Original Article

Comparative evaluation of smear layer removal by using different irrigant activation techniques: An *in vitro* scanning electron microscopic study

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Abstract

Aim: This *in vitro* study aims to assess and compare the effectiveness of different irrigation activation techniques in removing the smear layer from the root canal dentin using Scanning electron microscope (SEM) analysis.

Materials and Methods: A total of 60 extracted single-rooted premolar with straight canal and mature apex were used for this study. After the selection of teeth, all the samples were decoronated followed by biomechanical preparation. The sample after preparation was irrigated with sodium hypochlorite and randomly divided into three groups with 20 sample in each group ($n = 20$), (Group 1) control, (Group 2) ultrasonic, and (Group 3) laser. The irrigant activation was done in all the groups and then sample was prepared for the scanning electron microscope analysis.

Statistical Analysis: The statistical analysis was performed using the Mann–Whitney-*U*-test.

Results: The findings suggested that the diode laser irrigant activation technique was superior to the ultrasonic and conventional techniques to eradicate smear layers.

Conclusion: With the limitation of this study, diode laser activation showed better cleaning of root dentinal walls compared to ultrasonic activator and traditional method.

Keywords: Dentinal tubule; irrigation; laser; smear layer; ultrasonic

INTRODUCTION

Irrigation plays the pivot role in root canal debridement and removing of smear layer. It allows cleaning beyond the areas where our instrument might not reach. Removing the smear layer is a controversial phenomenon by Violich and Chandler, suggesting the presence of a smear layer prevents the penetration of intracanal medicaments and also influences the adaptation of filling materials to dentinal walls.[1]

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The use of irrigants such as sodium hypochlorite (NaOCl) deproteinizing agent and ethylenediaminetetraacetic acid (EDTA) by Mohammadi *et al*. is recommended for the efficient removal of smear layer.[2] Irrigants need to contact the dentinal walls directly for their par effectiveness. Hence, to achieve that, different techniques of delivery systems have come into play to increase the flow and distribution of irrigants.

Earlier, manual and positive pressure irrigation has been advocated as an efficient method of irrigant delivery. However, the mechanical flushing action created by conventional side vented needle irrigation is relatively weak.[3] Therefore, machine-operated irrigation techniques such as sonic, ultrasonic, negative pressure

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agitation, and laser activation have been introduced in recent years.

Tronstad *et al*. were the first to report the use of a sonic instrument for endodontics in 1985.[4] Sonic irrigation is different from ultrasonic irrigation in that it operates at a lower frequency (1–6 kHz) and produces smaller shear stresses, but it generates significantly higher amplitude. Sonic activation operated with one single positive and negative node. The movement of the sonic instrument results in a pure longitudinal file oscillation.[5]

Ultrasonic devices produce high frequencies (25–30 kHz) but low amplitudes. They operate in a transverse vibration, setting up a characteristic pattern of nodes and antinodes along their length.[6] During passive ultrasonic irrigation, the energy is transmitted from an oscillating tip to the irrigant in the root canal by means of ultrasonic waves.[6,7] That latter induces acoustic streaming and cavitation of the irrigant aids in removing dentin debris from the root canal.[8]

The clinical application of lasers in endodontics started in the late 90s.[4] Currently, there are many laser systems, such as diode laser, neodymium: yttrium-aluminum-garnet, erbium-doped yttrium aluminum garnet, and carbon dioxide lasers. Among all, the diode laser has been used extensively for smear layer removal because it is easy to use with flexible tip, compact, and economical.[9]

Laser agitation is accompanied by shock waves and along with secondary bubbles that enhance the removal of smear layer from areas unreached by endodontic shaping instruments during canal preparation.[10] The temperature of irrigation fluid inside the root canal rises up to 30°C during laser irradiation of irrigant with 940 nm and 980 nm diode lasers.[11] This elevation in temperature improves the chemical reactions of irrigation solutions and assist in debridement of the root canal.

The purpose of this study is to evaluate the removal of the smear layer after treating the root canal with NaOCl, then activating the final irrigant with different irrigant activation techniques.

MATERIALS AND METHODS

Sixty extracted human mandibular first premolar teeth were collected for the study. The teeth that had a single root with mature apex were chosen. Tooth with decay, anatomical variations, canal calcifications, fractured roots, root resorption, and cracks on the surface were excluded from the study. A hand scaler was used to debride the external surfaces of the teeth. Until further use, all teeth were kept at the room temperature in physiological saline.

Sample preparation

Decoronation of samples was done using a diamond disk to get a 16-mm standard working length for all the teeth. A round diamond bur was used to gain endodontic access, and a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the root canal until the tip was just seen at the foramen, then subtraction of 1 mm from the measured length.[1,5]

Root canal instrumentation

Biomechanical preparation to the working length was achieved using Protaper Next® rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) up to X4 (40/0.06 size/taper) file.[5] Irrigation was performed with 1 ml of 5.25% NaOCl between each instrumentation file during the shaping procedure, using a 31G double side-vented needle (Ultradent, USA) held at 2 mm shorter than the working length. The complete endodontic procedure was carried out by a single investigator, and a blinding procedure was followed.[11]

Sample grouping

The specimens were randomly divided into three groups, with 20 samples per group ($n = 20$). Later, each group was exposed to final irrigation by means of three irrigation systems. Final irrigation was done using 5 ml of 5.25% NaOCl.

Group A: Conventional needle irrigation

The canals were flushed for 1 min with 1 mL of normal saline followed by the use of 5.25% NaOCl (5 mL) for canal flushing.

Group B: Irrigation with ultrasonic activation

An ultrasonic, passive activation of the irrigants was done using an ultrasonic activator (Eighteeth Ultra X-Ultrasonic activator by Changzhou Sifary Medical Technology). The ultrasonic tip (size 15.21 mm) for 2 min was inserted into the canal at 1 mm less than the working length with no contact with the walls, and it works at 45 kHz ultrasonic frequency.

Group C: Laser activation

Laser agitation was done with a 200 μm fiber optic tip. It was introduced into the root canal, 2 mm short of the apex. Diode laser of 970 nm, 1.5 watts of power, and pulsed mode was used. The laser was activated and withdrawn gently from the root canal to the coronal region with a helicoid movement in a speed of 1 mm/s and reintroduced to the apex for a total laser irradiation cycle of 1 min. This was accomplished in three cycles of 20 s each, as followed by the manufacturer instructions.

A total of 5 ml of 5.25% NaOCl was used between each cycle of activation for all groups, and the root canals were finally flushed using 5 ml of saline to terminate the action

of irrigating solutions. Sterile paper points were then used to dry the canals, and a cotton pellet was kept, and the access cavity was closed.

Sample preparation for SEM evaluation

After the final irrigant protocols, the specimens were grooved at 4, 8, and 12 mm from the root apex, defining the coronal, middle, and apical third, respectively. Longitudinal grooves were also made along the buccal and lingual root surfaces until a transparent root canal was visualized using a diamond disc at low speed.[12] Then, the roots were split into two halves with a chisel and a mallet. One half of each root was selected and prepared for the SEM analysis. The dehydration of specimens was done with ethyl alcohol using the ascending concentrations of (30%–100%) for 24 h at each concentration.[11] Metallic stubs were used to mount the samples and were gold sputtered in a vacuum chamber. Each sample was evaluated for residual smear layers at the coronal, middle, and apical third of the root under a scanning electron microscope (CARL ZEISS) at ×1000 magnification.

The SEM images were separately scored by another examiner who was blinded to specimen groups using the criteria reported by Torabinejad *et al*.[13]

- Score 0 = no smear layer (absence of smear layer on the surface of the root canal, all dentinal tubules clean and open)
- Score 1 = moderate smear layer (no smear layer on the surface of the root canal, but dentinal tubules contain debris)
- Score 2 = heavy smear layer (smear layer covers the root canal surface and dentinal tubules).

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) software version 20 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. The comparison was statistically done using the one-way analysis of variance and Tukey's honestly significant difference *post hoc* test. The significance level for the statistical analysis was set at $P < 0.05$.

RESULTS

According to the results, at coronal level, Group B and C showed significant removal of a smear layer with a lower mean score compared to Group A, as illustrated in Table 1. There were no significant differences between Group B and C at coronal level. At middle and apical third, the scores of debris in all the groups showed significant differences. In Group A, the highest mean score was obtained at all levels and among Group B and Group C at middle and apical level, Group C had the least mean score.

A comparison between root levels illustrated in Table 2: Group A showed a lower mean score in the coronal region.

Table 1: Mean distribution score of various groups at coronal, middle, and apical levels

Group	Coronal		Middle		Apical	
	Mean	SD	Mean	SD	Mean	SD
Conventional	1.25	0.72	1.35	0.67	1.55	0.61
Ultrasonic	0.95	0.51	0.70	0.73	1	0.65
Laser	0.80	0.69	0.30	0.57	0.60	0.50

SD: Standard deviation

Table 2: Intergroup comparison of remaining smear layer score at various levels

Group	Mean	SD	ANOVA test	*P*
Coronal				
Conventional (Group A)	1.25[a]	0.72	7.18	0.008*
Ultrasonic (Group B)	0.80[b]	0.69		
Laser (Group C)	0.95[b]	0.51		
Middle				
Conventional (Group A)	1.35[a]	0.67	10.32	0.001*
Ultrasonic (Group B)	0.70[b]	0.73		
Laser (Group C)	0.30[c]	0.57		
Apical				
Conventional (Group A)	1.55[a]	0.61	9.68	0.003*
Ultrasonic (Group B)	1[b]	0.65		
Laser (Group C)	0.60[c]	0.50		

*Statistically significant, [a,b,c]Values with different letter indicate statistically significant difference. SD: Standard deviation

In Group B, there was no significant difference between the coronal and middle region; both showed lower mean scores, but the apical region showed a higher mean score. In Group C, all the levels showed lower mean scores with significant differences compared to Group A and Group B.

The complete removal of the smear layer with any system was higher in the coronal and middle third regions than the apical regions except the laser group. Laser and ultrasonic groups significantly removed more smear layers [Figures 1 and 2] than the conventional group [Figure 3] in the coronal, middle, and apical third.

DISCUSSION

Successful root canal therapy requires the effective elimination of the necrotic pulp tissue and smear layer from the dentinal walls. During mechanical instrumentation, a smear layer clogs the open dentinal tubule which further prevents the sealer to penetrate deep down and achieving a monoblock effect. Irrigation plays an important role in the removal of smear layer and activating it causes more effectiveness of these irrigants.

The most commonly used irrigants are NaOCl, chlorhexidine, EDTA, and a mixture of tetracycline, an acid, and a detergent. Among all, NaOCl is the golden standard irrigants for chemomechanical debridement of root canals due to its antimicrobial action in addition to its exceptional capacity to dissolve remnants of necrotic tissue.[14] NaOCl is used in varying concentrations from 0.5% to 5.25%. Several

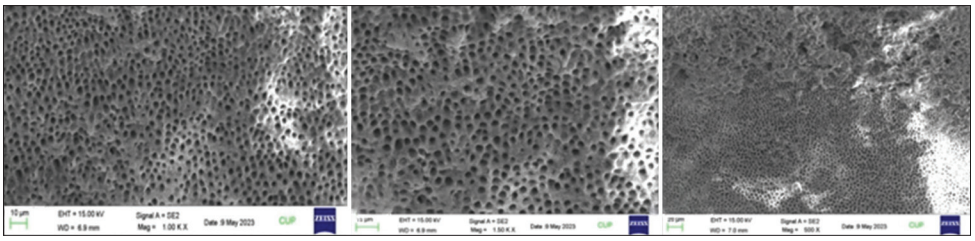

Figure 1: Group C SEM images at coronal, middle, and apical levels

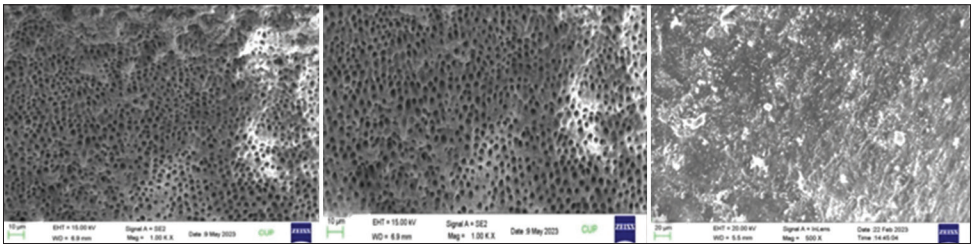

Figure 2: Group B SEM images at coronal, middle, and apical levels

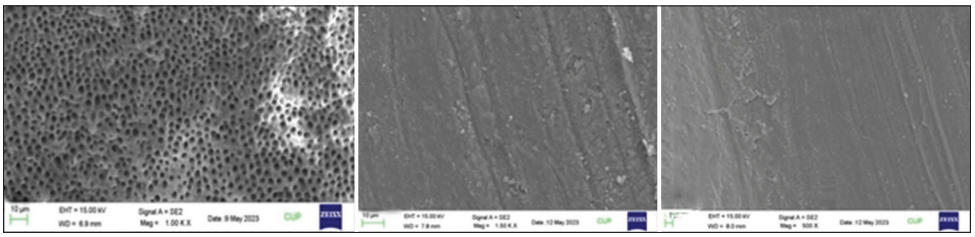

Figure 3: Group A SEM images at coronal, middle, and apical levels

studies have recommended the use of 5.25% NaOCl, similar to a study by Mohmmed *et al*. stated NaOCl is more efficient in biofilm removal at higher concentration.[15]

Irrigants alone are insufficient to flush out the debris from dentinal tubules. Hence, in attempts to improve the efficacy and deeper penetration of irrigant into dentinal tubules, many agitation techniques have been evolved into the field of endodontics. According to the consensus of many studies, machine-assisted agitation and laser agitation with EDTA are more efficient than NaOCl in smear layer removal.[16]

Therefore, in this study, the effectiveness of removing smear layer and dentin debris from the root canal system by the activation of NaOCl with positive pressure irrigation, ultrasonic activation irrigation, and laser activation irrigation was compared.

In Group A, results showed smear layer covers through out the root canal walls, which is similar to previous studies by Torabinejad *et al*. and Karunakar *et al*. that unveiled positive pressure irrigation without activation would be ineffective in removing the smear layer, especially in the apical third of the root canal.[13,17] In the present study, middle to apical part of the root canal was the main areas where the SEM images of Group I revealed a significant presence of smear layer and the closure of dentinal tubules.

In Group B, ultrasonic agitation of irrigant showed perceivable results attributable to activation of NaOCl result in an upsurge in temperature which enhanced its solvent action on dentinal debris. This result is in accordance to previous study by Mohammadi *et al*.[18] The mechanical actuate of NaOCl with ultrasonic tip generates a microstreaming and provides continuous flow of active products of hypochlorite such as hypochlorous acid and chlorine ions.[19] This microstreaming moves the irrigant against the root canal surfaces, enhancing mechanical cleansing of the canal walls and eradication of smear layer.

Furthermore, in Group B, effective smear layer removal from the coronal and middle third as compared to the apical third due to the larger canal diameter in the coronal and middle third exposes the dentin to a higher volume of irrigants, allowing a better flow of the solution. This similar result was obtained by Souza *et al*.[8] Another cause could be the oscillation of the tips of ultrasonic instruments being decreased by constraining where the diameter of the canal is smallest, which was in agreement with the results of study done by Walmsley and Williams.[8,18,20]

In Group C, the parameters of laser settings were used according to the study by Alfredo *et al*. who demonstrated that 1.5 watts of power settings produced an increase in

the temperature of nearly 10°C, which does not exceed the limit tolerated by the periapical tissues.[21]

In comparison of ultrasonic, the laser group exhibits astounding outcome with effective smear layer removal from the coronal, middle, and apical third of the root canal. The result are in accordance with a previous study done by Wang *et al*.[22] They agitate the irrigant at maximum of 5W, which is approximately 3-fold more compared to the present study. Hence, the similarity of the results could be due to time of exposure in this study in each cycle was 20 s which was nearly three times more compared to the study of Wang *et al*.[22] in which they operated cycle for 7 s.

The apical third of Group C (laser) had lesser smear layer scores than the apical third of Group A and B, with a statistically significant difference. This can be attributed to the narrower diameter of the canal in the apical region resulting in a closer approximation of the laser tip to the root canal walls and thus melting and evaporating the smear layer easily.[9]

The laser effect is explained by ablative and cavitation process. As a result of the ablative process, a large bubble forms, this raises pressure inside the canal. When the bubble bursts, a negative pressure is produced. This pulls the irrigation solution back into the canal and results in cavitation effects.[23] The vapor bubble begins to contract as soon as the irradiation pulse ends. During bubble collapse, a high-speed liquid jet forms, and this creates a significant shear stress on the root canal wall that eliminates debris and the smear layer.[24]

The statistical analysis gives significant result in the removal of the smear layer with NaOCl agitated with a diode laser. The results of this study indicate that NaOCl without EDTA can efficiently remove the organic and collagen debris from the root canal surface with laser agitation.

CONCLUSION

Under the conditions of this study, it can be concluded that the irigant activation systems (laser and ultrasonic) used in the study showed more success in removing the smear layer than the "conventional" irrigation method. Based on the results, NaOCl activation with laser has been demonstrated to be effective in removing the smear layer. Nevertheless, complete eradication from the apical part of the root canal remains a significant challenge. Because none of the irrigation regimens came up with root canals that were entirely devoid of smear layers.

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Conflicts of interest
There are no conflicts of interest.

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