

Effectiveness of different irrigation systems on smear layer removal: A scanning electron microscopic study

Fuat Ahmetoglu¹, Ali Keles¹, Muhammet Yalcin², Neslihan Simsek¹

Correspondence: Dr. Fuat Ahmetoglu
Email: fuat.ahmetoglu@inonu.edu.tr

¹Department of Endodontics, Faculty of Dentistry, Inonu University, Malatya, Turkiye,

²Department of Restorative Dentistry, Faculty of Dentistry, Inonu University, Malatya, Turkiye

ABSTRACT

Objectives: To evaluate effectiveness of the apical negative pressure irrigation (EndoVac), passive ultrasonic irrigation (PUI), and conventional needle irrigation (CI) systems on smear layer (SR) removal. **Materials and Methods:** Sixty single-rooted canines were prepared using NiTi rotary files and subjected to different irrigation regimens: EndoVac with NaOCl (Group 1) or NaOCl/EDTA (Group 2); PUI with NaOCl (Group 3) or NaOCl/EDTA (Group 4); CI with NaOCl (Group 5) or NaOCl/EDTA (Group 6). The roots were split longitudinally. SEM images were taken to evaluate the amount of residual SR.

Results: In Groups 1, 3, and 5, there was no removal of SR ($P > 0.05$). The coronal thirds within Groups 2, 4, and 6 were cleaned completely, but the middle and the apical thirds was achieved partially or completely ($P > 0.05$). **Conclusion:** Regardless of which irrigation system was used, the use of NaOCl alone failed to remove the SR. In NaOCl/EDTA combination groups, the SR was removed partially or completely and no statistical significance. This study demonstrated that in order to remove the SR should be used EDTA solution for final irrigation in the root canal, regardless of the technique in each of the three.

Key words: Conventional needle irrigation, EndoVac system, passive ultrasonic irrigation, scanning electron microscopy, smear layer

INTRODUCTION

Endodontic instrumentation techniques produce a layer of organic and inorganic particles called the smear layer (SL).^[1,2] The particles that range in size from <0.5 to $15 \mu\text{m}$, and include residues of dentine, pulp tissue, and odontoblastic processes; and, in infected teeth, micro-organisms and their by-products.^[3,4]

The prognosis of root canal treatment may be poor if the SR is not removed during the final irrigation. The layer blocks the instrumented canal walls and may serve as a reservoir of microbial irritants. As a consequence, it can prevent penetration of disinfectants into the dentinal tubules and can act as a barrier between filling and canal wall; furthermore, given that it is a

loosely adherent structure, it can prevent the adhesion of root fillings to canal walls.^[1] There has already been plenty of data indicating that removal of SR increases the success of root canal treatment.^[5,6]

For successful root canal treatment, a system that delivers the irrigant effectively to the working length (WL) is required. Conventional irrigation with needles (CI) is the standard procedure but unfortunately, it is not effective in apical third of the root canal and in isthmuses or oval extensions.^[5,6] Current methods for removal of SR include ultrasonic techniques and apical negative pressure systems. Passive ultrasonic irrigation (PUI) relies on the transmission of acoustic energy from an oscillating file or smooth wire to an irrigant in the root canal.^[7] After

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the root canal has been shaped to the master apical file, an irrigation file is placed in the center of the root canal, as far as the apical region. Then, the irrigation file is stimulated to oscillate ultrasonically and activates the irrigant.^[8] The EndoVac system (Discus Dental, Culver City, CA, USA) is one of the apical negative pressure irrigation systems that have been showcased recently. The aim of this system is to provide safe and effective cleaning, especially within the apical zone of the root canal. It is designed to deliver irrigation solutions to the apical end of the canal system for suction removal of debris.^[9,10] The system comprises three parts: The master delivery tip (MDT), macro- and micro-cannulae. The macro- and micro-cannulae are inserted into the apical part of the root canal. The irrigant is then sucked into the apical part of the root canal and is prevented from passing through the apical foramen by applying negative pressure.

The purpose of this study was to evaluate effectiveness of the EndoVac, PUI, and CI systems with respect to removal of SR after instrumentation.

MATERIALS AND METHODS

Sample selection and preparation

Sixty freshly extracted, single-rooted canines without caries or cracks were used in this study. To standardize the samples, all the teeth selected were 23-25 mm in length. External surfaces of the teeth were debrided with a hand scaler. Then, apical parts of the teeth were sealed with nail polish to prevent extrusion of irrigant through the apical foramen. All teeth were stored in physiological saline at room temperature until use.

Canal instrumentation

Standard endodontic access cavity preparations were performed on the pulp chamber, and then a no. 10 K-file (Mani, Tochigi, Japan) was placed in the canal until it was visualized at the apical foramen. The WL was determined by subtracting 1 mm from this measurement. The samples were divided randomly into 6 groups of 10 teeth. Coronal flaring was performed using Gates-Glidden drills sizes 2-4 (Dentsply Maillefer, Ballaigues, Switzerland). All the canals were instrumented with a rotary nickel-titanium files (HeroShaper; Micro-Mega, Besançon, France) using a crown-down technique. The instrumentation sequence was as follows no-taper-length of file: 0.06-no. 30-21 mm, 0.04-no. 30-25 mm. During instrumentation, for the groups that would undergo PUI or CI, teeth were irrigated with 4 mL of 5% NaOCl between every file change, using a plastic

syringe with a 27-gage closed-end needle (irrigation probe; KerrHawe, Bioggio, Switzerland). For the EndoVac group, irrigation was in accordance with the manufacturer's recommendations.^[11] It began after the use of the Gates-Glidden drills and continued for each change of file. After the Gates-Glidden drills were deployed, the EndoVac MDT was placed above the access opening, and 4 mL of 5% NaOCl were delivered and evacuated. The blue macro-cannula was inserted as deep as possible into the root canal without binding and its point moved constantly up and down.

Final irrigation

In Group 1, the canals were irrigated by using the EndoVac system, in which micro-cycles were used. The micro-cannula was placed at the WL, and was repositioned constantly 2 mm up and down in the canal. This constant active irrigation was used during the first cycle with 4 mL of 5% NaOCl. The active irrigation was followed by a second passive cycle with 4 mL of 5% NaOCl. In Group 2, the same protocol for irrigation was followed as for Group 1, but this group underwent a further active cycle micro-irrigation with EDTA. The first cycle used 4 mL of 5% NaOCl, the second cycle 4 mL of 15% EDTA, and the third cycle 4 mL of 5% NaOCl. In Group 3, 4 mL of 5% NaOCl solution were infused into the canal by using a closed-end needle, and then the solution was activated for 1 min by using a non-cutting ultrasonic tip (EMS, Nyon, Switzerland) located at 1 mm from the WL. The tip was operated by an ultrasonic unit (MiniPiezon; EMS). Finally, a rinse of 4 mL of 5% NaOCl was applied with a closed-end needle. In Group 4, 4 mL of 5% NaOCl and then 4 mL of 15% EDTA were each activated for 1 min using a non-cutting ultrasonic tip (EMS) at 1 mm from the WL. Finally, a rinse of 4 mL of 5% NaOCl was applied with a closed-end needle. The intensity of ultrasonic unit was used maximum 50% of power output for 1 min. According to the manufacturer, the frequency employed under the mentioned conditions was approximately 30 kHz. In Group 5, each canal was irrigated with 4 mL of 5% NaOCl by using a closed-end needle that was inserted to the deepest apical point possible without binding, and then this procedure was repeated. In Group 6, the final irrigation sequence was 4 mL of 5% NaOCl, 4 mL of 15% EDTA, and 4 mL of 5% NaOCl, which were applied using a closed-end needle that was inserted to the deepest apical point possible without binding.

Scanning electron microscopy evaluation

The anatomical crowns of the teeth were removed using a diamond disc. All teeth were grooved

vertically on the buccal and lingual surface of the root, using a water-cooled diamond bur. The roots were then split with a surgical chisel and mallet, which resulted in a mesial and distal half for each canal. The canal halves were sputter coated, and viewed with a SEM (LEO Evo 40X VP; Carl Zeiss AG, Oberkochen, Germany). Digital images at $\times 2000$ were taken at the center of coronal, middle, and apical thirds of each root canal for evaluation of the SR. The SEM images were separately scored by two examiners who were blinded to specimen groups using the criteria reported by Torabinejad *et al.*^[12] [Figure 1]. Both examiners assessed the first 20 specimens together for standardization purposes.

Statistical analysis

The differences in SR scores between the different groups were analyzed by means of the Kruskal-Wallis and Mann-Whitney *U* tests. The level of statistical significance was set at $P < 0.05$.

RESULTS

Examples of removal of the SR in the coronal, middle, and apical thirds are shown in Figure 1. The results for each of the groups in the study are shown in Table 1 in the form of the percentage distribution of the SR. When NaOCl was used as the sole irrigation solution, in Groups 1, 3, and 5, the SR could not be removed and remained on the surface, whether in the coronal, middle, or apical thirds. In Groups 2, 4, and 6, in which NaOCl and EDTA were applied successively, it was noted that the SR was removed partially or completely. In each of the three groups in which EDTA was used, the SR was completely removed from the coronal third and partially removed from middle and apical thirds. There were statistically significant differences in the results for removal of the SR among the groups ($P < 0.05$). Groups 2, 4, and 6 showed a significantly better performance than Groups 1, 3, and 5 regarding the removal of the SR in

each third ($P < 0.05$). Groups 1, 3, and 5 showed the worst performance regarding the removal of the SR by registering the score level 2 throughout the entire root canal. There were no significant differences among Groups 1, 3, and 5 regarding removal of the SR ($P > 0.05$). Although a statistically significant difference was found between Groups 2, 4, and 6 and Groups 1, 3, and 5 ($P < 0.05$), no difference was found among the groups themselves ($P > 0.05$).

DISCUSSION

In the present study, we compared the effectiveness of different irrigation methods, namely, the EndoVac

Table 1: Results for removal of the SR in six experimental groups

Group	Score 0	Score 1	Score 2
1			
Coronal	0	0	10 (100)
Middle	0	0	10 (100)
Apical	0	0	10 (100)
2			
Coronal	10 (100)	0	0
Middle	6 (60)	3 (30)	1 (10)
Apical	3 (30)	2 (20)	5 (50)
3			
Coronal	0	0	10 (100)
Middle	0	0	10 (100)
Apical	0	0	10 (100)
4			
Coronal	10 (100)	0	0
Middle	9 (90)	1 (10)	0
Apical	1 (10)	4 (40)	5 (50)
5			
Coronal	0	0	10 (100)
Middle	0	0	10 (100)
Apical	0	0	10 (100)
6			
Coronal	10 (100)	0	0
Middle	8 (80)	2 (20)	0
Apical	1 (10)	4 (40)	5 (50)

*The values in parentheses are percentages. SR: systems on smear layer

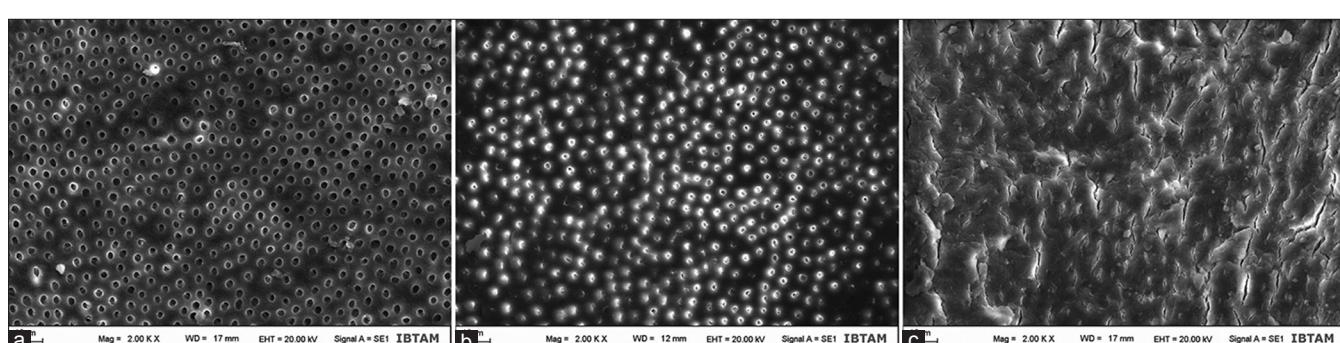


Figure 1: Representative SEM photomicrographs with (a) score 0; no SR on the surface of canal walls; all tubules were clean and open, (b) score 1; moderate SR; no SR on the surface of canal walls, but tubules contained debris, (c) score 2; heavy SR; SR covered the canal surface and the tubules

system, which has been promoted recently, and the PUI and traditional endodontic methods, with respect to removal of the SR using NaOCl or a combination of NaOCl and EDTA as the irrigation solutions.

The SR is produced on root canal walls during the process of root canal preparation. Although there has been no consensus on the subject, it is suggested that this layer should be removed to provide better disinfection of canal and root canal sealer adaptation.^[1,13] Removal of the SR can be accomplished by the effective irrigation techniques with the use of irrigation solutions that dissolve both organic and inorganic components of the layer.^[14] The ability to clean the root canal efficiently depends on both the method and the irrigation solutions used. NaOCl can dissolve organic structures, whereas EDTA, by reacting with calcium ions, dissolves inorganic structures. As a result of this difference, the recommended method is the utilization of NaOCl and EDTA both successively and simultaneously.^[1,14,15] For NaOCl, a concentration of 1-6% is advised.^[14] For EDTA, a concentration greater than 15% causes peri- and inter-tubular dentine erosion.^[16] Therefore, it was used concentrations of 5% NaOCl and 15% EDTA.

The main emphasis of the present study was to establish the ability of the solutions to remove the SR. A significant difference in relation to the removal of the SR was observed between the groups in which NaOCl was used solely as the irrigation solution and the groups in which both NaOCl and EDTA were used. As in previous studies,^[4,12] president study was showed that when NaOCl was used as the sole irrigation solution, it did not remove the SR to any degree. However, when NaOCl and EDTA were used in combination, it was observed complete or partial removal of the SR depending on the region of the root canal.

The secondary emphasis was to establish which irrigation method was most effective for removal of the SR. Uroz-Torres *et al.*^[14] evaluated traditional and passive ultrasonic/sonic irrigation methods with a combination of NaOCl and EDTA. They demonstrated that the SR was removed completely in the coronal third of the root canal, and removed partially in the middle third. They had a success rate of 10-20% removal within the apical third. Similar results for the conventional irrigation method were achieved by Abarajithan *et al.*,^[17] Lui *et al.*^[4] demonstrated the effectiveness of PUI for removal of the SR, with success in areas that were 6 and 2 mm from the apical zone. Similar results were obtained in the present study.

This study was found that when NaOCl and EDTA were used in combination, the SR in the coronal region was removed completely, and better cleaning results were achieved in the middle than in the apical region, regardless of which method was used. Although the level of effectiveness that was expected from the EndoVac^[11] was not achieved entirely in the apical third, it did yield better results than the other methods. However, it did not show a statistical difference between other groups.

Ultrasonic irrigation is based on removal of the SR by acoustic streaming from the passive tip.^[9] This method is particularly effective on teeth with straight canals. To obtain the maximum effect from ultrasonic irrigation, the passive file should oscillate freely within the canal without contacting the canal walls.^[18,19] The above conditions were all met in the present study. However, the failure that was experienced with this method, in particular in the apical region, can be explained by the intensity of ultrasonic activation; it was used the lowest power intensity of the device. Jiang *et al.*^[20] have shown that cleaning efficiency increases in parallel with the output of the ultrasonic activation. They found that the best cleaning results were achieved in the group subjected to the greatest output. In the present study, low level ultrasonic irrigation proved to be completely successful for removal of the SR in the coronal and middle regions; however, no such success was seen in the apical third. In future research, success could possibly be achieved in the apical third by increasing the output of the ultrasonic activation.

The effectiveness of the positive pressure method, which has been used for many years, has now become a subject of debate. The negative pressure irrigation system offers the possibility of safe and effective cleansing, especially in the apical region of the root canal.^[5,21] In the coronal and middle regions, successful results have been achieved in other studies^[17,22] using the EndoVac system, as in the present study. However, it achieved no complete success in the apical region. The main reason for such failure is that effective disinfection and cleansing in the root canal are related closely to the volume of irrigant. Increased volumes provide more effective irrigation.^[23,24] Perhaps the most important problem regarding the EndoVac system is that a certain amount of irrigant is sectioned out of the canal before it reaches the apical region. Therefore, the amount of cleaning solution that comes into contact with the canal wall decreases gradually as it nears the apical region. This might explain the lesser

effect in the apical third. Brunson *et al.*^[13] achieved more effective irrigation by delivering a larger volume of irrigant to the apical region. Although the EndoVac system resulted in the lowest smear score in the apical third, it failed to achieve complete cleaning.

CONCLUSIONS

The present results indicated that, regardless of which irrigation was used, the use of NaOCl alone failed to remove the SR. In the groups that used NaOCl/EDTA in combination, the SI was removed partially or completely. Although the best results for cleaning in the apical third of the root canal were achieved in Group 2, in which the EndoVac system was used, no statistical significance was recorded between it and Groups 4 and 6, in which PUI and CI were used, respectively.

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