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Scanning Electron Microscopic Evaluation of Smear Layer Removal and Estimation of Dentin Microhardness Using TRITON Endodontic Irrigant: An In Vitro Study

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ABSTRACT

Background and objectives: Irrigation is essential in endodontic therapy, and traditional irrigation was done with NAOCl and EDTA to remove the smear layer and clean the canal, but it had several difficulties. Many solutions, such as Smearoff, Qmix and MTAD, are available as a single irrigant solution to disinfect and remove the smear layer. TRITON is a revolutionary two-in-one irrigant that can both remove smear layer and disinfect the canal. This study aims to evaluate the effect of Triton on smear layer removal and compare it with Qmix and conventional NaOCl and EDTA irrigation protocols.

Methods: Thirty extracted single canal teeth were divided into three groups; Group 1 was irrigated with NaOCl and EDTA. Group 2 received Triton treatment, but Group 3 received Qmix irrigation. Each tooth was then cut in half and subjected to Scanning electron microscope.

Results: There was no significant difference between the groups investigated, however, there was a significant difference between the middle and apical thirds in Group 2 (P=0.009).

Conclusion: Triton intracanal irrigant revealed effectual capability to eradicate smear layer from radicular dentin as conventional root canal irrigating solutions (NaOCl/EDTA).Triton can be used as an alternative to NaOCl+EDTA and Qmix as an irrigant.

Keywords: TRITON, NaOCL, EDTA, SEM, Irrigation.

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INTRODUCTION

The mechanical instrumentation of root canals and the cutting of dentin leads to the generation of a delicate smear layer overlaying the entire root canal wall.[1] It is imperative to prepare the root canal in such a way that the filling materials are placed adequately for a competent apical seal. The presence of the smear layer will have a nocent effect, as it prevents the penetration of the irrigants and intracanal medicaments into dentinal tubules.[2] Although the influence of smear layer removal on a successful root canal treatment remains controversial, it seems that its removal is beneficial.[3] Different irrigants and chelating agents, such as ethylene diamine tetra acetic acid (EDTA), citric acid, and phosphoric acid, have been recommended to remove the inorganic component of the smear layer, and sodium hypochlorite (NaOCl) has been well known for its ability to remove the organic component.[4] Smear layer removal needs a combination of organic component solvents and acids or chelating agents for the removal of inorganic portions.

Numerous irrigants and irrigating devices are present, the removal of the smear layer through remains obscure. Thus, there arises a need to combine irrigants, as the removal of both organic and inorganic debris is strenuous with a single irrigant.[5] Irrigants are of paramount importance of the complete debridement of the root canals with mechanical instrumentation.[6]

Studies have shown that there is no single potent solution appropriate for removing both the organic and inorganic parts of the smear layer. Therefore, to eliminate this smear layer, a mix of sodium hypochlorite (NaOCl) and a strong chelating agent such as ethylenediaminetetraacetic acid (EDTA) is recommended.[7]

Recently, Vista-Dental Company, Racine, USA offers a novel single irrigating solution called as Triton. According to the manufacturer, Triton is multi-functional root canal irrigant. It consists of NaOCl (4% concentration) as well fourteen different chelators and surfactants. It is a multi-functional, all-in-one, dual-action irrigant, which effectively eradicates organic and inorganic smear layer and rapidly dissolves the pulpal tissue remnants.[8]

Unlike traditional irrigants or other advanced 2:1 solution, Triton works differently by avoiding the use of EDTA and CHX together. The non-NaOCl components in Triton proactively dissolve the dentinal debris, allowing for a lower concentration of NaOCl to be exposed to organic debris without as much buffering. Synergistic and simultaneous dissolution of organic and inorganic debris permits the clinician to use lower volumes of the irrigation solution and ensures maximum clinical efficiency.[8]

Triton was statistically more effective than EDTA with NaOCL in removing the smear layer and debris from all root canal thirds ($P< 0.05$). No significant difference was found between Triton and 6% NaOCl for tissue dissolution and antimicrobial testing. Triton was significantly more effective statistically at dissolving tissue and killing bacteria than Q-Mix. After six hours Triton still had an effective concentration of NaOCl (≥2.0%).[9]

The conventional chelating agents bring about an increased reduction in microhardness of the root dentin, thereby affecting the integrity of the tooth structure. Chelators are stable complexes of metal ions with organic substances because of ring-shaped bonds.[10]

So, the present study aimed to evaluate the effect of Triton on smear layer removal using scanning electron microscope (SEM) as well as dentin microhardness using Vickers indenter test and compare it to NaOCl/EDTA and Qmix root canal irrigants.

MATERIALS AND METHOD

Preparation of tooth specimens:

30 straight single-rooted lower premolars with closed apices were extracted for orthodontic reasons and collected from adult patients (18-30years old). Teeth with previous root caries, cracks, curved canals, endodontic treatment, internal resorption or calcification would be excluded.

Teeth were thoroughly cleaned from any soft tissue or calculus deposition, then they were stored in isotonic saline solution at room temperature till the time of use and then radiographed in proximal view to confirm the presence of a patent single canal. The crowns of all specimens were decoronated transversally at the cemento-enamel junction (CEJ) with a double-faced diamond disc at low speed with water coolant to ensure a uniform sample length of 13 mm.

Working length determination:

Before beginning the rotary preparation, the working length determination phase (increment of file size 10 till the file tip can just be seen from the apical foramen then 1mm deduction) was used to determine the canal's patency using a K-file size 10. After the size 10 K file became extremely brittle, the glide route would be prepared with an endodontic rotary tool. One G #14 3% Glide path with a setting speed of 400 rpm was placed into the canal at its full working length. The file would halt after it reaches its full working length and then patency will be checked once more using K-file #10 (per MicroMaga business guidelines).

Root canal preparation:[11]

The cervical third of each canal was prepared with orifice opener file up to the one third of the canal, then the teeth were prepared with nickel titanium heat treated T-wire, 2Shape TS1 #25 4%, TS2 #25 taper 6% and size 35 taper 6% (COLTENE Mircromega, France). The TS1 and TS2 at setting of speed of rotation: 400rpm and torque: 2,6 N.cm through. Progressive movement was performed in three waves (3 up-and-down motion) with brushing movement in 4 directions, then the file was removed from the root canal, the root canals were cleaned and irrigated.

The samples were randomly divided into three groups according to the irrigant used (n=10).

The 30 samples of extracted teeth will be divided to 3 groups

1- group (A) ten sample irrigated by NaOCL5.25% and EDTA17% as controle

2- group (B) ten sample irrigated by TRITON irrigant

3- group (C) ten sample irrigated by Qmix

For group 1 the tooth sample was irrigated with NaOCL 5.25% during the irrigation (2 ml of irrigating solution between each file, then finally with 1 ml of 17% EDTA as final irrigant for 1 min. To stop the delayed effect of EDTA a one ml of NaOCL 5.25% were used then 2ml of distilled water then dryness with paper point size 30 until the paper point became completely dry visually by naked eye. The endodontic needle gauge 27 was inserted up to 2 mm from working length.

For group 2 the same technique of irrigation except that IRITON instead of (NaOCL and EDTA) was used during instrumentation and finally with 1mil of the same solution for 90 seconds (manufacturing instruction).

For group 3, irrigation was delivered by placing the needle tip safely in canal (at least 2 mm from apex). QMix 2in1 was expressed into the canal and continuously irrigated for 60-90 seconds.

Specimen preparation for smear layer evaluation:

Each tooth after root canal preparation was longitudinally grooved in a bucco-lingual direction by using a double-faced diamond disk at low speed, then the tooth was sectioned without passing through the canal space, paper point was inserted inside the canal to protect the inner dentin surface, by using a chisel to split the root in to 2 halves. Each half was divided to 3 thirds (coronal, middle, and apical). The mid of each third Figure (1), was examined under scanning electron microscope (SEM) Figure (2). It was assessed according to criteria suggested by (Torabinejad et al., 2002).[6]

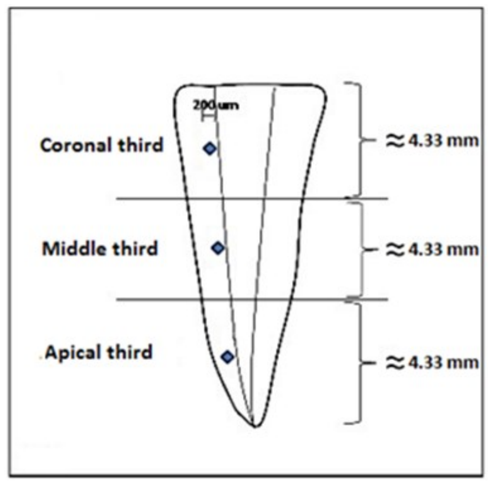


Figure 1: Diagram showing the location of three different points of measurement (coronal, middle & apical)

Figure 2: Scanning electron microscope used for smear layer removal evaluation test

Statistical analysis:

The recorded data from SEM examination were analyzed using SPSS (Statistical Packages for the Social Sciences 26.0, IBM, Armonk, NY, USA). Cohen's kappa coefficient was used for verifying inter- & intra-raters reliability. Kolmogorov-Smirnov and Shapiro-Wilk tests were executed to find out the normality of the collected data. Also, Kruskal-Wallis nonparametric analysis of variance and Mann-Whitney test were performed to statistically analyze the collected smear layer data of the tested groups regarding the type of applied intracanal irrigant and the root canal region. The level of statistical significance was set at 0.05.

RESULTS

Results of smear layer removal capacity:

The results of smear layer removal capacity (Mean±SD) for all groups at different root regions were summarized and statistically analyzed in table (1).

Table (1): The mean, standard deviation (SD) and Kruskal-Wallis test of smear layer scores for different groups recorded in one root segment and for different root segments of each group.

Groups / Root segments		Group I		Group II		Group III		**Kruskal-Wallis** test for different groups recorded in one root segment	
		Mean	±SD	Mean	±SD	Mean	±SD	Kruskal-Wallis H	p-value
Cervical		1.2	0.632	1.6	0.699	1.2	0.422	3.849	0.146
Middle		1.4	0.267	2	0.943	1.5	0.85	2.641	0.267
Apical		1.8	0.632	2.6	0.699	2	0.943	5.484	0.064
Kruskal-Wallis test for different root segments of each group	Kruskal-Wallis H	6.131		6.828		4.475			
	p-value	0.047*		0.033*		0.107			

*values had statistically significant difference at (P<0.05).

The effect of the intracanal final irrigation solution on smear layer removal capacity:

The results of smear layer removal capacity for all groups showed that the highest smear layer score mean value was recorded with group II (Triton root-canal irrigant group) (2.6 ± 0.699) at middle region, followed by group III (Qmix root-canal irrigant group) (2 ± 0. 943) at apical region, then group I (NaOCl/EDTA root-canal irrigants group) (1.8 ± 0.632) at apical region. While groups I (1.2 ± 0.422) and III recorded the lowest smear layer score mean value (1.2 ± 0.632) at cervical region. (Table 2).

There was no statistically significant difference between all tested groups at all investigated root segments (P>0.05). (Table 2).

Table 2: The mean, standard deviation (SD, rank) and Kruskal-Wallis test of smear layer scores for different groups recorded at root canal segments.

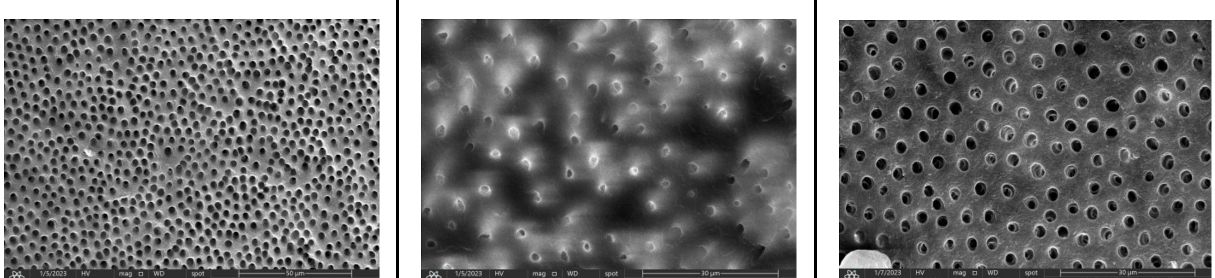
Groups / Root segments	Group I			Group II			Group III			Kruskal-Wallis test for different groups recorded in one root segment	
	Mean	±SD	Rank	Mean	±SD	Rank	Mean	±SD	Rank	Kruskal-Wallis H	p-value
Cervical	1.2	0.632	13.3	1.6	0.699	18.9	1.2	0.422	14.3	3.849	0.146
Middle	1.4	0.267	13.8	2	0.943	18.8	1.5	0.85	13.9	2.641	0.267
Apical	1.8	0.632	11.9	2.6	0.699	20.3	2	0.943	14.3	5.484	0.064

*values had statistically significant difference at (P<0.05).

At cervical region:

At the cervical region, group II showed the highest mean smear layer score value (1,6 ± 0.699), followed by groups I (1.2± 0.632), & III (1.2 ± 0.422). (Table 3, Figure 3).

There was no statistically significant difference between all groups at cervical root third (p>0. (Table 3).



a b c

Figure 3: 2000X ESEM photos of smear layer removal at cervical root segment using a: NaOCl/EDTA, b: Triton, c: Qmix root canal irrigants

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Table 3: The mean, standard deviation (SD), rank and Kruskal-Wallis test of smear layer scores of different groups at cervical third.

Groups / Root segments	*Group I*			*Group II*			*Group III*			**Kruskal-Wallis** *test for different groups recorded in one root segment*	
	Mean	±SD	Rank	Mean	±SD	Rank	Mean	±SD	Rank	Kruskal-Wallis H	*p*-value
Cervical	1.2	0.632	13.3	1.6	0.699	18.9	1.2	0.422	14.3	3.849	0.146

*values had statistically significant difference at (P<0.05).

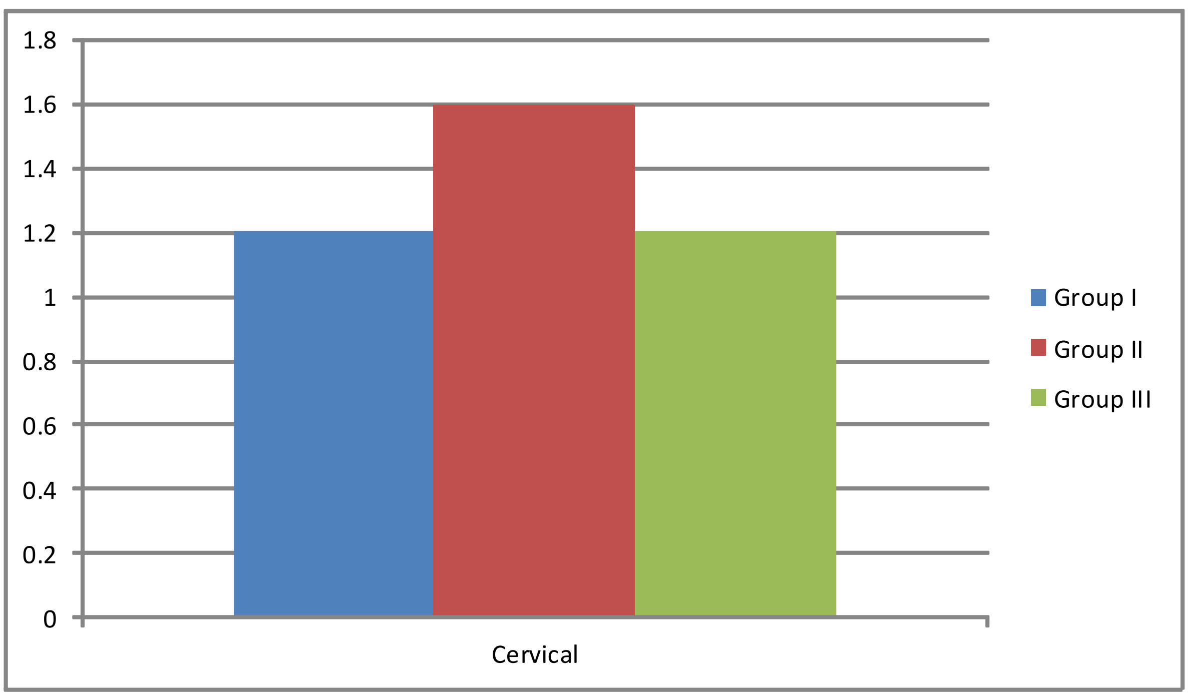

Figure 4: The mean of smear layer scores of different groups recorded at cervical root third.

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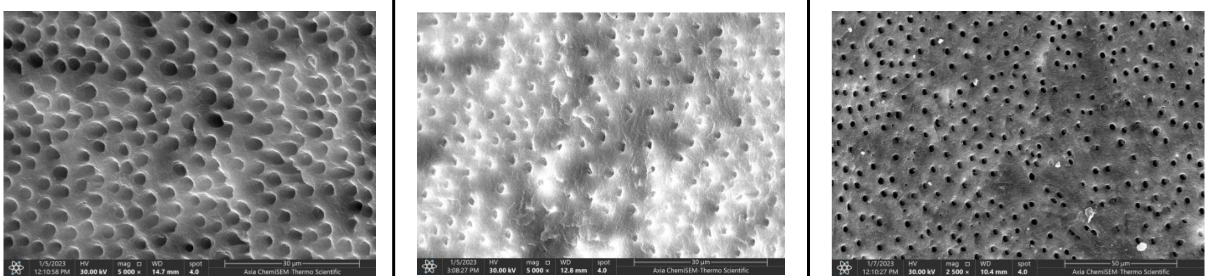
At middle region:

At the middle region, group II showed the highest mean smear layer score value (2 ± 0.943), followed by group III (1.5 ± 0.85). While group I recorded the lowest mean smear layer score value (1.4 ± 0.267). (Table 4, Figure 5).

There was no statistically significant difference between all groups at middle root third ($p>0.05$). (Table 4).



a | b | c

Figure 5: 2000X ESEM photos of smear layer removal at middle root segment using a: NaOCl/EDTA, b: Triton, c: Qmix root canal irrigants

Table 4: The mean, standard deviation (SD, rank) and Kruskal-Wallis test of smear layer scores of different groups at middle third.

Groups / **Root segments**	***Group I***			***Group II***			***Group III***			**Kruskal-Wallis** *test for different groups recorded in one root segment*	
	Mean	±SD	Rank	Mean	±SD	Rank	Mean	±SD	Rank	Kruskal-Wallis H	*p*-value
Middle	1.4	0.267	13.8	2	0.943	18.8	1.5	0.85	13.9	2.641	0.267

*values had statistically significant difference at ($P<0.05$).

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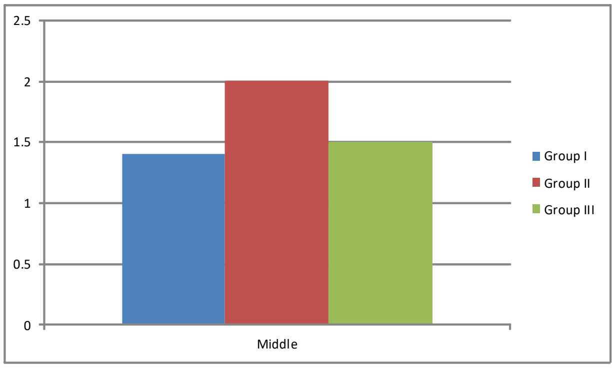

Figure 6: The mean of smear layer scores of different groups recorded at middle root third.

At the apical region, group II showed the highest mean smear layer score value (2.6± 0.699), followed by group III (2 ± 0.943). While group I recorded the lowest mean smear layer score value (1.8 ± 0.632). (Table 5., Figure 7).

There was no statistically significant difference between all groups at the apical root third (p>0.05). (Table 5).

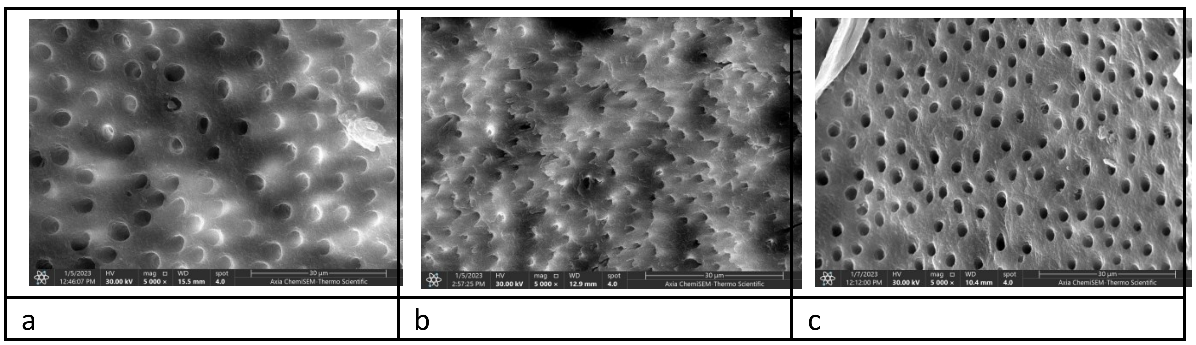

Figure 7: 2000X ESEM photos of smear layer removal at apical root segment using a: NaOCl/ EDTA, b: Triton, c: Qmix root canal irrigants

Table 5: The mean, standard deviation (SD, rank) and Kruskal-Wallis test of smear layer scores of different groups at apical third.

Groups / **Root segments**	***Group I***			***Group II***			***Group III***			**Kruskal-Wallis** *test for different groups recorded in one root segment*	
	Mean	±SD	Rank	Mean	±SD	Rank	Mean	±SD	Rank	Kruskal-Wallis H	*p*-value
Apical	1.8	0.632	11.9	2.6	0.699	20.3	2	0.943	14.3	5.484	0.064

*values had statistically significant difference at (P<0.05).

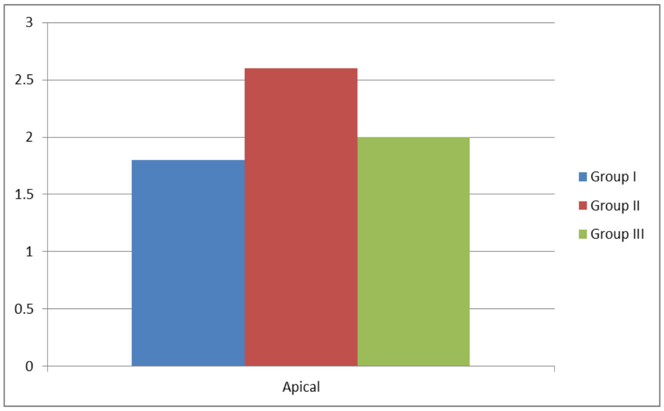

Figure 8: The mean of smear layer scores of different groups recorded at apical root third.

The effect of the root canal level on smear layer removal capacity:

The results of smear layer removal capacity for all root segments of each group showed that the highest smear layer score mean value was recorded with group II (2.6 ± 0.699) at middle region, followed by group III (2 ± 0. 943) at apical region, then group I (1.8 ± 0.632) at apical region. While groups I (1.2 ± 0.632) and III (1.2 ± 0.422) (recorded the lowest smear layer score mean value at cervical region. (Table 6, Figure 9).

There was a statistical significant difference between all root segments of group I & II (P=0.028). (Table 6).

Table 6: The mean, standard deviation (SD), rank and Kruskal-Wallis test of smear layer scores for different root segments of each group.

Groups / Root segments		*Group I*			*Group II*			*Group III*		
		Mean	±SD	Rank	Mean	±SD	Rank	Mean	±SD	Rank
Cervical		1.2	0.632	11.5	1.6	0.699	11	1.2	0.422	12.4
Middle		1.4	0.267	15.1	2	0.943	14.9	1.5	0.85	14.7
Apical		1.8	0.632	19.9	2.6	0.699	20.6	2	0.943	19.4
Kruskal-Wallis test *for different root segments of each*	Kruskal-Wallis H	6.131			6.828			4.475		
	p-value	0.047*			0.033*			0.107		

*values had statistically significant difference at (P<0.05).

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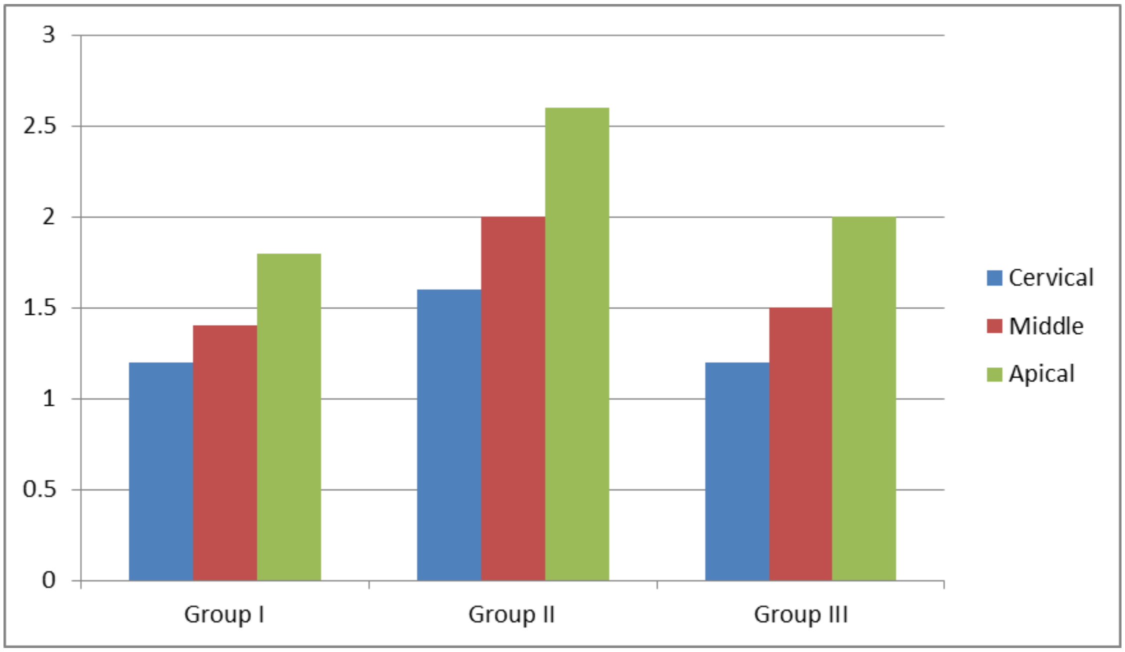

Figure 9: The mean of smear layer scores of different root segments of each group.

a. Group I:

For group I, the highest mean smear layer score value was recorded at the apical region (1.8 ± 0.632), followed by the middle region (1.4 ± 0.267). While the lowest mean smear layer score value was recorded cervically (1.2± 0.632). (Table 7, Figure 10).

There was statistical significant difference between cervical and apical two thirds at group I (P=0.019). (Table 11)

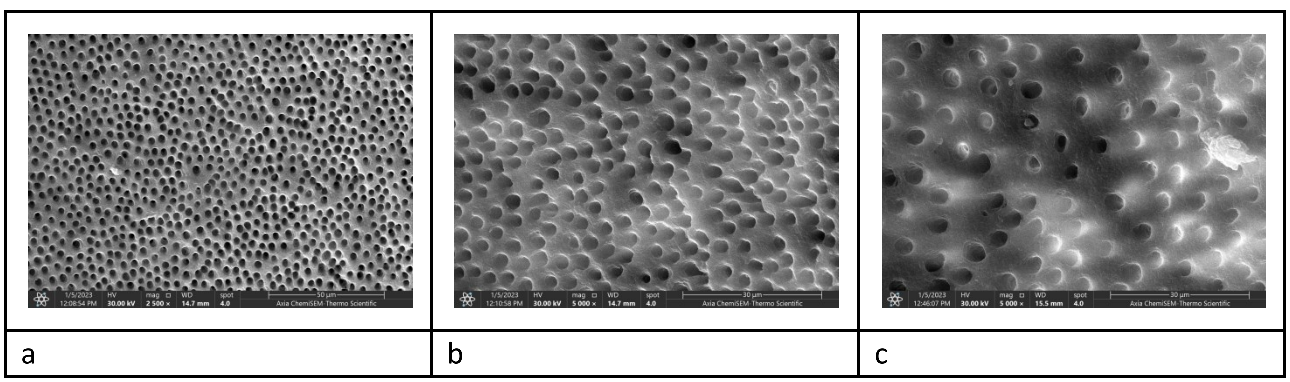

Figure 10: 2000X ESEM photos of smear layer removal of group I (NaOCl root canal irrigant group) a: cervical, b: middle, c: apical root thirds

Table 7: The mean, standard deviation (SD), rank and Kruskal-Wallis test of smear layer scores of different root segments of group I.

Groups / Root segments		*Group I*		
		Mean	±SD	Rank
Cervical		1.2	0.632	11.5
Middle		1.4	0.267	15.1
Apical		1.8	0.632	19.9
Kruskal-Wallis test *for different root segments of each group*	Kruskal-Wallis H	6.131		
	p-value	0.047*		

*values had statistically significant difference at (P<0.05).

Table 8: Mann-Whitney U statistics of smear layer scores of different root segments of group I.

Area of comparison	Root third	Mean rank	Sum of ranks	Mann-Whitney U statistics			
				Mann-Whitney U	*Wilcoxon W*	*z- value*	*p- value*
Cervical - Middle	Cervical	9.2	92	37	92	-1.3	0.194
	Middle	11.8	118				
Cervical-Apical	Cervical	7.8	78	23	78	-2.344	0.019*
	Apical	13.2	132				
Middle - Apical	Middle	8.8	88	33	88	-1.45	0.147
	Apical	12.2	122				

*values had statistically significant difference at (P<0.05).

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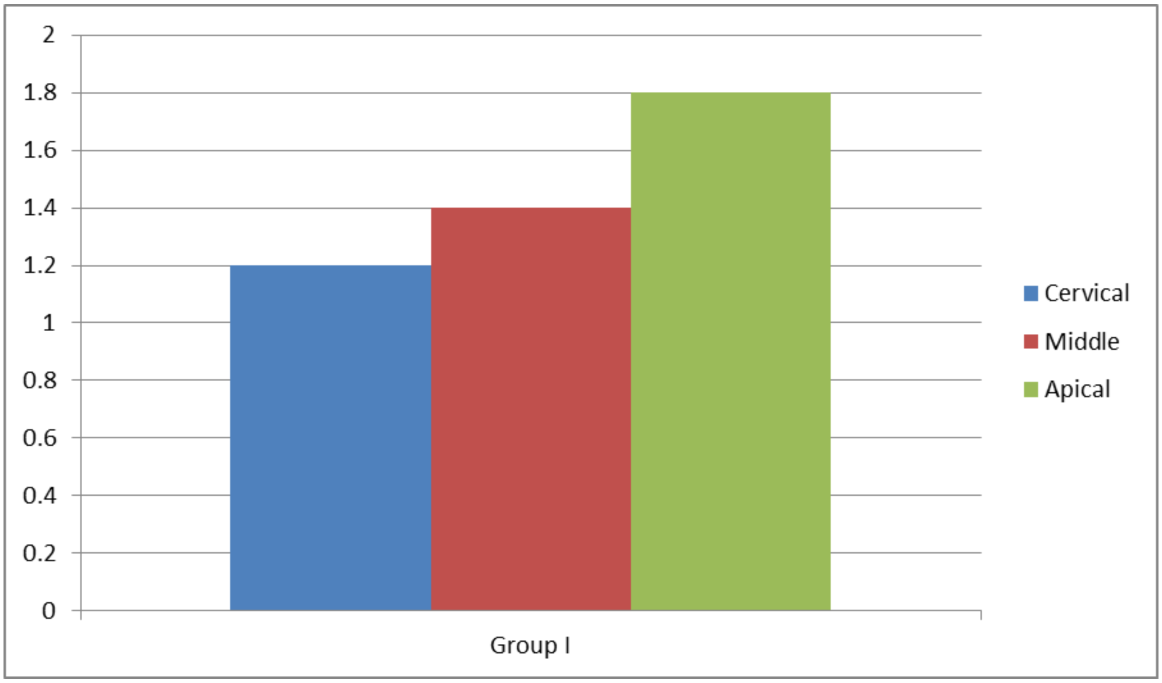
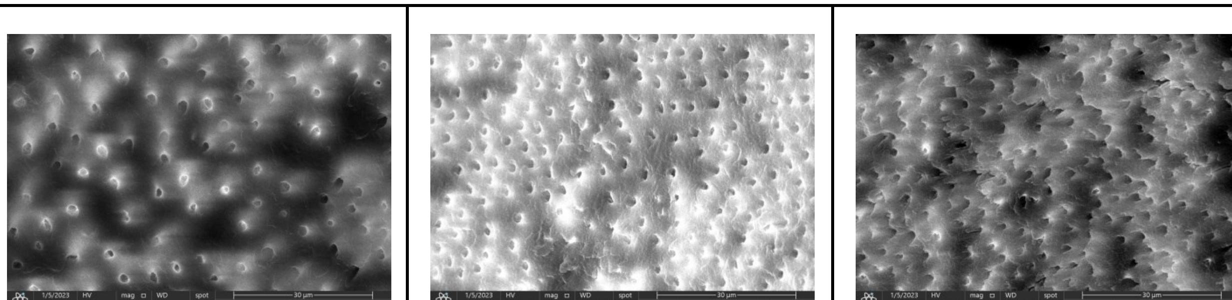


Figure 11: The mean of smear layer scores of different root segments of group I.

b. Group II:
For group II, the highest mean smear layer score value was recorded at the apical region (2.6 ± 0.699), followed by the middle region (2 ± 0.943). While the lowest mean smear layer score value was recorded cervically (1.6± 0.699). (Table 9, Figure 12).

There was statistically significant difference between cervical and apical two thirds at group II (P=0.008). (Table 13).



a	b	c

Figure 12: 2000X ESEM photos of smear layer removal of group II (Triton root canal irrigant group) a: cervical, b: middle, c: apical root thirds

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Table 9: The mean, standard deviation (SD), rank and Kruskal-Wallis test of smear layer scores of different root segments of group II.

Groups		***Group II***		
		Mean	±SD	Rank
Cervical		1.6	0.699	11
Middle		2	0.943	14.9
Apical		2.6	0.699	20.6
Kruskal-Wallis test *for different root segments of each*	Kruskal-Wallis H	6.828		
	p-value	0.033*		

*values had statistically significant difference at (P<0.05).

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Table 10: Mann-Whitney U statistics of smear layer scores of different root segments of group II.

Area of comparison	Root third	Mean rank	Sum of ranks	Mann-Whitney U statistics			
				Mann-Whitney U	*Wilcoxon W*	*z- value*	*p- value*
Cervical - Middle	Cervical	9.3	93	38	93	-0.973	0.33
	Middle	11.7	117				
Cervical-Apical	Cervical	7.2	72	17	72	-2.653	0.008*
	Apical	13.8	138				
Middle - Apical	Middle	8.7	87	32	87	-1.51	0.131
	Apical	12.3	123				

*values had statistically significant difference at (P<0.05).

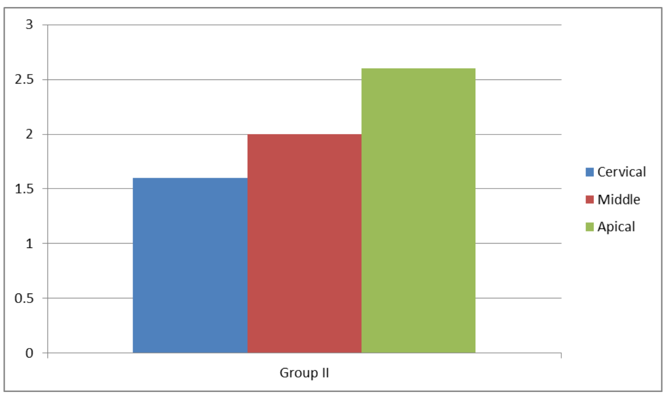
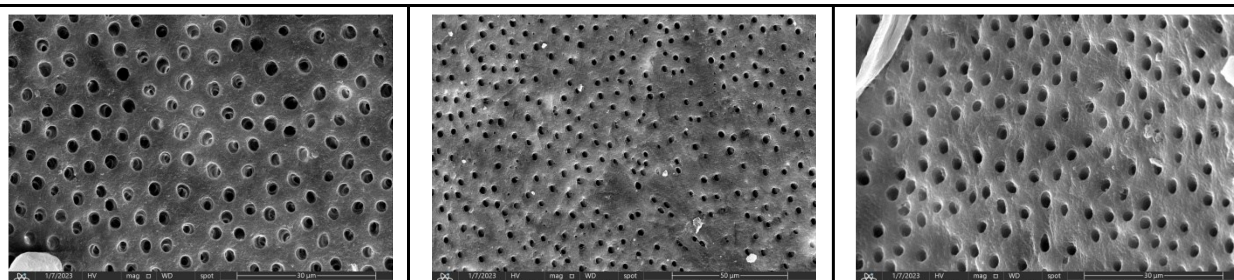


Figure 13: The mean of smear layer scores of different root segments of group II.

c. Group III:
For group III, the highest mean smear layer score value was recorded at the apical region (2 ± 0.943), followed by the middle region (1.5 ± 0.85). While the lowest mean smear layer score value was recorded cervically (1.2± 0.422). (Table 11, Figure 14).
The difference in smear layer score between all regions with group III was statistically non-significant (p>0.05). (Table 14).



a	b	c

Figure 14: 2000X ESEM photos of smear layer removal of group III (Qmix root canal irrigant group) a: cervical, b: middle, c: apical root thirds

Table 11: The mean, standard deviation (SD), rank and Kruskal-Wallis test of smear layer scores of different root segments of group III.

Groups / **Root segments**		*Group III*		
		Mean	±SD	Rank
Cervical		1.2	0.422	12.4
Middle		1.5	0.85	14.7
Apical		2	0.943	19.4
Kruskal-Wallis test *for different root segments of each group*	Kruskal-Wallis H	4.475		
	p-value	0.107		

*values had statistically significant difference at (P<0.05).

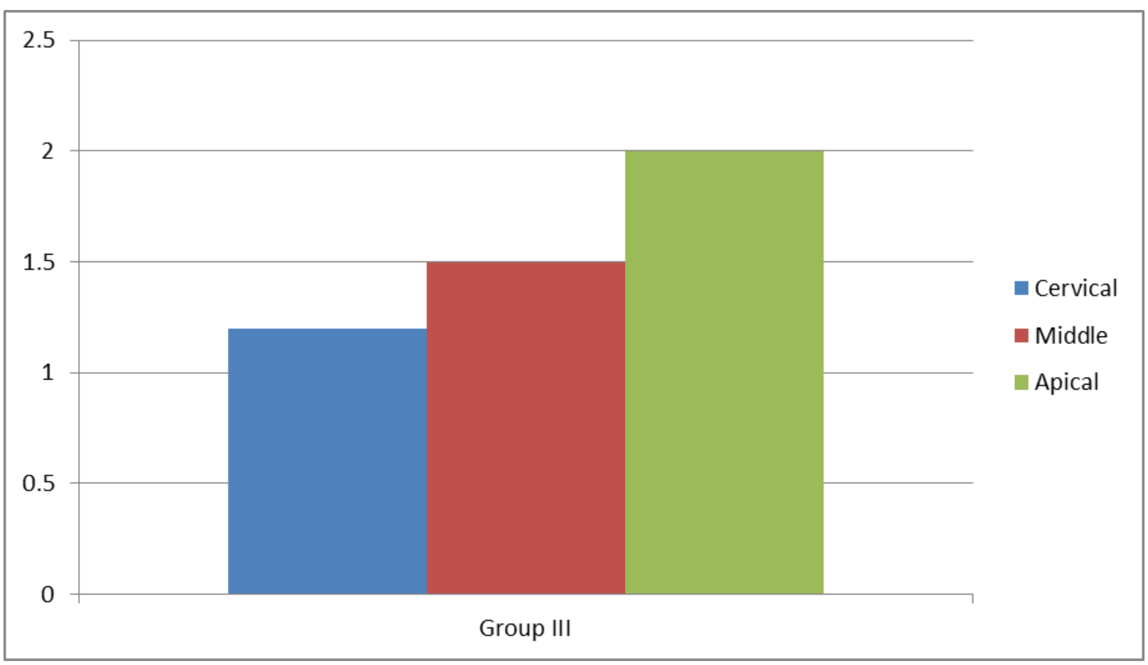


Figure 15: The mean of smear layer scores of different root segments of group III.

DISCUSSION:

The lack of success of root canal treatments mainly happena due to presence of pathogenic bacteria remaining on the radicular dentin wall during and after root canal therapy or the invasion of bacteria into the root canal system after completing the endodontic obturation then, they re-colonize inside the filled root canal system. Consequently, the primary rationale of root canal treatment is achieving the complete cleaning of the root canal system and elimination of root canal debris.[12]

According to earlier research,[13,14,15] the criteria for choosing teeth were set up. Furthermore, in order to confirm the high work standardizations during this study, it was done to decoranate teeth with a standard 13-mm root-canal length,[11] instrument the root canal wall up to a specific size (TiNi F35 file taper 6%), and use the same endodontic irrigation solution (2.5% NaOCl) between root canal filing and a specific volume of final flush irrigant (5 ml).

The root canal of each decapitated tooth was mechanically instrumented to size (TiNi F35 file taper 6%) in order to grant sufficient root canal space allowing more flushing and diffusion for the applied endodontic irrigation solutions.[14] Additionally, the root canal instrumentation up was executed to (TiNi F35 file taper 6%) lessen the jeopardy of root canal overpreparation essentially arising at the apical region, and other intracanal iatrogenic errors during the endodontic cleaning and shaping procedure.[14]

Application of Triton and Qmix root canal irrigants was performed according to the manufactures' instructions to prevent the undesirable irrigation effect which could negatively change the results of this study.

Utilizing the 3-point grading system created by Torabinejad M. et al., after tooth sectioning, SEM investigations were performed.[6] by expert raters, and microscopic images were captured at a magnification of x2000 for more accurate dentin wall evaluations at root zones coronal, middle, and apical. [15,16,17]

The smear layer scores results of NaOCl/EDTA root-canal irrigants group (group I) were attributed to the magnificent capability of NaOCl solution to dissolve necrotic dental pulps as well as the organic compositions of the smear layer; and to the powerful competence of 17% EDTA to eradicate the inorganic constituents of smear layer.[18] These findings were in full agreement with many prior studies.[9,20]

Moreover, the smear layer scores result of Qmix root-canal irrigant group (group III) were ascribed to Qmix automixed compositions (17% EDTA, 2% chlorhexidine, and several surfactants) that had proven their ability to eliminate the smear layer from the radicular dentin in previous studies. [17,21,22,23,24,25,26]

Furthermore, the smear layer scores result of Triton root-canal irrigant group (group II) were credited to presence of 4% NaOCl in its combined constitutions which can dissolve organic pulp structures besides EDTA and other chelators that are effective for the elimination of inorganic debris. These findings coincided with a previous study.[9]

Regarding the group I (NaOCl/EDTA root-canal irrigants group) recorded the lowest mean smear layer score value followed by group III (Qmix root-canal irrigant group) then group II (Triton root-canal irrigant group), previous studies showed dissimilar results.[27,28,9,26]

Other studies presented that Qmix had greatest cleaning capacity in comparison to 1%, 2.5%, and 5.25% NaOCl, respectively.[27,28,26] The differences were attributed to the fact that no study used NaOCl combined with EDTA and each study utilized different score system[27] utilized Takeda et al. score system,[28] employed Ghisil et al. score system, and 26 used a specific criteria. Additionally, lower concentrations of NaOCl were used in.[27,28] Who also reported that Triton had presented higher smear layer eradication capacity than Q-Mix and 6% NaOCl. The differences between the two studies results may be duo to dissimilarity of methods conducted in the two studies, besides other study did used EDTA in combination with 6% NaOCl.[9]

Regarding the effect of the smear layer's site on the root canal system's radicular dentin on the ability of various investigated intracanal irrigants to clean the canals, the SEM analysis showed that when using the same root canal irrigation solution, the mean value of the smear layer score gradually increased in the apical direction for the NaOCl/EDTA, Triton, and Qmix root-canal irrigants groups (groups I through II),

The statistical analysis of the collected data showed that there were statistically significant

differences between cervical and apical two thirds of group I (NaOCl/EDTA root-canal irrigants) and group II (Triton root-canal irrigant group).
This may be due to the root canal anatomical complexity present at apical third,[29] and the presence of heavy apical tubular sclerosis,[13] which can considerably diminish the smear layer eradicating capacity of root canal irrigation solutions. These results are in accordance with different previous studies.[17,19,20,21,22,23,24]
Conclusion: Triton intracanal irrigant revealed effectual capability to eradicate smear layer from radicular dentin as conventional root canal irrigating solutions (NaOCl/EDTA).
Conflict of interest: There is no conflict of interest for this paper.

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