The Effect of Sonic Activation Tip Placement and Root Canal Irrigants On Smear Layer Removal

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ABSTRACT

Background: *Root canal preparation produces a smear layer. Smear layer removal is mandatory before obturation, which could be achieved by using root canal irrigants such as EDTA 17% and maleic acid 7%. As reported in previous research, irrigant solutions combined with sonic irrigation systems can remove the smear layer. This study aims to assess the effectiveness of an irrigation solution with a sonic activation tip placement at 2 mm and 4 mm from the working length within 30 seconds in eliminating the smear layer in the apical third of the root canal.*

Method: *120 extracted single-rooted premolars were decoronated and prepared with a reciprocating file (#25/06), then randomly divided into six groups for final irrigation. Group 1: EDTA 17% + activation tip 2 mm from working length, Group 2: Maleic acid 7% + activation tip 2 mm from working length, Group 3: Distilled water + activation tip 2 mm from working length, Group 4: EDTA 17% + activation tip 4 mm from working length, Group 5: Maleic acid 7% + activation tip 4 mm from working length, Group 6: Distilled water + activation tip 4 mm from working length. Teeth were split in half using a chisel and mallet and observed by Scanning Electron Microscope with 1000x magnification.*

Result: *Maleic acid 7% and EDTA 17% are effective in removing the smear layer when used with sonic activation and 2 mm tip placement from the working length in 30 seconds.*

Conclusion: *Sonic activation tip placement influences the cleanliness of the apical third of the root canal*

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INTRODUCTION

Successful endodontics treatment depends on root canal preparation, irrigation, and thorough disinfection to achieve three-dimensional obturation. Root canal preparation using hand or rotary instruments will produce a smear layer, which is an irregular, granular, and amorphous layer covering the root canal dentin.[1] Smear layer will disrupt intracanal medicament diffusion and endodontic sealer penetration to root canal dentin, which compromises the root canal seal.[2] Smear layer removal is mandatory before obturation, which could be achieved by using root canal irrigants. *Ethylene diamine tetraacetic acid* (EDTA) 17% is the most commonly used irrigant. EDTA chelates calcium ions in dentin, causing decalcification within 20-30 µm depth.[3] Studies reported the cytotoxic effect of EDTA 17%. Thus, research continues for more biocompatible irrigants as an alternative.[4] Maleic acid 7% was reported to have a similar effect of removing the smear layer, especially in the apical third. It was more effective than EDTA 17%.[3] *Maleic acid* has a lower cytotoxic effect than EDTA.[4]

Irrigation procedures can have an impact on the cleanliness of the root canal.[5] Manual irrigation was reported to be ineffective in smear layer and debris removal due to the complexity of root canal anatomy, particularly in the apical third.[6] The limitations of irrigation methods led to the development of machine-assisted irrigation activation tools such as passive ultrasonic irrigation (PUI), sonic irrigation, and apical negative pressure (ANP). Through acoustic streaming and cavitation, sonic irrigation systems produce hydrodynamic activation that can remove the smear layer and reduce bacterial load.[7] Sonic activation in final irrigation with a tip placement of 2 mm from the working length caused apical extrusion.[8] Extrusion of irrigation material towards the apex during endodontic treatment will increase when the irrigation procedure is performed closer to the working length.[8,9] Shear stress generated by the sonic activator tip is thought to extend 3-4 mm around the apex.[10]

Besides the activation of the irrigation material, other factors that influence the action of the irrigation material are the irrigation material contact time and concentration. Based on previous research, the optimum contact time required for the irrigation material to be in the root canal with 7% maleic acid for 1 minute was more effective in removing smear layer and debris than EDTA 17%.[11] Faster irrigation time will shorten endodontic treatment time, providing better patient comfort. The effectiveness of sonic activator tip placement has never been reported before. This study aims to assess the effectiveness of an irrigation solution with sonic activation tip placement at 2 mm and 4 mm from the working length within 30 seconds in eliminating the smear layer in the apical third of the root canal.

RESEARCH METHOD

This research obtained Ethical Clearance with number 738A/S2-Sp/KEPK/FKG/5/2024 from the Research Ethics Commission, Faculty of Dentistry, Universitas Trisakti. One hundred twenty extracted single-rooted, straight-root, and mature apex mandibular premolars were used in this study. Teeth were decoronated using a low-speed diamond disk to achieve a length of 14 mm. Root canals were shaped with a reciprocating file #25/06 (E-flex rec) on working length. After instrumentation, root canals were irrigated with 5 mL of 5% sodium hypochlorite and rinsed with 5 mL of distilled water.

Teeth were randomly divided into six groups for final irrigation.

Group 1: EDTA 17% + activation tip placement 2 mm from working length

Group 2: Maleic acid 7% + activation tip placement 2 mm from working length

Group 3: Distilled water + activation tip placement 2 mm from working length
Group 4: EDTA 17% + activation tip placement 4 mm from working length
Group 5: Maleic acid 7% + activation tip placement 4 mm from working length
Group 6: Distilled water + activation tip placement 4 mm from working length

Irrigation was conducted with 2,5 mL and sonic activation (EDDY) for 30 seconds. Root canals were rinsed with 3 mL of distilled water after final irrigation. Paper points #25/06 were used to dry root canals. Longitudinal grooves were prepared with a low-speed diamond disk on the mesial-distal aspect, ensuring the preparation did not penetrate the canal. Teeth were split in half using a chisel and a mallet. All samples were prepared to be observed by a scanning electron microscope with 1000x magnification on the apical third. Smear layer scoring was obtained from two observers by using modified Takeda criteria: score 1 = no smear layer, with all tubules cleaned and opened; score 2 = few areas covered by smear layer, with most tubules cleaned and opened; score 3 = smear layer covering almost all the surface, with few tubules opened; and score 4 = smear layer covering all the surfaces.[12]
The Kappa Cohen test verified intra-examiner and inter-examiner reliability for the SEM evaluation. The Kruskal-Wallis test, followed by Mann-Whitney as a post hoc test, was used to analyze this study's results with a confidence level of 95% (α=0.05).

RESULTS

The Kappa Cohen test for intra-examiner and inter-examiner reliability value was based on a previous study. Intra-agreement showed very strong agreement (0.97). The inter-agreement test showed strong agreement between the two observers (0.9).

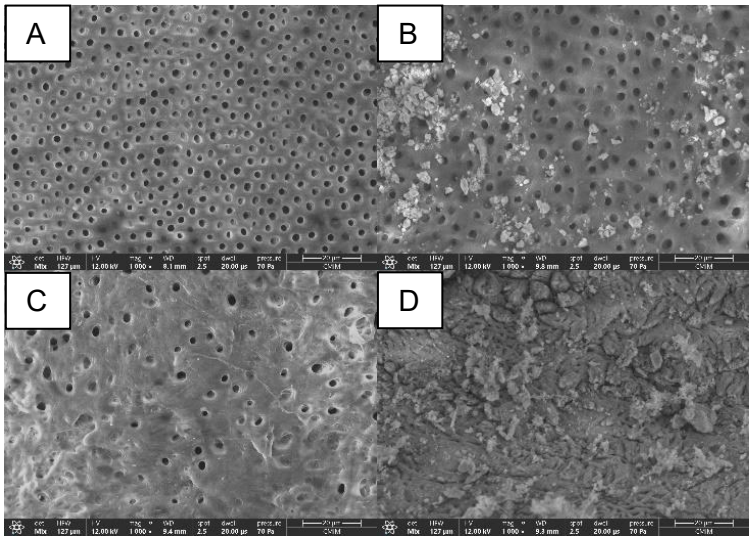

Figure 1. A representative of the scoring system was used to analyze the SEM results. (A) Score 1 (B) Score 2 (C) Score 3 (D) Score 4

Figure 1 showed a representative of the scoring system used to analyze the SEM results. Figure 1.A showed no smear layer, with all tubules cleaned and opened, figure 1.B showed few areas covered by smear layer, with most tubules cleaned and opened, figure 1.C showed smear layer covering almost all the surface, with few tubules opened, figure 1.D showed smear layer covering all the surfaces. Results in Table 1 showed

the smear layer median score. Groups 1 and Group 2 showed the lowest score, 1 ± (1-2). Group 3 and group 6 had the highest smear layer score, 4 ± (3-4). Kruskal-Wallis test showed a significant difference among the groups (p<0.001).

Table 1. Result of the median score and Kruskal-Wallis test for apical third smear layer removal

Group	Median (Min-Max)	p
Group 1	1 ± (1-2)	0.001*
Group 2	1 ± (1-2)	
Group 3	4 ± (3-4)	
Group 4	2 ± (2-3)	
Group 5	3 ± (2-3)	
Group 6	4 ± (3-4)	

*Sig. p < 0.05

Table 2. Post-hoc test Mann-Whitney test for apical third smear layer removal

	Group 2	Group 3	Group 4	Group 5	Group 6
Group 1	0.264	0.001*	0.003*	0.001*	0.001*
Group 2		0.001*	0.001*	0.001*	0.001*
Group 3			0.001*	0.001*	1.000
Group 4				0.117	0.001*
Group 5					0.001*

*Sig. p < 0.05

Mann-Whitney as a post hoc test was used to test between the groups. Groups 1 and 2; groups 3 and 6; groups 4 and 5 showed no significant difference between groups (p<0.001).

DISCUSSION

Smear layer removal in the apical third is more challenging compared to the coronal and middle thirds.[13] The smear layer in the apical third may cause apical leakage, resulting in treatment failure.[14] This study aims to assess the effectiveness of an irrigation solution with sonic activation tip placement in eliminating the smear layer in the apical third of the root canal. Irrigation solutions work as chelating agents that soften dentin by forming chelates with calcium ions, whereas acids typically demineralize dentin by breaking and weakening the bond between its organic and inorganic structures. These irrigation solution can cause changes in dentin structure and alter the ratio of calcium/phosphorus or leave residues in the form of crystal structures in the canals.[15] In figure 1B appeared a white precipitate, which could be residual crystal structures or mineral-rich deposits, this condition needs further specific research.

The group with distilled water as irrigant (control) showed a significant difference compared to EDTA 17% and maleic acid 7% either with tip placement 2 mm or 4 mm from working length. The distilled water group score shows the smear layer covering the surface, meaning this material is the least effective in removing the smear layer. There was no significant difference between the maleic acid 7% and EDTA 17% groups in the final irrigation in 30 seconds. SEM showed most group scores with no smear layer, with all tubules cleaned and opened, meaning EDTA 17% and maleic acid 17% effective in smear layer removal. A previous study showed

maleic acid 7% irrigation in 1 minute was more effective in removing the apical third smear layer compared to EDTA 17%, which is in contrast with this study.[16] 30 seconds contact time in this study showed no significant difference between the EDTA 17% and *maleic acid* 7% group, possibly as a result of sonic activation application. Sonic activation will shorten the irrigation time to 30 seconds to clean the apical third of the root canal, but it can still clean the apical third of the root canal in a longer time of 1 minute.[17,18]

Sonic activation with the EDDY system is effective in root canal cleaning.[19] Sonic activation tip 2 mm tip placement from working length showed the cleanest apical third with no significant difference either in group EDTA 17% or maleic acid 7%. Eddy system (EDDY; VDW GbmH, Munich, Germany) as a sonic activator is an air scaler-powered activation system with a frequency of 5000-6000 Hz.[20] The Distal end of the tip has the highest amplitude with the flow pattern both upward and downward. It also has a flow pattern perpendicular to the axial flow along the canal. These flow patterns will develop a push-pull mechanism, enhancing the smear layer and removing debris.[10] Sonic activation will induce irrigant solution movement, making shear stress on the root canal wall. Eddy sonic activation has a high *displacement amplitude* (350 µm).[21] *High-speed imaging* at 100.000 *frames per second* showed that the EDDY tip moves in three dimensions with orbital movement; thus, the activator tip will generate fluid dynamics inside the root canal that induces shear stress against the root canal walls.[21,22] Shear stress will have a mechanical effect on the biofilm, tissue remnants, dentin debris, or smear layer attached to the root canal wall.[23]

Maleic acid 7% and EDTA 17% sonic activation tip placement 4 mm from working length showed a significant difference compared to activation tip placement 2 mm from working length. The 4 mm tip placement is not as effective as the 2 mm tip placement from the working length; this showed that sonic activation tip placement from the working length affects the cleanliness of the apical third of the root canal. Further tip placement from the working length will produce less apical pressure, but irrigant exchange becomes less efficient, lowering wall shear stress.[24]

The Reciprocal systems were used in this study. A single file in the reciprocal system will reduce the number of instruments used during root canal preparation, but produce smear layer and debris accumulation in the apical part.[25,26] The Reciprocating file has backward motion, which compacts the debris along dentinal walls and pushes it into lateral canals and over the apex.[27] The accumulated smear layer is packed and less soluble in this system; therefore, greater shear stress is needed to eliminate the smear layer, which can be achieved by sonic activation tip placement 2 mm from the working length.[28]

CONCLUSION

Maleic acid 7% and EDTA 17% have the same potential to remove the smear layer. Sonic activation tip placement influences the cleanliness of the apical third of the root canal, with 2 mm activation tip placement from the working length being more effective than 4 mm activation tip placement from the working length. Smear layer removal can be achieved using maleic acid 7% and EDTA 17% when used with sonic activation and 2 mm tip placement from working length in 30 seconds.

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