker, Fotona, Ljubljana, Slovenia) source (2,940 nm, 20 mJ per pulse, 15 Hz, 0.3 W power, and 50

$\mu$ s pulse frequency). The SWEEPS tip placed in the access cavity was kept in a stable position, and activation was performed in SWEEPS mode.

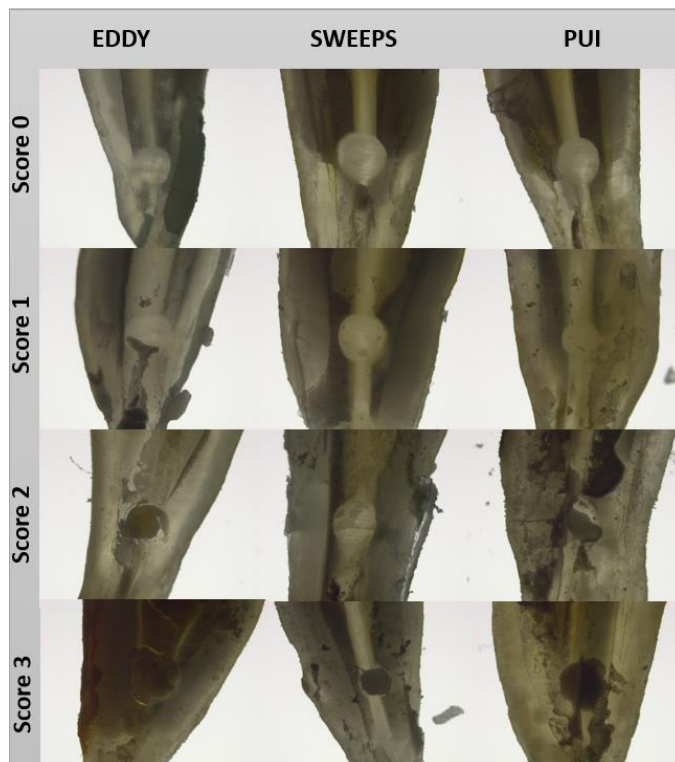
### PUI activation

The irrigation solutions were used by adapting an ultrasonic tip (IRRI S 21/25; VDW, Munich, Germany) to an ultrasonic device (VDW Ultra; VDW, Munich, Germany). The ultrasonic tip was placed 2 mm behind the WL without touching the canal walls.

### Sonic activation with EDDY

The EDDY tip was placed 2 mm behind the WL in the root canal. The tip was integrated into the Micron TA-200 air scaler (Micdent, Tokyo, Japan) and applied with 2-3-mm vertical movements.

All procedures were performed by a single operator, who is an experienced endodontist. Residual calcium hydroxide paste in the simulated IRR cavities was examined under x20 magnification with an endodontic operating microscope (Leica M320, Leica, Germany). A digital image of each root half of the samples was obtained and scored separately by two calibrated raters as follows: Score 0, empty cavity; score 1, less than half of the cavity is filled with calcium hydroxide; score 2, more than half of the cavity is filled with calcium hydroxide; and score 3 (Fig. 1), the cavity is completely filled with calcium hydroxide (19). Inter-rater agreement for each assessment was confirmed by the Kappa test. In cases of disagreement, a third opinion was sought.



**Figure 1.** Representative images of calcium hydroxide removal from different groups: Score 0, Score 1, Score 2, and Score 3.



## Statistical analysis

Analyses were performed by using SPSS software (IBM SPSS Statistics version 20, IBM Inc., Armonk, NY, USA).

The Kolmogorov-Smirnov test revealed that the data had a non-normal distribution. The Kruskal-Wallis H test was used to detect statistically significant differences between the groups. The level of significance was set at  $\alpha = 5\%$ . Inter-rater agreement was calculated using Cohen's kappa statistics.

## Results

Table 1 shows the mean, standard deviation, median, minimum, and maximum scores of each group. The kappa test results indicated no statistically significant differences in the inter-rater values for the scoring of calcium hydroxide removal in any of the groups (kappa value: 0.747). The mean values for the EDDY, SWEEPS, and PUI groups were determined to be 1.9, 1.1, and 2.2, respectively. The SWEEPS group removed significantly more calcium hydroxide than the PUI ( $p < 0.003$ ) and EDDY ( $p < 0.035$ ) groups. There was no significant difference between the EDDY and PUI groups ( $p = 1.000$ ).

**Table 1.** Descriptive statistics of the calcium hydroxide removal scores of the groups.

Activation	n	Mean $\pm$ SD	Median (Min-Max)	H	P
EDDY	30	1.9 $\pm$ 1.2	2.5 (0-3) <sup>a</sup>		
SWEEPS	30	1.1 $\pm$ 1.2	1 (0-3) <sup>b</sup>	11.678	0.003
PUI	30	2.2 $\pm$ 1.1	3 (0-3) <sup>a</sup>		

\*Kruskal-Wallis H test

The calcium hydroxide removal score was 0 in 40% of the samples in the SWEEPS group, compared to 20% in the EDDY group and 10% in the PUI group. The score was 1 in 26.7% of the samples in the SWEEPS group, 20% of those in the PUI group, and 16.7% of those in the EDDY group. The rate of score 2 was found to be 13.3% in all groups. Lastly, 56.7% of the samples in the PUI group, 50% of those in the EDDY group, and 20% of those in the SWEEPS group had a score of 3 (Table 2).

**Table 2.** Score distribution of calcium hydroxide removal among the groups [n (%)].

	EDDY	SWEEPS	PUI
Score 0	6 (20)	12 (40)	3 (10)
Score 1	5 (16.7)	8 (26.7)	6 (20)
Score 2	4 (13.3)	4 (13.3)	4 (13.3)
Score 3	15 (50)	6 (20)	17 (56.7)

## Discussion

Prior to obturation, residues of intracanal ss, such as calcium hydroxide, must be completely removed from the root canal since they can adversely affect the quality of root canal obturation (8). This study aimed to compare the efficacy of sonic activation with SWEEPS, PUI, and EDDY to remove calcium hydroxide from simulated IRR cavities in root canals. The complete removal of calcium hydroxide from the root canal was not achieved by any of these methods. This is consistent with the findings reported in the literature (3, 4, 13, 19).

PUI presents as an irrigation method that is commonly preferred by endodontists (22). PUI has been shown to have superior or similar results to other irrigation techniques in terms of the removal of calcium hydroxide (23). Consistent with these findings, in the current study, PUI had similar but less successful results than SWEEPS in the removal of calcium hydroxide from simulated IRR cavities. In previous studies, no significant difference was found between PUI and EDDY in terms of calcium hydroxide removal from root canals (12, 13), which also support our results. Sonic or ultrasonic agitation causes a streaming motion with a thin boundary layer, which then produces a large shear stress on the instrument surface and the root canal wall. Ultrasonic agitation also creates large-scale streaming, which can penetrate the irrigation zone established in the apical portion of the root canal system (24). In addition, the break-resistant flexible polyamide tip of EDDY can generate acoustic streaming by creating spiral eddies along the tip. The high efficacy of EDDY in removing calcium hydroxide can be explained by its higher operating oscillation frequency (5,000-6,000 Hz) than other sonic systems (25).

Laser activation, which has recently been frequently used, is also an effective procedure recommended to improve conventional endodontic irrigation protocols (26, 27). Laser activation has been reported to have higher efficacy than other irrigant activation methods in removing residues from root canals (28). According to the results of the current study, activation with SWEEPS technology was more successful in removing calcium hydroxide from artificial IRR cavities than PUI or EDDY. Two previous studies, in which the calcium hydroxide removal efficacy of SWEEPS was compared to that of different agitation techniques, found SWEEPS to be more effective than PUI (17, 18), which was also confirmed by our findings. Manufacturers of SWEEPS claim that the pressure waves produced by this modality result in an amplified laser beam deflection probe signal (29). In addition, in this modality, the first laser pulse is followed by a subsequent pulse after secondary bubbles have formed, leading to an accelerated collapse and pushing bubbles deeper into the root canals (30). We consider that this can explain the higher success of SWEEPS technology compared to PUI and EDDY.

This study had a similar methodology to previous studies on the removal of intracanal medicaments (4).

The standardized position and size of simulated IRR cavities allowed for the comparison of the results and presented more reliable data on the efficacy of the evaluated methods in calcium hydroxide removal. In addition, scoring based on the emptiness/filling of the cavities probably provided more reproducible results than the scoring or percentage assessment of all canal walls (13). Furthermore, the two raters in the current study were found to have a satisfactory level of agreement concerning the scoring of all groups. As another strength of the study, root canals were prepared to size 50/.04, considering that this diameter and the conic shape allowed for sufficient variation of the irrigant and provided sufficient space for the tips to activate irrigation without causing any friction. Irrigation volumes and activation times were also the same for all groups. It is clear that this design increased the internal validity of this study by reducing the evaluation bias.

## Conclusion

Within the limitations of this study, none of the methods tested were able to completely remove calcium hydroxide from simulated IRR cavities in root canals. SWEEPS was more effective than the EDDY and PUI techniques, but EDDY and PUI did not significantly differ in terms of their calcium hydroxide removal performance.

## Disclosures

**Ethical Approval:** Ethics committee approval was received for this study from Medipol University Institutional Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2023/250).

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Conception - E.E., R.N.A.; Design - E.E., S.F.; Supervision - M.G.; Materials - E.E., R.N.A.; Data Collection and/or Processing - S.F., M.Y.Ö.; Analysis and/or Interpretation - E.E., S.F.; Literature Review - E.E., S.F., M.Y.Ö.; Writer -E.E.; Critical Review - M.G.

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