Evaluation of the effect of SmearOFF on Smear Layer Removal and Erosion of Root Canal Dentin: An in Vitro Study

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Background and Objectives: Root canal instrumentation produces a smear layer that covers the root canal walls and may have adverse effects on endodontic treatment. SmearOFF is a new endodontic irrigant, which proposes smear layer removal and microbial elimination in one step. The aim of the present study was to evaluate and compare the effect of SmearOFF with other final irrigants regarding smear layer removal and degree of erosion from the apical third of root canals.

Methods: Forty mandibular premolar roots with single canals were selected. The teeth were randomly divided into 4 groups of 10 teeth each according to the type of final irrigants used during and after instrumentation: G1 6% NaOCl/ distilled water (control), G2 6% NaOCl/Qmix, G3 6% NaOCL/SmearOFF, G4 6% NaOCL/ 17% EDTA. All teeth were shaped by using ProTaper NEXT rotary system till X2. 6% NaOCl was applied with a 27-G side-vented syringe needle as an initial irrigant followed by the final irrigants. Endoultra ultrasonic device was used for irrigation activation. The samples were then submitted to scanning electron microscopy to evaluate the effectiveness of proposed treatments.

Results: In smear layer variables score 2 was the most occurred value for G2 (QMIX) and G3 (SmearOFF), whereas in G1 (Distilled water) and G4 (17% EDTA) are 3 and 1 respectively. For erosion variable, erosion was most evident in G4 (6% NaOCL/ 17% EDTA). There were no significant differences between G2 and G3 and also between G3 and G4 in both smear layers and erosion.

Conclusion: 17% EDTA, SmearOFF, and QMix using PUI can remove smear layer effectively from the apical third. In the future, SmearOFF may act as a promising chelating agent as well as an antimicrobial irrigant.

Keywords: SmearOFF, endodontics, irrigation, smear layer, erosion.

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Introduction

Bacteria and their products are the main cause of pulp and periapical pathology.[1] Therefore, chemomechanical procedures are necessary to control bacterial agents and gain adequate cleanliness during root canal therapy.[2] A smear layer is composed of organic and inorganic substances that may contain bacteria and bacteria by-products.[3] Smear layer forms during root canal preparation and remains adhered to the root canal walls.4 The smear layer can protect bacteria inside dentinal tubules, act as a barrier against disinfecting agents, and interfere with the adhesion of filling materials.3 It should thus be removed because of its potential for contamination and to maximize the effects of medicaments and irrigants.[5]

Presently cleaning and disinfection of the root canal system requires the use of an inorganic and organic solvent in addition to an antimicrobial agent. However, no single solution can

achieve these goals and the combined, concomitant or sequential use of two or more irrigating solutions is required. Using a combination of NaOCl and EDTA has been reported to be the most optimal irrigation protocol.[6,7]

Considerable efforts have been made on developing new irrigants and/or establishing new irrigation protocols to facilitate the eradication of microbes from the root canal system.[8] SmearOFF is a novel irrigant having synergistic combination of both EDTA and chlorhexidine. So, it not only aids in removal of smear layer but also kills bacteria in one step.[9] However, due to the anatomical complexity of the root canal system, inorganic and organic components cannot always be reached by irrigants, requiring the use of auxiliary techniques to promote an effective smear layer removal.[10]

The ultrasonic activation (US) is the activation of an endodontic instrument by an ultrasonic device placed inside the root canal. This promotes mechanical agitation of a chemical substance without instrument contact with the root canal wall.[11]

Vista Dental Products introduced the Endoultra which uses ultrasonic technology in a compact, easy to use, and cordless handheld device. It is the only cordless activator unit that generates the tip frequency to (40,000 Hz) which is required to create enough acoustical streaming and the cavitation essential to effectively disrupt biofilm, clean, reduce bacteria levels, improve penetration of irrigants, and remove vapor lock.[12]

According to the researcher's knowledge, little information is available on the ability of SmearOFF in removing canal wall smear layers; therefore the objective of the present study was to evaluate and compare its effectiveness with other final irrigants in removing the smear layer and presence of erosion from the apical third of root canals.

Methods and Materials

Forty human mandibular premolar roots with single canals were selected for use in this study. The teeth were those that have been freshly extracted for orthodontic reasons, the age between (15-25). An inclusion criterion included straight and mature roots. Exclusion criterion included teeth that exhibit the presence of micro cracks, any variation in canal anatomy, fractures, resorption, defects, previous endodontic treatment, calcification, and curved canals. The teeth were cleaned to remove soft tissues and calculus with a periodontal scaler. The teeth were stored in 4°C distilled water and used within three months.

Each tooth was decoronated at a point 12 mm from the anatomic apex, using a diamond disc.[13] After decoronation for each tooth, initially, a size 10 K-file was used to verify the patency of the canals. Working length was set by deducting 1 mm from lengths of the file when it was extruded just beyond the apical foramen.[14] The root apices were sealed with wax (Polywax toughened dental modeling wax, Bilkim company, Turkey), to prevent extrusion of irrigants through the apical foramen and simulate the clinical condition of the presence of periapical tissues during chemomechanical preparation.[15] Custom made moulds were constructed to hold the samples by using a water pipe which was cut to (23mm length and 25mm width) and heavy putty condensation silicone impression material (Protesil putty condensation silicone, Vannini Dental Industry, Italy). For standardization of the position and the orientation of canal preparation, the moulds were fixed to a table using a table clamp. The teeth were randomly divided into 4 groups of 10 teeth each according to the type of final irrigants used during and after instrumentation:

Group	Initial Irrigant	Final Rinse
1	6% NaOCl	Distilled Water
2	6% NaOCl	Qmix
3	6% NaOCl	SmearOFF
4	6% NaOCl	17% EDTA

The foramens were standardized to the size of #15 K-file (Dentsply Maillefer). All teeth were shaped by using ProTaper

NEXT nickel-titanium rotary instruments in the following sequence: X1, X2 at 300 rpm and a torque of 3 Ncm. Irrigation and recapitulation with a small-sized hand file after each sequential ProTaper NEXT instrument irrigation was performed using 2 ml 6 % NaOCl and applied with a 27-G side-vented syringe needle and the needle was placed 1 mm from the WL and then moved backward and forward where total irrigation of 4 ml was used.[16]

Then Endoultra (Vista Dental Products, USA) was used to activate the 6% NaOCl for 30 sec following each sequential file. To determine the effect of experimental and control solutions as a final rinse on the surface of instrumented root canals, the canals were treated with 4 ml of one of the following solutions: 1) Distilled water, 2) QMix 2 in 1(Dentsply), 3) SmearOFF, 4)17% EDTA. The irrigants in each group were activated by EndoUltra technique (Vista Dental Products, Racine, Wisconsin, USA) by initial irrigation using a 27-G side vented needle and disposable syringe, filling the pulp chamber with specific irrigants depending on the group (2 mL). Then, activation of the final endodontic irrigation solutions by the Endoultra ultrasonic device for 30 seconds which was performed by moving the activator tip up and down using a small (2-3 mm) vertical motion, maintaining a distance of 2mm from working length according to manufacturer's instructions. Finally, 2 mL of the final irrigant was introduced again and activated again for another 30 seconds. Therefore, a total of 4 mL of the final irrigation solution was activated for a total of 60 seconds to obtain optimal canal cleanliness.

Smear layer removal and erosion evaluation. Two longitudinal grooves were prepared on the external root surfaces by a diamond disc without reaching the canal space. Subsequently, the roots were split into two halves with a chisel. For each root, the half containing the most visible part of the canal was taken, and then it was divided into three main parts (coronal, middle, and apical) by creating two horizontal grooves using a tapered fissure carbide bur perpendicular to the canal. Then the specimens were examined by SEM photographs at ×2000 and ×5000 magnification, and photographs were taken randomly at the apical level.[17,18] SEM pictures were evaluated by three calibrated evaluators. A standard scoring system depending on Torabinejad et al.[19] was used, and all the scores for both smear layer and erosion were considered in the study as follows:

1 - No smear layer: No smear layer appears on the surface of the root canals; all dentinal tubules were clean and open.

2 - Moderate smear layer: The surface of the root canal does not show a smear layer, but the dentinal tubules consisted of debris.

3 - Heavy smear layer: The root canal surface and the dentinal tubules are covered by smear layer.

Additionally, the same evaluators scored the degree of erosion of dentinal tubules as follows:

1 - No erosion: The appearance and size of all dentinal tubules appeared normal.

2 - Moderate erosion: The peritubular dentin showed erosion.

3 - Severe erosion: Destruction of the intertubular dentin, and connection of dentinal tubules with each other.

Statistical analysis. The statistical analysis was performed using the SPSS software package (Version 23). Descriptive analysis for the sample, mean values, median, mode, and standard deviation were calculated and using Kruskal Wallis Test and Mann Whitney U Test. The level of statistical significance was set at $p < 0.05$.

Results

For the data mode technique was counted on because it displays the most repeated value. In (Table 1) one the results showed that in smear layer variables score 2 is the most occurred value for G2 (QMIX) and G3 (SmearOFF), whereas in G1 (Distilled water) and G4 (17% EDTA) are 3 and 1 respectively. On the other hand, this result is totally different for erosion variable as it can be seen that for G2, G3 and G4 a score of 2 is recorded mostly, and G1 is 1 as seen in (Table 1). So basically, according to descriptive analysis there is a difference between all groups in smear layer variable, but in Erosion the difference is only with G1.

Table 1: Descriptive statistics (Mean, Mode, Standard deviation) of four groups for Smear_Layer and Erosion.

Variables	Groups	N	Mean	Mode	Std. Deviation
Smear_Layer	G1	10	3.0000	3.00	0.00000
	G2	10	2.1000	2.00	0.31623
	G3	10	1.7000	2.00	0.48305
	G4	10	1.4000	1.00	0.51640
Erosion	G1	10	1.0000	1.00	0.00000
	G2	10	1.7000	2.00	0.67495
	G3	10	2.2000	2.00	0.42164
	G4	10	2.4000	2.00	0.51640

Table 2: Frequency distribution of four groups for Smear_Layer and Erosion.

Variables	Group	1		2		3	
		N	%	N	%	N	%
Smear_Layer	G1	0.0	0%	0.0	0%	10.0	100%
	G2	0.0	0%	9	90%	1	10%
	G3	3.0	30%	7.0	70%	0.0	0%
	G4	6.0	60%	4	40%	0	0%
Erosion	G1	10.0	100%	0.0	0%	0.0	0%
	G2	4.0	40%	5	50%	1	10%
	G3	0.0	0%	8.0	80%	2.0	20%
	G4	0.0	0%	6	60%	4	40%

In (Figure 1), G1 shows that all of the samples were scored as 3. SEM images shown in (Figure 3) are the result of 6% NaOCl/ distilled water irrigation in the apical 1/3rd where the dentin is completely covered in the smear layer. However, in G2 90% of the scores are 2. In G3 and G4, samples were scores as only 1 and 2 where 70% of the scores recorded in G3 are 2, whereas 40% are 2 in G4. In conclusion, the dissimilarity between some groups is clear. The pie charts in (Figure 2) showed that there is no change shown in G1 regarding erosion, but with different percentage the scores are occurred in other groups with the most erosion being seen in G4 (17% EDTA) where 40% of scores occurred as 3.

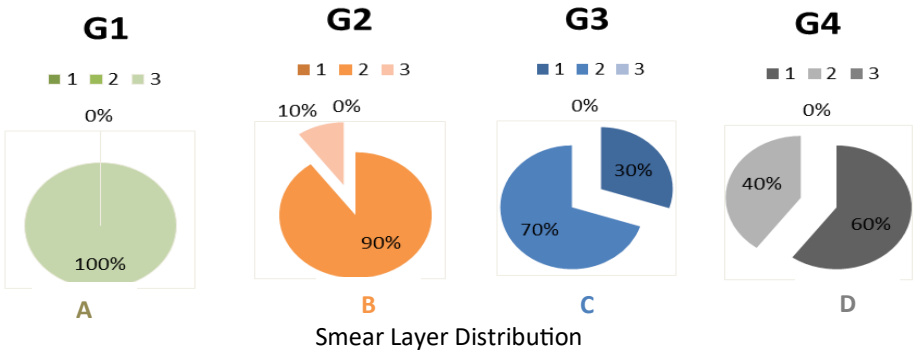

Figure 1: A-Pie chart of Smear Layer Distribution for G1 (Distilled water), B- Pie chart of Smear Layer Distribution for G2 (Qmix), C- Pie chart of Smear Layer Distribution for G3 (SmearOFF), D-Pie chart of Smear Layer Distribution for G4 (17% EDTA).

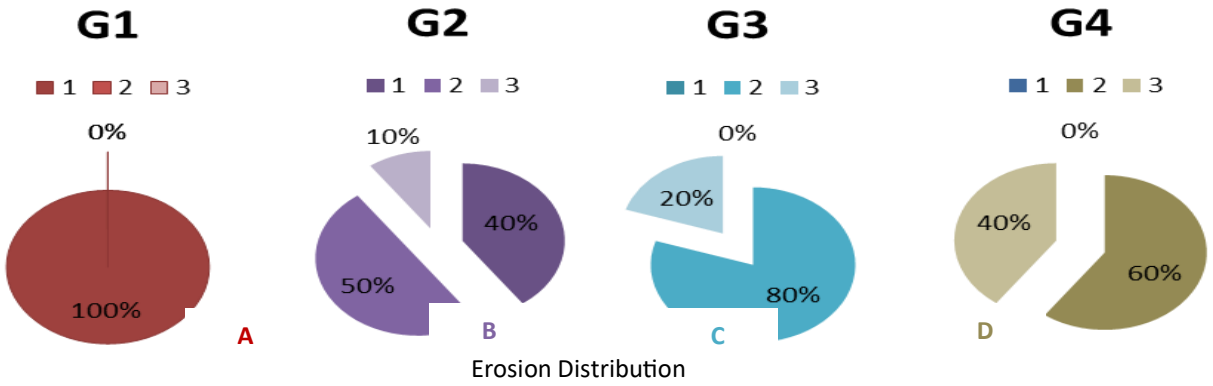

Figure 2: A-Pie chart of Erosion Distribution for G1 (Distilled water), B- Pie chart of Erosion Distribution for G2 (Qmix), C- Pie chart of Erosion Distribution for G3 (SmearOFF), D-Pie chart of Erosion Distribution for G4 (17%EDTA).

The image in (Figure 6) is the result of %6 NaOCL/%17 EDTA irrigation in the apical third where the dentinal tubules and dentin surface is clean and free of smear layer. Severe erosion is evident in (Figure 6C)., further tests were undertaken to confirm our results and it was clear that there is a statistically significant difference between the groups for both variables Smear Layer and Erosion taken into account in our study since the p-values are much less than 0.05. In (Table 3), Kruskal Wallis Test explains that groups might be the cause of this variation, yet it is not clear which group differs from the others. Hence, multiple comparisons using Mann-Whitney U Test were conducted.

Table 3: Kruskal Wallis Test for (smear layer and erosion)

	Smear Layer	Erosion
Chi-Square	28.915	24.687
df	3	3
P-Value	0.000	0.000

In (Table 4) the differences between every two pairs were clarified. In the Kruskal Test table it was seen that there was a statistically significant difference between groups. In (Table 4) results show that there are no significant differences between G2 and G3 and also between G3 and G4 in both smear layer and erosion. (Figures 4, 5, and 6) show the SEM images of smear layer removal and degree of erosion among G2, G3, and G4.

Table 4: Whitney U Test for multiple comparisons between the groups (G1, Distilled water, G2, Qmix, G3, SmearOFF, G4, 17% EDTA)

		N	Smear Layer		Erosion	
			Mann-Whitney U	Exact P-Value	Mann-Whitney U	Exact P-Value
G1	G2	10	5.000	<0.001	20.000	0.023
	G3	10	<0.001	<0.001	<0.001	<0.001
	G4	10	<0.001	<0.001	<0.001	<0.001
G2	G1	10	5.000	<0.001	20.000	0.023
	G3	10	31.500	**0.165**	29.000	**0.123**
	G4	10	18.000	0.015	23.000	0.043
G3	G1	10	<0.001	<0.001	<0.001	<0.001
	G2	10	31.500	**0.165**	29.000	**0.123**
	G4	10	35.000	**0.280**	40.000	**0.481**
G4	G1	10	<0.001	<0.001	<0.001	<0.001
	G2	10	18.000	0.015	23.000	0.043
	G3	10	35.000	**0.280**	40.000	**0.481**

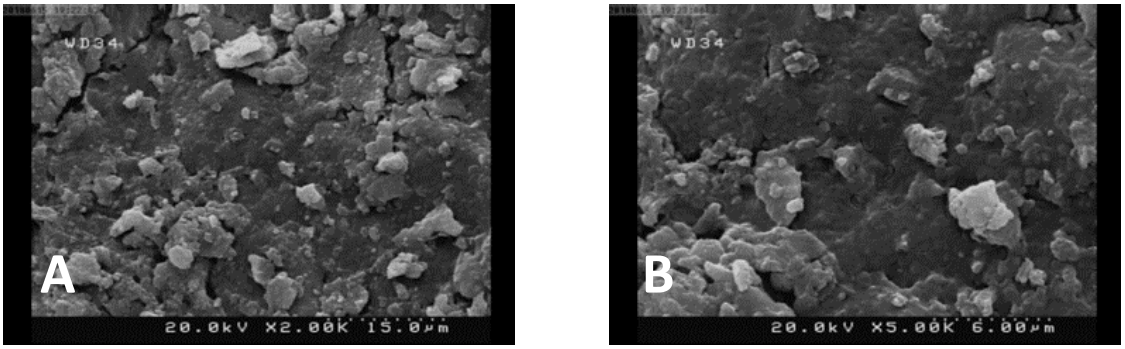

Figure 3: SEM images of NaOCl/distilled water irrigation at x2000 (A) and x5000 (B) in the apical 1/3rd. The dentin is completely covered in the smear layer.

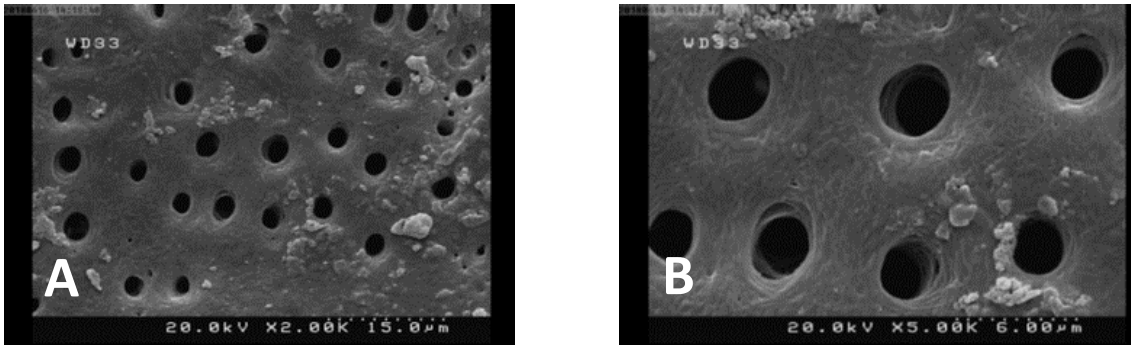

Figure 4: SEM images of NaOCl/Qmix irrigation at x2000 (A) and x5000 (B) in the apical 1/3rd. Moderate smear layer and erosion of the peritubular dentin are evident.

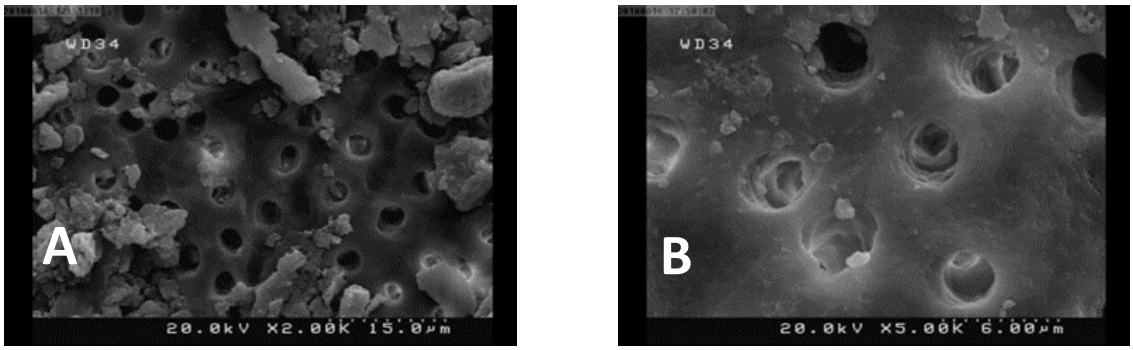

Figure 5: SEM images of NaOCl/SmearOFF irrigation at x2000 (A) and x5000 (B) in the apical 1/3rd. Moderate smear layer and erosion of the peritubular dentin are evident.

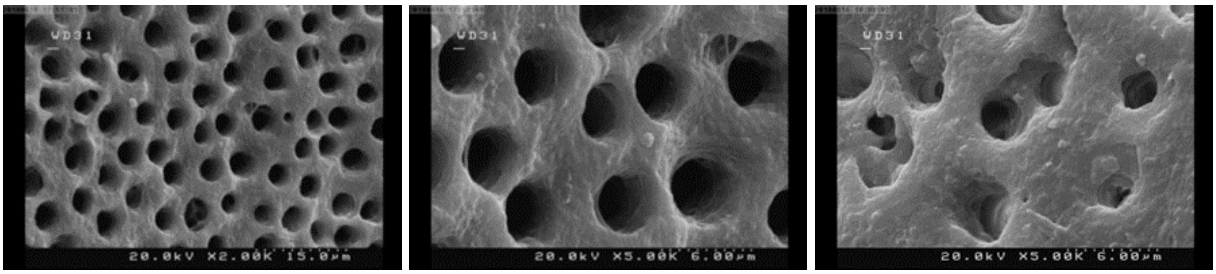

Figure 6: SEM images of NaOCl/17% EDTA irrigation at x2000 (A) and x5000 (B) in the apical 1/3rd. The surface is free of smear layer and dentinal tubules are clean and open. Severe erosion is evident using 17% EDTA (C).

Discussion

The present study evaluated and compared the effect of SmearOFF, a novel endodontic irrigant, on the degree of smear layer removal and presence of erosion at the apical third of root canals with three other different final endodontic irrigating solutions. The initial irrigant, 6% NaOCl and the four final irrigants (Distilled water, QMix, SmearOFF, and 17% EDTA) were irrigated with a 27-gauge side-vented needle and activated using Endoultra ultrasonic device.

Endoultra harnesses ultrasonic technology and is the only cordless activator unit capable of generating the tip frequency (40,000 Hz) required to create sufficient acoustical streaming and the cavitation necessary to effectively disrupt biofilm, clean, reduce bacteria levels, improve penetration of irrigants, and remove vapor lock.[12] Passive ultrasonic irrigation (PUI) has been found to be more effective than syringe irrigation in eliminating pulp tissue and dentin debris. This difference may be due to the fact that ultrasound creates a faster speed and flow volume of the irrigant in the root canal during irrigation, thus removing more debris, producing less apical packing, improved access of the chemical product to accessory canals, and even the flush effect formed by ultrasound but not manual irrigation.[20]

Descriptive analysis showed that the presence of smear layer for G1 (Distilled water) was the greatest, which is in accordance with previous studies.[21- 23] This is due to the fact that it is only used as a lubricant and has no effect on the dentin smear layer or bacteria.[24] Therefore, that is why it was used as a negative control group.

The endodontic irrigants, Qmix and SmearOFF were compared with 17% EDTA because they have also been used as a final irrigation protocol in endodontics while being gentle on the dentin. QMix (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) and SmearOFF, contain EDTA, chlorhexidine and surfactant agent in their composition and are products that can remove the smear layer and also kill bacteria in one step.[25] Ethylene diamenine tetraacetic acid (EDTA) is the most commonly used irrigant for smear layer removal. EDTA reacts with calcium ions in dentine, resulting in decalcification of the dentine within 5 min at approximate depths of 20-30μm.[26] EDTA is generally accepted as the most effective chelating agent in endodontics.[27]

The results obtained from this study showed that a combination of %6 NaOCl/ %17 EDTA performed better in SL removal than the other irrigating solutions with a score of 1 being the most occurred value followed by SmearOFF, Qmix, and distilled water respectively. These results are in agreement with studies conducted by Suchithra et al.[21] and Monea et al.[22] This is probably because the concentration of EDTA increases the effect of EDTA to a certain extent.[28] Haapasalo et al.[29] reported that high concentrations of 15-17% eliminates calcium from dentine leaving an organic matrix and efficiently removes the smear layer. The alternate use of NaOCl, a deproteinizing agent, and EDTA, a calcium -chelating agent, has been recommended for the efficient removal of the smear layer. However, there is concern that this combined irrigation regime causes inadvertent erosion of the intraradicular dentin.[19,30] In our study similar findings were obtained where erosion was more evident with the use of 17% EDTA than Qmix or SmearOFF. The drawback of using such concentration is that high concentrations cause more demineralization of the dentin leading to erosion. No erosion was evident with the use of distilled water because the canals were completely covered in smear layer and it has no eroding or adverse effect.

According to the manufacturers of QMix and SmearOFF the EDTA is present in the solutions at lower concentrations so claiming to be less aggressive on the dentin. Another reason for its gentleness may be because the only function of these products is not smearing layer removal but also that it contains Chlorhexidine to kill bacteria as well so it may affect the performance of EDTA. In addition, when irrigation is performed using these solutions a precipitate may develop when combined with NaOCl (pilot studies) and this precipitate may appear in the SEM images as a smear layer. These results can explain why less smear layer was removed in G2 (Qmix) and G3 (SmearOFF) than G4 (17% EDTA). So ba-

sically, there is some difference between all groups in smear layer variable. However, Table 4 shows that there are no significant differences between G2 (Qmix) and G3 (SmearOFF), and also between G3 (SmearOFF) and G4 (17% EDTA) in both variables smear layer and erosion, since the p-values are greater than 0.05. Though, there was a significant difference between G2 (Qmix) and G4 (17% EDTA). The results of this study were not in agreement with studies by Stojicic et al.[25] , Banode et al.[31], Souza et al.[2] in that they found the ability to remove smear layer by QMix to be comparable to 17% EDTA and the difference between the chelating agents were found to be insignificant.

Conclusion

Based on the result of this study, 17% EDTA, SmearOFF, and QMix are all chelating agents that with the aid of PUI are capable of removing the smear layer effectively from the apical third of root canals. In the future, SmearOFF may act as a promising chelating agent as well as an antimicrobial irrigant. However, further investigations are required to determine the efficacy of SmearOFF as root canal chelating agent.

Conflicts of interest

The author reported no conflict of interests.

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