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Comparison of the smear layer removal ability of four different final activation techniques after retreatment procedures: a SEM investigation

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Objective: To compare the effectiveness of IrriSafe, EndoActivator, CanalBrush, and conventional irrigation in the removal of the smear layer after retreatment procedures.

Methods: One hundred human maxillary central incisors with single and straight root canals were instrumented up to #40.02 with manual K-files and obturated using the continuous wave of condensation technique. Removal of the gutta-percha and sealer was performed using ProTaper Universal retreatment system. Then, the final activation techniques was performed using one of the following techniques: IrriSafe, EndoActivator, CanalBrush, or conventional irrigation. Teeth were split longitudinally, and specimens were observed under a scanning electron microscope. Data were analyzed with Kruskal-Wallis test.

Results: There was no statistically significant difference between the EA, CB, and CI groups in the total scores of the smear layers seen in the root canals ($p>.05$), but the IS group had statistically significantly more smear layer removed than the CI group ($p<.05$).

Conclusion: Within the limitations of this in vitro study, none of the final activation techniques applied after the retreatment procedures could totally remove the smear layer in the root canal walls.

Keywords: CanalBrush; EndoActivator; endodontics; IrriSafe; retreatment.

The elimination of vital and necrotic tissue remnants and microorganisms from the canal is one of the main objectives of endodontics.[1,2] The debris and smear layers on dentin surfaces is reported to occur because of anatomic variations in a root canals and limitations during the shaping.[3] The importance of irrigation for removing the debris and smear layer has increased in modern endodontics, and the use of systems and techniques that activate the irrigation agents has become more popular.[4,5] Among the chemical agents used in the final irrigation after the shaping process, the main ones are sodium hypochlorite (NaOCl) and ethylene-diamine-tetra-acetic-acid (EDTA).[6] Although the systems and techniques that activate the chemical irrigation agents improve the efficiency of the agents, they may be insufficient, especially in the apical 1/3 of the canal.[7,8]

The most frequently used irrigation method is conventional irrigation (CI), which is based on irrigation with positive pressure and performed with a syringe and side-vented needle. However, the effectiveness of this method in the apical 1/3 of the curved canal is debated.[8,9]

Device-assisted irrigation techniques can be exempli-

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fied by passive ultrasonic irrigation (PUI) and sonic irrigation (SI). The IrriSafe (IS; Satelec, Acteon Group, Mericnac Cedex, France), which operates with the principles of PUI and was released in recent years, has ISO #20 and #25 tip diameters. The IrriSafe activates the irrigation agent without contacting the canal walls.[10] Due to its design, it increases the micro streaming and micro cavitation in the fluids. The manufacturer asserts that the turbulence created by the IrriSafe within the canal facilitates the removal of the biofilm layer on the canal walls. After placing the IrriSafe passively to 1 mm shorter than working length (WL), the solution is activated by running it within the canal. Blank-Gonçalves et al.[11] reported that after the activation of irrigation agents in the apical 1/3 of curved root canals by using ultrasonic systems, the rate of smear layer removal only reached 75–80%. EndoActivator (EA; Dentsply Tulsa Dental Specialties, Tulsa, OK) has been designed for more efficient irrigation. This system, which utilizes sonic activation, consists of a cordless angle driver and 3 different diameter (15.02, 25.04, and 35.04) flexible polymer tips that do not cut the dentin. In a study that compared the EA to CI and examined the amount of debris in the lateral regions that were 2–4 mm away from apical, the EA was reported to statistically significantly remove the debris better.[12]

CanalBrush (CB; Roeko, Coltene/Whaledent, Langenau, Germany) is a micro brush that was manufactured for the activation of the irrigation solution within the canal. This system has a high level of flexibility, which is manufactured from polypropylene and used via rotational motion. Garip et al.[13] reported that there was not any statistically significant difference in the removal of the smear layer between CB and CI.

In the literature review, no study was found that compared the amount of the smear layer on the canal walls after using final activation techniques after retreatment procedures. The objective of the present study was to compare the effectiveness of IrriSafe, EndoActivator, CanalBrush, and conventional irrigation in the removal of the smear layer after retreatment procedures. The null hypothesis of the present study was that there would be no difference between the groups in terms of effectiveness in the removal of the smear layer.

Materials and methods

Specimen preparation

After obtaining the approval of the ethics committee, 100 upper central incisor teeth that were extracted due to periodontal reasons were used in this study. The teeth had mature apexes, contained no calcification or resorption in the canal, had no previous root canal fillings, and had roots that curved less than 5°.[14] The soft and hard tissue remnants on all the teeth were mechanically removed using a periodontal curette.

Root canal preparation

The endodontic access cavities of the teeth were prepared with a high-speed dental aerator under water-cooling. The WL was set as 1 mm shorter than the length of a #10 K-file (Dentsply Maillefer) from the apical foramen. Root canal preparation was performed by using manual K-files via the crown-down technique in the way that ensured a 40.02 apical diameter. After every file change, the canals were irrigated using 2 mL 5.25% NaOCl. In the final irrigation, after applying 2 mL 5.25% NaOCl and 2 minutes of 2 mL 17% EDTA, 5 mL of distilled water was used.

Root canal obturation

The root canal obturation was performed with a 40.02 master apical cone reaching the WL (Diadent Group International, Chongchong BukDo, Korea) and an AH Plus (Dentsply DeTrey, Konstanz, Germany) canal sealer by using the vertical compaction technique via a Calamus 3D Obturation System (Dentsply International, Johnson City, TN). Gutta-percha was removed by cutting at a point 16 mm away from the apex. After restoring the canal orifices with temporary filling material (Cavit G; 3M ESPE, GmbH, Seefeld, Germany), the teeth were kept for 14 days at 37° and 100% moisture level for canal sealer setting.

Retreatment procedures

ProTaper Universal Retreatment (Dentsply Maillefer, Ballaigues, Switzerland) files were used for the removal of the root canal filling via the crown-down technique. D1 (30.09) was used in the coronal 1/3, D2 (20.07) in the medial 1/3, and D3 (20.07) in the WL, and the removal of the canal filling was performed. Finally, the ProTaper Universal F5 file (50.05) was used in apical preparation. The procedures were continued until there was no canal sealer or gutta-percha in the samples or on the used files. During the retreatment process, a total of 20 mL 5.25% NaOCl was used with a syringe and a 30-G closed-end tip and side-vented needle (Canal Clean, Biodent, South Korea) for each sample.

Final activation procedure

The 100 retreated samples were randomly divided into 4 groups (n=25), and the procedures mentioned below were performed.

Group 1: Conventional irrigation

Final irrigation was performed with a needle. Irrigant was applied with a syringe and a 30-G closed-end tip and side-port opening needle. The irrigation needle was placed 1 mm short of the WL. A total of 6 mL irrigation solution (3 mL 5.25% NaOCl and 3 mL 17% EDTA) was used and the flow rate was completed within 1 min.

Group 2: IrriSafe

Final irrigation was performed with ultrasonic method. 3 mL of 5.25% NaOCl was flushed into the canal using a syringe and a 30-G closed-end tip and side-port opening needle and ultrasonically agitated with IrriSafe tip #20/25 (IRR20.25) placed inside the canal at WL with an up-and-down motion for 30 seconds. The canals were then flushed with 3 mL of 17% EDTA and activated using the same method for 30 seconds. The ultrasonic file was placed into the canal 1 mm short of the WL without touching the walls, enabling it to vibrate freely. A total of 6 mL irrigation solution was used and the total activation time was 1 min.

Group 3: EndoActivator

Final irrigation was performed with the EndoActivator. Three mL of 5.25% NaOCl was flushed into the canal using a syringe and a 30-G closed-end tip and side-port opening needle and activated using the EndoActivator hand-piece set at 10.000 cycles per minute, with a red (25.04) tip inserted 1 mm short of the WL for 30 seconds. The canals were then flushed with 3 mL of 17% EDTA and activated using the same method for 30 seconds. A total of 6 mL irrigation solution was used and the total activation time was 1 min.

Group 4: CanalBrush

Final irrigation was performed with CanalBrush. Three mL of 5.25% NaOCl was flushed into the canal using a syringe and a 30-G closed-end tip and side-port opening needle and activated using a small CanalBrush (25.04) operated on a slow-speed contra angle handpiece at 600 rpm for 30 seconds. The brush was used on the full WL with a gentle up-and-down motion. The canals were then flushed with 3 mL of 17% EDTA and activated using the same method for 30 seconds. A total of 6 mL irrigation solution was used and the total activation time was 1 min.

Scanning electron microscopy evaluation

To facilitate the splitting of the roots, 2 longitudinal grooves were prepared on the buccal and lingual surfaces with a diamond disc. The roots were then split into 2 halves with a chisel, and the half containing the most visible part of the apex was conserved for observation. The roots were split along the longitudinal axis into 2 halves, and both halves were dehydrated in an ascending alcohol series for 24 hours (70%–100%), sputter coated with gold, and then examined with a scanning electron microscope (JEOL, JSM-7001F, Tokyo, Japan). Scanning electron microscopic photomicrographs were taken at 1000x magnification of the coronal, middle, and apical thirds of the root canals (Figure 1).

The smear layer left on the root canal walls after the final activation procedures was scored independently by two calibrated endodontists using a score system based on Schafer and Lohmann's criteria.[15] The cleanliness of each canal was evaluated by means of the following numeric evaluation scale:

Score 1: No smear layer, orifices of the dentinal tubules patent

Score 2: Small amount of smear layer, some open dentinal tubules

Score 3: Homogeneous smear layer along almost the entire canal wall, with only very few open dentinal tubules

Score 4: The entire root canal wall covered with a homogeneous smear layer, with no open dentinal tubules

Score 5: A thick homogenous smear layer covering the entire canal wall

The percentage of inter-agreement between the raters needed to be more than 90%; if this percentage was lower than 90%, a consensus had to be reached.

Table 1. Means and standard deviations of smear layer scores of the experimental groups

Group	Apical	Middle	Coronal	Total	p
Conventional irrigation	$4.55\pm0.78^{a,x}$	$3.40\pm0.58^{a,y}$	$3.29\pm0.74^{a,y}$	3.75 ± 0.12^{a}	<.05
Canal brush	$4.01\pm0.54^{ab,xz}$	$3.21\pm0.81^{a,yz}$	$2.78\pm0.90^{ac,y}$	3.33 ± 0.12^{ab}	<.05
IrriSafe	$3.32\pm0.69^{b,x}$	$3.33\pm0.85^{ab,x}$	$2.32\pm0.94^{b,y}$	2.99 ± 0.12^{b}	<.05
EndoActivator	$3.73\pm0.97^{ab,x}$	$3.53\pm0.67^{b,x}$	$2.55\pm0.89^{bc,y}$	3.27 ± 0.13^{ab}	<.05
P value	<.05	<.05	<.05		

*Different superscripts indicate significantly difference (xyz; for rows and ab; for columns) (p<.05).

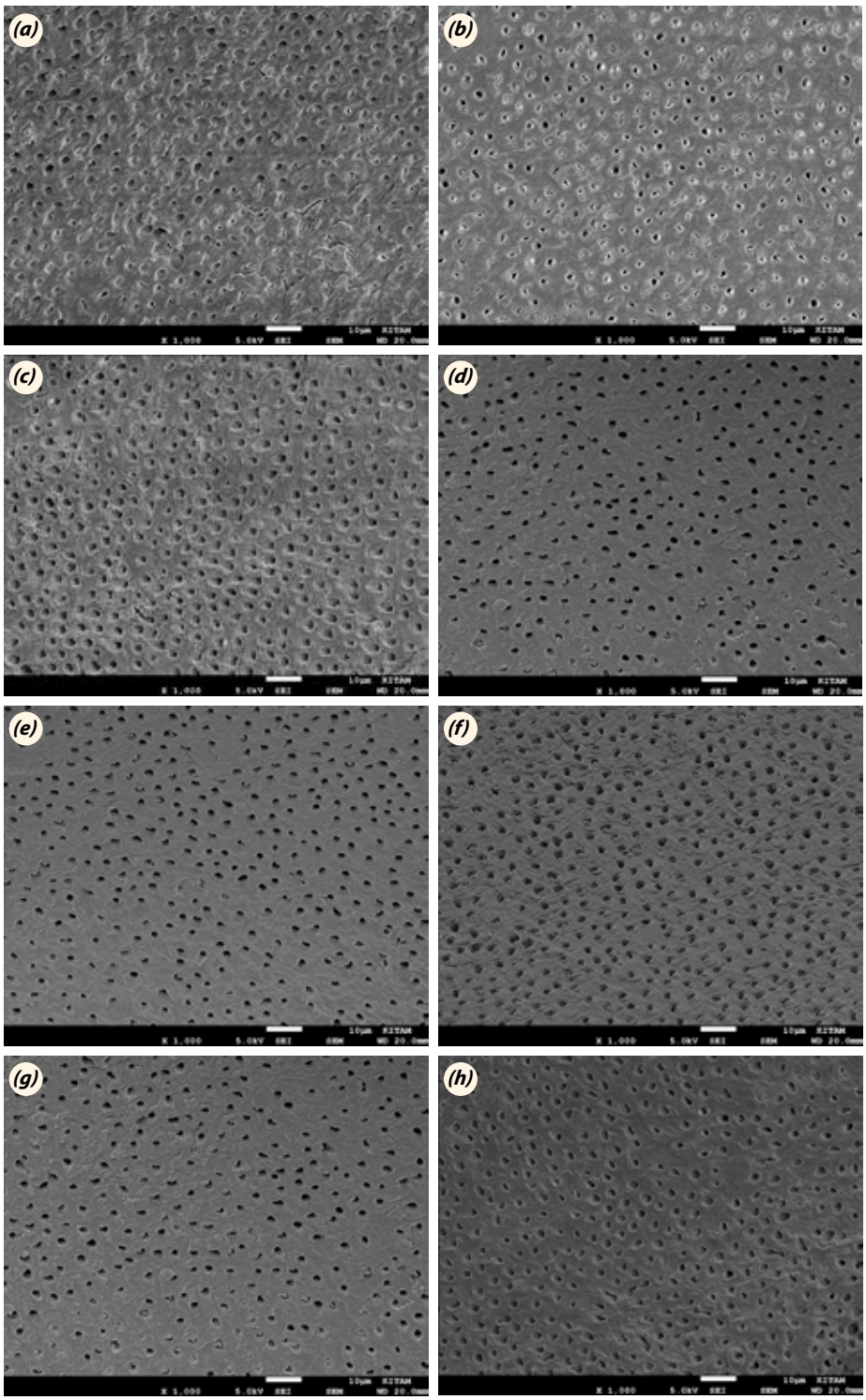

Fig. 1. Representative scanning electron microscopic images showing selected samples from the different thirds representing the different final irrigant activation techniques used after retreatment (magnification 1000x) (**a, b**: Conventional irrigation group; **c, d**: IrriSafe group; **e, f**: CanalBrush group; G-H: EndoActivator group).

Statistical analysis

Kolmogorov-Smirnov tests showed that the data were not normally distributed; therefore, Kruskal-Wallis tests were used to compare the smear layer scores and the studied parameters of different canal regions. The significance level was set at p=0.05.

Results

The 2 investigators differed in the scoring of 7 specimens; agreement was reached after discussion (Kappa >0.90, almost perfect agreement). The mean and standard deviations of the smear scores after the final activation procedures are shown in Table 1.

There was no statistically significant difference between the EA, CB, and CI groups in the total scores of the smear layers seen in the root canals (p>.05), but the IS group had statistically significantly more smear layer removed than the CI group (p<.05).

Among the apical 1/3, a statistically significantly higher level of smear layer was observed in the CI group than IS group (p<.05). Among the middle 1/3, in comparison with the CB and IS groups, a statistically significantly higher amount of smear layer was observed in the CI and EA groups (p<.05). In the coronal 1/3, a statistically significantly lower level of smear layer was observed in the IS group (p<.05).

Discussion

The removal of the smear layer that forms on the root canal walls due to the mechanical procedures used during the shaping phase is one of the most important stages of root canal treatment.[16] To remove all the organic and inorganic content, irrigation solutions are utilized.[17] For this purpose, generally, using a 1–6% NaOCl and 5–17% EDTA solution for the final irrigation is preferred. But there is no consensus on the optimal amounts of the solutions to be applied,[18] the duration of the application,[19] or how the solutions will be activated.[20] Mancini et al.[21] reported that a low volume of irrigation solution (3 mL 5.25% NaOCl and 1 mL 17% EDTA) usage was inefficient, especially in the removal of the smear layer on the apical 1/3 of the root canal. However, higher volumes (5 mL 1% NaOCl and 5 mL 17% EDTA) of the irrigation solution have been reported to be more effective in removing the smear layer.[6]

According to the results of the present study, when the efficiencies of the groups were compared, the IS group was found to have a statistically significantly higher level of the smear layer removed compared to the CI group. For this reason, the null hypothesis of the present study was rejected. During the literature review, no study was found that compared the final activation procedures, which are performed after the retreatment process, in terms of smear removal efficiency. In previous studies, the smear levels of different final activation procedures were compared after the root canal preparation procedures not after retreatment and, in parallel with the present study results, PUI was reported as more effective than other sonic and CI methods.[22–24] Researchers have attributed the success of PUI to the high speed and volume of the irrigation solution in the canal, and hence the better penetration of the irrigation solution into the dentin tubules.[25] Comparing PUI and CI, Blank-Gonçalves et al.[11] reported that PUI was more effective in the removal of the smear layer on the root canal walls, which is in accordance with the present study. However, Rödig et al.[26] compared PUI to CI in terms of the removal of the smear layer, and they found no significant difference. Moreover, Ahuja et al.[27] compared the EndoVac (Discus Dental, Culver City, CA, USA) and PUI systems from the aspect of the removal of the smear layer in curved canals, and reported that the EndoVac was more effective. Researchers have attributed the success of the EndoVac system to the fact that it allows the apical 1/3 of the canal to receive a higher volume of the irrigation solution. In parallel with the present study findings, a study that compared EA with CI reported that there was no statistically significant difference between CI and EA in terms of the removal of the smear layer from the root canal walls. Researchers have attributed this result to a lower frequency than PUI and the insufficient contribution of the irrigation solutions to cleaning efficiency.[8] In a study examining CB's efficiency, the use of CB was determined to be more effective than CI in terms of removing the smear layer.[1] Because of the results of the present study, we believe that the high-frequency turbulence effect of the device within the canal and the better penetration of the irrigation solutions into the dentin tubules might be the reason for the better smear removal efficiency of IS, which is based on the PUI principle.

According to the results of the present study, the smear scores of the samples at the apical 1/3 after the final activation procedure were found to be higher than the medial and coronal 1/3. The exposure of dentin in the root canal's regions with higher diameters to a high level of irrigation solution can be asserted as the reason of high apical smear layer score.[15,28] At the same time, the vapor lock that occurs due to air bubbles stuck in the apical 1/3 during irrigation decreases the effects of the irrigation solutions in the apical region.[29] In parallel with the findings of the present study, Ahuja et al.[27] reported that the irrigation techniques utilized for final irrigation in their study removed a higher amount of smear layer in the coronal and medial 1/3 in comparison with the apical 1/3.

Conclusion

Within the limitations of this in vitro study, none of the final activation techniques applied after the retreatment procedures could totally remove the smear layer in the

root canal walls. IrriSafe removed more smear layer than conventional irrigation. The smear layer removal efficiencies of the final activation techniques were found more efficient in the apical 1/3 than the coronal and medial 1/3 of the root canal.

Conflict of interest: None declared.

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