ORIGINAL RESEARCH

Assessment of Smear Layer Removal and Penetration Depth of Root Canal Irrigant Using Different Irrigation Activation Systems: A Comparative Study

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Abstract

Aim: The aim of the current study was to evaluate the penetration depth and smear layer removal of root canal irrigant using various irrigation activation techniques.

Materials and methods: In this investigation, sixty single-rooted premolars extracted for orthodontic purposes were chosen. Diamond burs were used to create an access cavity, and #10 K-file was used to determine the patency. About sixty samples were divided into the following three groups (20 samples in each group), group I: Irrigation with conventional needle, group II: Activation of EndoVac system, group III: Passive ultrasonic irrigation (PUI). The efficacy of the smear layer was assessed using a scanning electron microscopy at a ×2000 magnification. One-way ANOVA was used to record and analyze the data. All statistical analyses were performed with a significance level of $p < 0.05$.

Results: At coronal third, the maximum smear layer was removed in group II (1.26 ± 0.02) followed by group III (1.84 ± 0.16) and group I (2.89 ± 0.21). At middle third, smear layer removal was maximum in group I (1.18 ± 0.10) followed by group III (1.72 ± 0.09) and group I (2.66 ± 0.18). At apical third, the more smear layer was removed in group II (1.02 ± 0.01) followed by group III (1.58 ± 0.08) and group I (2.38 ± 0.06). There was a highly significant difference found between the three different irrigation systems at all three levels ($p < 0.001$).

Conclusion: In conclusion, every irrigation device that was evaluated was successful in removing the smear layer from the root canal. However, the EndoVac system group removed a greater amount of smear layer compared with PUI and conventional needle group.

Clinical significance: With the goal of promoting cleaning that is beyond the ability of mechanical devices, irrigation is a crucial part of root canal therapy. If an efficient irrigation delivery system is used, the irrigants can reach the working length (WL). This type of distribution system needs to provide a suitable amount of irrigants up to the WL, as well as have enough flow and be effective at debriding the entire canal system.

Keywords: Irrigation systems, Root canal, Scanning electron microscopy, Smear layer.

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Introduction

The goal of an endodontic treatment is to eradicate microorganisms from affected radicular canals by combining a biomechanical technique with an antibacterial therapy to induce periapical tissue repair. The purpose of instrumentation in clinical practice is to remove a portion of hard tissue from the root canal, make it easier for irrigants to reach the apical anatomy, and shape the canal system so that a permanent root filling can be placed in it. It is not possible to reliably eradicate the bacteria from infected root canals using mechanical instrumentation or saline irrigation alone; nevertheless, enough irrigation in conjunction with instrumentation is necessary to finish the cleaning process and lower the microbial load in the canal system.[1]

The irrigants must reach the working length (WL) through an efficient irrigation delivery system. To effectively debride the entire canal system, such a delivery system must have sufficient flow and deliver a sufficient volume of irrigant all the way to WL. There have been reports that the smear layer and debris from the intricate anatomy of the root canal system could not be removed by hand irrigation.[2]

The traditional needle irrigation method is the one that is most frequently utilized. It entails changing and restocking the irrigant in the canal's apical third.[3] Since this irrigating technique's effectiveness is not all that great, better cleaning especially in complex areas requires improved procedures. Over time, a number of additional methods have emerged, including ultrasonically

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activated irrigation and hand dynamic agitation of gutta percha cones.[4] Recently, an EndoVac system was showcased and it is one among the irrigation systems which creates a negative apical pressure. The objective of this system is to deliver an effective and safe canal cleaning, particularly in the apical portion of the root canal. 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.[5] An irrigation file is positioned in the center of the root canal, as far as the apical region, after the root canal has been shaped to the master apical file. Next, the irrigant is activated by stimulating the irrigation file to oscillate ultrasonically.[6] There is a dearth of information on the comparison between PUI devices and conventional needles with EndoVac. Hence, the present study was conducted to evaluate the penetration depth and smear layer removal of root canal irrigant using three various irrigation activation techniques.

Materials and Methods

Sample Selection and Preparation

The present *in vitro* investigation was conducted in the Department of Conservative Dentistry and Endodontics, Aditya Dental College, India during the year of 2023. Sixty single-rooted premolars extracted for orthodontic purposes were chosen for the present study. Using a hand scaler, the teeth's exterior surfaces were debrided. Then, to avoid the irrigant from extruding through the apical foramen, the apical portions of the teeth were sealed with nail paint. Before being used, every tooth was kept at room temperature in physiological saline.

Instrumentation of Canal

Diamond burs were used to create an access cavity and #10 K-file (Mani, Utsunomiya, Japan) was used to determine the patency. Using a microscope, the length of each canal was measured by inserting the file until the tip was barely visible at the apical foramen. Using a diamond disc, the teeth's anatomical crowns were removed. Sixty root canals were manually instrumented employing the step-back approach. Initially, 5.25% NaOCl (5 mL) irrigation was combined with K-files corresponding to #40 master apical sizes for manual canal instrumentation.

Sample Allocation

The sixty samples were divided into the following three groups (20 samples in each group):

Group I: Irrigation with Conventional Needle

5 mL of 5.25% NaOCl, 5 mL of 17% EDTA, and 5 mL of 5.25% NaOCl were used for the final irrigation. Activation was not applied to this group; irrigation was performed with a 30-gauge needle (NaviTip, Ultradent, South Jordan, UT, USA).

Group II: Activation of EndoVac System

The canals were irrigated using the EndoVac system (EndoVac, Discus Dental, Culver City, CA, USA), with using microcycles. After being placed at the WL, the microcannula was repeatedly moved 2 mm up and down in the canal. About 5 mL of 5.25% NaOCl, 5 mL of 17% EDTA, and 5 mL of 5.25% NaOCl were used in the first cycle of this continuous active irrigation. The active irrigation was followed by a second passive cycle using the same methodology.

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Group III: Passive Ultrasonic Irrigation

A noncutting size 25 IRRI S ultrasonic tip (VDW) powered by an ultrasonic device with a 30% power setting was used for the final irrigation, which involved passive ultrasonic activation of the irrigants (VDW Ultra, VDW). A power setting of 4 was used to activate the ultrasonic file, which was inserted into the canal 2 mm short of the WL without hitting the walls. About 5 mL of 5.25% NaOCl with a 1-minute activation period made up the final irrigation. Next came 5 mL of 17% EDTA, which was activated for 1 minute, and 5 mL of 5.25% NaOCl, which was similarly activated for 1 minute.

Evaluation of Samples under Scanning Electron Microscopy

Using a water-cooled diamond bur, the buccal and lingual surfaces of the roots of every tooth were grooved vertically and two halves were obtained from each sample. After being sputter coated, the canal halves were examined using a SEM (LEO Evo 40X VP; Carl Zeiss AG, Oberkochen, Germany). To assess the smear layer, digital photos at a magnification of ×2000 were captured in the coronal, middle, and apical thirds of every root canal. Single investigator participated and recorded the data. The SEM pictures were given individual scores based on the stated by Torabinejad M et al.[7]

Score 1 = Absence of smear layer. Every tubule was open and clean, and the root canal surface was free of smear layers.

Score 2 = Moderate coating of smears. The root canal surface does not have a smear layer, but the tubules contain debris.

Score 3 = Heavy coating of smears. Smear layer present on the tubules and surfaces of the root canals.

Statistical Analysis

The software program SPSS for Windows 17.0 (SPSS Inc., Chicago, IL, USA) was used to perform the statistical analysis. One-way ANOVA was used to examine the variations in smear layer removal efficacy scores between the groups. All statistical analysis was performed with a significance level of $p < 0.05$.

Results

Table 1 presents the mean smear layer removal efficacy of three different irrigation activation systems at coronal third. The maximum smear layer was removed using activation of EndoVac system group (1.26 ± 0.02), followed by PUI group (1.84 ± 0.16) and irrigation with conventional needle group (2.89 ± 0.21). There was a highly significant difference found between the three different irrigation systems.

Table 2 depicts the mean smear layer removal efficacy of three different irrigation activation systems at the middle third. The more smear layer was removed using activation of EndoVac system group (1.18 ± 0.10), followed by PUI group (1.72 ± 0.09) and irrigation with conventional needle group (2.66 ± 0.18). There was a highly significant difference found between the three different irrigation systems ($p < 0.001$).

Table 3 presented the mean smear layer removal efficacy of three different irrigation activation systems at the apical third. The more smear layer was removed using activation of EndoVac

Table 1: Comparison of the mean smear layer removal efficacy of three different irrigation activation systems at coronal third

Experimental groups	*Mean ± SD*	*F-value*	*p-value*	*Significance*
Group I: Irrigation with conventional needle	2.89 ± 0.21			
Group II: Activation of EndoVac system	1.26 ± 0.02	18.174	0.001	HS
Group III: Passive ultrasonic irrigation	1.84 ± 0.16			

HS, highly significant

Table 2: Comparison of the mean smear layer removal efficacy of three different irrigation activation systems at the middle third

Experimental groups	*Mean ± SD*	*F-value*	*p-value*	*Significance*
Group I: Irrigation with conventional needle	2.66 ± 0.18			
Group II: Activation of EndoVac system	1.18 ± 0.10	18.904	0.001	HS
Group III: Passive ultrasonic irrigation	1.72 ± 0.09			

HS, highly significant

Table 3: Comparison of the mean smear layer removal efficacy of three different irrigation activation systems at the apical third

Experimental groups	*Mean ± SD*	*F-value*	*p-value*	*Significance*
Group I: Irrigation with conventional needle	2.38 ± 0.06			
Group II: Activation of EndoVac system	1.02 ± 0.01	18.224	0.001	HS
Group III: Passive ultrasonic irrigation	1.58 ± 0.08			

HS, highly significant

system group (1.02 ± 0.01) followed by PUI group (1.58 ± 0.08) and irrigation with conventional needle group (2.38 ± 0.06). A highly significant difference was observed between the three different irrigation systems ($p < 0.001$).

The inference of the present study includes that the maximum smear layer removed in EndoVac system group was compared with the PUI and conventional needle group.

Discussion

Debridement of the root canal system is crucial to the success of endodontics. Smear layers are created by biomechanical preparation processes and consist of both inorganic and organic particles. Cleaning results from irrigation are superior to those from root canal preparation alone. It eliminates the smear layer, flushes out trash, and destroys bacteria. Treatment outcome could be affected if the smear layer is not removed during the final irrigation.[8]

The most effective irrigant solution currently available for removing the smear layer is EDTA; in the current investigation, a final rinse using 17% EDTA, and then 5.25% NaOCl was utilized following instrumentation since it consistently removed debris. Regarding the ideal volume or activation technique for the irrigating solutions, there is, nevertheless, disagreement.[9]

Even though there have been a lot of new endodontic instruments developed in the past 10 years, research indicates that at least 10% of the primary root canal walls are still unaffected by the instruments, and that the number rises to over 50% in cases where the root canal has anatomic abnormalities that include isthmuses and recesses.[10] Research carried out by Lacerda MFLS et al.[11] and Zuolo ML et al.[12] revealed that even in straight root canals, over 10% of the dentine walls remained unaltered by tools that claimed to mechanically clean the root canal in three dimensions. Thus, cleaning untreated walls and places inaccessible to mechanical equipment requires efficient irrigation.

According to the current study's findings, the EndoVac system statistically removes more debris ($p < 0.05$) than the conventional irrigation in the middle and coronal sections of the samples in addition to the apical third of the root canal. The EndoVac system's creation of a negative apical pressure may be the cause of these clean canal outcomes. The irrigant is drawn down the canal walls up to the apex by the negative apical pressure, creating a swift turbulent current force that travels toward the microcannula's termination. The debris is removed from the closed apical end of the root canals via the microcannula's orifices. The results of the present study were in agreement with Siu C and Baumgartner JC[13] and Nielsen BA and Baumgartner JC[14] who concluded that the EndoVac system is more effective than the conventional irrigation in the removal of debris at 1 mm from the WL ($p < 0.05$). At every 6 seconds, the microcannula in the current investigation was pushed 2 mm up from the WL to the coronal section. The microcannula was positioned at the WL after the timer went off, because this apical-coronal motion persisted for 30 seconds.

The current investigation found that the efficacy of PUI in removing smear layers was superior to that of conventional needle irrigation. Shear stress pressures are created adjacent to the canal walls by the oscillation of the instrument, and PUI activates the irrigant by producing acoustic microstreaming. The findings are consistent with the research done by Walmsley AD and Williams AR[15] and Blank-Gonçalves LM et al.,[16] which revealed that for ultrasonic irrigation to have the greatest impact, the passive file must be able to oscillate freely inside the canal without coming into touch with the walls. According to research done by Jiang LM et al.,[17] cleaning effectiveness rises in step with ultrasonic activation power. They discovered that the group with the greatest output had the best cleaning outcomes. In the current investigation, all three levels of the smear layer were successfully removed using low level ultrasonic irrigation.

The conventional irrigation is still used by both endodontists and general practitioners. It comprises either passively or actively agitating the irrigant while inserting needles of various gauges into the canal. The needle in the canal moves up and down to agitate the tissue. Certain needles are made to deliver the irrigant through the distal end, while others have a closed-ended side vent that allows the irrigant to be supplied laterally. The irrigant is delivered by the conventional needle irrigation approach no more than 0–1.1 mm beyond the needle tip. The intricate anatomical regions (such as the lateral canals, isthmuses, fins, and accessory canals) are not sufficiently cleaned by method.[18]

The present study's limitations include the fact that it was conducted *in vitro* and that a complete replication of the intraoral

environment was not possible. Long-term clinical investigations are therefore advised to validate the findings of this investigation.

Conclusion

Within limitation, the present study concluded that every irrigation device that was evaluated was successful in removing the smear layer from the root canal. However, EndoVac system group removed a greater amount of smear layer compared to PUI and conventional needle group. The success of endodontic treatment mainly depends on the removal of bacteria, dentin debris, and necrotic and inflammatory pulp tissue.

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