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Original Research

A Comparative Evaluation of Smear Layer Removal by using Three Different Irrigating Systems in Endodontics: An *In-Vitro* Scanning Electron Microscopic Study

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Abstract:

Background: The purpose of this study was to compare and evaluate the efficacy of conventional needle irrigation delivery system, EndoActivator system, and EndoVac irrigation in removal of smear layer in root canals.

Materials and Methods: 45 freshly extracted human mandibular premolar teeth were used. The teeth were decoronated to obtain standard working length of 17 mm for all samples. Working length determination was done, and samples were instrumented up to 40 size (K-file) with 2.5% NaOCl irrigation between each instrumentation followed by irrigation with 5 ml of saline. Then, each sample was subjected to irrigation with 5 ml of 17% ethylenediaminetetraacetic acid (EDTA) using three different irrigating systems. Group I: 15 samples with 17% EDTA using conventional needle irrigation. Group II: 15 samples with 17% EDTA using EndoActivator irrigating system. Group III: 15 sample with 17% EDTA using EndoVac irrigation system. Final irrigation was done with 5 ml of Saline using a 27-gauge needle with 20 mm length. Longitudinal sectioning of the samples was done. Then, the samples were observed under scanning electron microscope at apical, middle, and coronal levels. The images were scored according to the criteria given by Torabinejad *et al.*: (i) 1 = No smear layer, (ii) 2 = Moderate smear layer, (iii) 3 = Heavy smear layer. Data obtained were analyzed using Kruskal-Wallis analysis of variance followed by Mann–Whitney U-test for individual comparison. The level of significance was set as 0.05.

Results: The results of the present study showed that all the irrigating systems used removed smear layer from the root canal. The EndoActivator (Group II) and EndoVac (Group III) irrigating systems had no difference among them and showed better smear layer removal at all levels of the root canal compared to conventional needle irrigation.

Conclusion: EndoActivator and EndoVac give relatively cleaner surfaces of root canal walls when used with EDTA for smear layer removal than conventional needle irrigation and probably aid in a better clinical outcome of the root canal treatment.

Key Words: Ethylenediaminetetraacetic acid, EndoActivator, EndoVac, scanning electron microscope, smear layer

Introduction

Debridement of root canal system is critical for endodontic success, as it allows for cleaning beyond what might be achieved by root canal instrumentation alone.[1,2] Ideally, root canal irrigants should flush out all debris, dissolve organic tissue, kill microorganisms, and destroy microbial byproducts, as well as remove the smear layer.[2] The smear layer impedes the penetration of intra-canal disinfectants and sealers into dentinal tubules.[3] The presence of smear layer negatively influences the coronal and apical seal of root canal treated teeth.[1]

Ethylenediaminetetraacetic acid (EDTA) is the most frequently used chelator in endodontics.[4] Several studies have shown that the use of a combination of sodium hypochlorite (2.5-5%) and EDTA (10-17%) is effective in the removal of the organic and inorganic debris. EDTA is a calcium chelating agent, and therefore, capable of removing the smear layer. It has been found that a final flush of EDTA can open up the dentinal tubules and increases the number of lateral canals to be filled.[5]

Hand and/or rotary instrumentation with needle irrigation does not productively clean the entire root canal.[6,7] Furthermore, the intricacies in the apical third of the root canal system make thorough debridement a clinical challenge.[8] Efficiency of the irrigating device depends on its ability of reaching out the irrigant to the most apical part of the canal and the non instrumented areas within the root canal system.[1]

EndoVac (Discus Dental, Culver City, CA, USA), an irrigation system was introduced in 2007. It was designed to safely deliver irrigant to the apical part of root canal space. The device comprises a delivery/evacuation tip that is attached to a syringe containing the irrigant, and the syringe in turn connected to a high-speed suction of the dental chair.[1]

The EndoActivator system (Dentsply Tulsa Dental Specialities, Tulsa, UK) was introduced to improve root canal irrigation. It is a canal irrigation system that is based on sonic technology; it includes a portable handpiece and three types of disposable flexible polymer tips of different sizes that do not cut radicular dentin. The vigorous agitation of the irrigant in the root canal by the device potentiates the action of the irrigant.[9]

Assuming the importance of smear layer removal, the present study evaluated and compared efficacy in smear layer removal of needle irrigation, EndoActivator, and EndoVac irrigation system.

Materials and Methods

The sample consisted of 45 freshly extracted human mandibular premolars. External surfaces of the teeth were debrided with hand scaler teeth were immersed in physiologic saline solution until use. Following criteria was used to select the teeth.

Inclusion criteria

a. Teeth that were caries-free
b. Teeth extracted for orthodontic purpose
c. Teeth extracted for periodontal reasons
d. Teeth with single root
e. Teeth with single canal and mature apex.

Exclusion criteria

a. Teeth with the presence of caries in the crown or root
b. Teeth with fracture lines or cracks
c. Teeth with more than one canal
d. Teeth with immature apex.

Teeth preparation for the study

Buccal and proximal radiographs were taken to affirm that the teeth had a single canal. The teeth were cleaned and stored in saline solution until use. On decoronation with a diamond disc, all teeth samples with a consistent working length of 17 mm were obtained. Following access opening, primary coronal preparation was completed by means of Gates-Glidden drills up to size number 3. An ISO size 15 K-file was used for canal negotiation, until it passed through the major diameter of apical foramen. The working length was assessed to be at 1 mm short of the length when the tip of the file passed through the major diameter of apical foramen. The samples were instrumented in a crown-down technique using sequentially sized K-files up to size #40 as a master apical file. 1 ml of 2.5% sodium hypochlorite was used as an irrigant between instruments. Samples were randomly divided into three groups, and each group had 15 teeth, the grouping was based on the irrigating device used with 17% EDTA as irrigant.

Group I - Conventional needle irrigation
Group II - EndoActivator irrigation system
Group III - EndoVac irrigation system

Group I

Instrumentation was done up to the master apical file size #40 with one ml of 2.5% sodium hypochlorite irrigation between each instrument. The root canals were then irrigated with 5 ml of 17% EDTA using a 27-gauge needle. The needle was placed 1 mm within the working length during irrigation; a constant coronoapical motion was used with the delivery tip. Then, the final irrigation was performed using 5 ml saline solution.

Group II

After optimally preparing the canal, using sodium hypochlorite irrigation, each canal was then irrigated with 5 ml of 17% EDTA using the 27-gauge needle. The intracanal solution was activated with a yellow (15/02) EndoActivator tip at a speed of 10 kHz for 30 s per canal followed by a final rinse with saline solution.

Group III

Irrigation using EndoVac system involves a macroirrigation and microirrigation. Once the master apical file reaches the working length, macroirrigation of the canal using 1 ml sodium hypochlorite was done. This was done by using the EndoVac delivery/evacuation tip while the macrocannula was constantly moved in a corono apical direction in the canal from a binding point at the most apical part of the canal to a position just below the orifice. Using the microcannula positioned at 1 mm from the working length, irrigation was done with 17% EDTA. A final rinse with 5 ml saline solution was done.

Sample preparation for scanning electron microscope (SEM) analysis

Absorbent paper points were used to dry the canals, and the orifice of the canals were secured with a cotton pellet. Deep grooves were cut on the buccal and lingual surfaces of root using diamond discs, taking care not to perforate the root canals. Chisel and a mallet were used to split the tooth. One-half of each tooth was chosen and set for SEM examination.

SEM analysis

On being assembled with coded stubs, the specimens were positioned in a vacuum chamber and sputter-coated with a gold layer of 300 A°.

The specimens were then interpreted using an SEM (Hitachi SE SEM-SU 6600). The dentinal surfaces were scrutinized at apical, middle, and cervical thirds at a magnification of ×2000 for the presence/absence of smear layer on the canal surface as well as dentinal tubules.

Photomicrographs (×2000) were taken at the apical, middle, and coronal thirds. Smear layer removal was evaluated by evaluators who were blind of the irrigation regimens. Scores were assigned in accordance with the rating system proposed by Torabinejad *et al*.[10]

- 1 = No smear layer (no smear layer on the surface of the root canal: All tubules were clean and open)

- 2 = Moderate smear layer (no smear layer on the surface of the root canal, but tubules contained debris)
- 3 = Heavy smear layer (smear layer covered the root canal surface and the tubules).

Statistical analysis
Data were analyzed using the following statistical analyses Kruskal-Wallis analysis of variance and Mann–Whitney U-tests. The level of statistical significance was set as $P > 0.05$.

Result
Representative SEM photomicrograph of scores 1, 2, and 3 are shown in Figure 1, the results for each group are tabulated in the form of percentage distribution of smear layer removal and shown in Table 1.

The results for the groups can be overviewed as follows under 3 levels of the root canal.

Coronal third
EndoActivator (Group II) and EndoVac (Group III) showed effective smear layer removal from the coronal third, without statistically significant difference between the groups ($P > 0.05$). Conventional needle irrigation (Group I) showed lesser smear layer removal compared to EndoActivator (Group II) and EndoVac (Group III) the difference being statistically significant ($P < 0.05$).

Table 1: Results of smear layer removal in 3 experimental group.

Group	Score 1 (%)	Score 2 (%)	Score 3 (%)
Needle			
Coronal	0	09 (60)	06 (40)
Middle	0	08 (53)	07 (47)
Apical	0	06 (40)	09 (60)
Endo activator			
Coronal	09 (60)	05 (33.3)	01 (6.7)
Middle	10 66.6)	04 (26.7)	01 (6.7)
Apical	09 (60)	05 (33.3)	01 (6.7)
Endo vac			
Coronal	11 (73.3)	04 (26.7)	0
Middle	10 (66.6)	05 (33.4)	0
Middle	10 (66.6)	05 (33.4)	0

Middle third
EndoActivator (Group II) and EndoVac (Group III) showed effective smear layer removal from the middle third, without statistically significant difference between the groups ($P > 0.05$). Conventional needle irrigation (Group I) showed lesser smear layer removal compared to EndoActivator (Group II) and EndoVac (Group III) the difference being statistically significant ($P < 0.05$).

Apical third
EndoActivator (Group II) and EndoVac (Group III) showed effective smear layer removal from the apical third, without statistically significant difference between the groups ($P > 0.05$). Conventional needle irrigation (Group I) showed lesser smear layer removal compared to EndoActivator (Group II) and EndoVac (Group III) the difference being statistically significant ($P < 0.05$).

Generally, it can be concluded that EndoActivator (Group II) and EndoVac (Group III) showed better smear layer removal from the coronal, middle, and apical third compared to needle irrigation group (Group I).

Discussion
According to Mader and Baumgartner, smear layer is formed on the dentinal wall during root canal preparation, which contains organic and inorganic components.[11] The removal of smear layer, increases the permeability of dentinal tubules to the irrigants, enhances the adaptation of root canal filling material, and improves the sealing of root canal obturation.[12]

Controversy exists as to either remove smear layer or leave it unaltered before the obturation of root canal. Microorganisms can remain on root canal surface or penetrate into dentinal tubules despite thorough chemomechanical preparation. Some authors propose that smear layer acts as an obstacle to passage of bacteria as well as their metabolites, back into the canal. Studies have shown that bacteria housed in smear layer not only endure the environment but also proliferate and move into the dentinal tubules. This would appear to strongly vouch for smear layer elimination.[13] Assuming the importance of smear

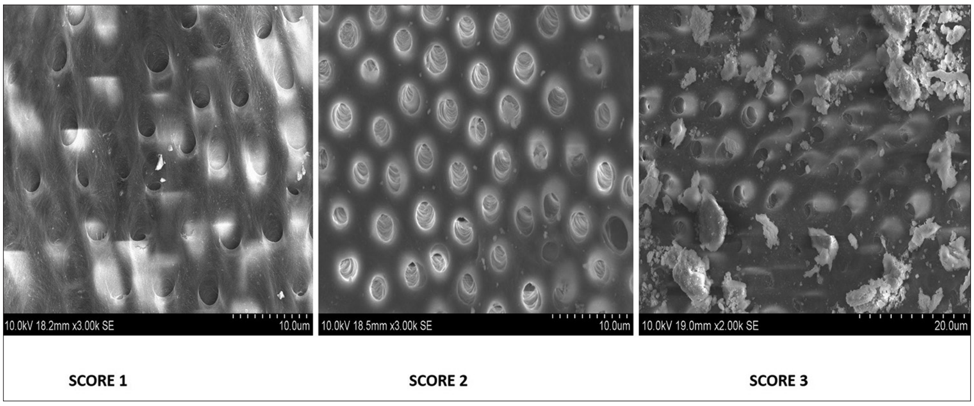

Figure 1: SEM images for the coronal, middle and apical areas of representative samples

layer removal, present study values and relates the efficiency of three different irrigating systems in their efficacy to remove smear layer subsequent to root canal preparation on extracted teeth using SEM.

In the present study, the apical part of the canal was enlarged up to ISO size 40. This is in accordance with several other studies that have provided a strong consensus that larger enlargement in apical area leads to a effective reduction in remaining bacteria and dentin debris as compared with smaller enlargement of canal.[14,15]

High centrifugal forces due to the movement, as well the contiguity of the instrument to the dentin wall led to formation of a thicker smear layer which was more difficult for removal with chelating agents.[16] The quantity of smear layer produced by motorized preparation, for example, with Gates-Glidden or post drills, has been shown to be greater in volume than that being produced with hand filing.[17] However, McComb and Smith observed under SEM similar surfaces being created on instrumentation by K-files, K-reamers, and Giromatic reciprocating files.[18] In the present study also K-files were used for instrumentation.

Sodium hypochlorite is both an oxidizing and hydrolyzing agent. It has a strong proteolytic effect, and therefore, serves as an excellent aid during instrumentation. Organic tissues are well-dissolved with an increase in temperature of sodium hypochlorite.[19] The study done by Torabinejad *et al.* has shown that, in effect, lower concentration form of NaOCl is not substandard to higher concentration.[10] In the present study, 2.5% NaOCl solution was used for the best effect.

EDTA, a common content of chelating agents, reacts with the calcium ions of dentin and forms soluble calcium chelates. Chelating agents were first introduced in endodontics for the preparation of calcified and narrow canal in 1957 by Nygaard-Ostby.[13]

In the present study also sodium hypochlorite was used during the instrumentation of root canal to prolong disinfection and tissue dissolution. Then, a chelator solution, EDTA was administered to clean the canal system of inorganic debris which in turn was activated using three different irrigating systems.

Conventional needle irrigation is still a generally recognized method of irrigant delivery by the clinicians. In the present study, needle irrigation was being compared with EndoVac and EndoActivator irrigation systems. Needle irrigation was not found to be very effective in removing the smear layer at apical, middle, and coronal thirds of the root canal when compared to other systems. Various studies have showed that by needle irrigation, the coronal third of the root canals may be effectively cleaned, but the apical part may remain uncleansed because the anticipated delivery of irrigant to the full working length with needle irrigation may not be achieved.[20,21] In the present study also cleaning efficacy at apical third was slightly lesser compared to that at coronal and middle thirds without any statistically significant difference. This is because irrigant can advance only 1 mm ahead of the tip of the needle.[8] Delivery of the irrigating solution by low positive pressure does not let the irrigant to reach the fullest of the working length. However, greater positive pressure and placing of the needle closer to the root canal working length could increase the chances of periapical extrusion of the irrigant. In a biological model, the root is encased in a bony socket, the root canal works out to be a channel with closed-end. The resultant gas entrapment at its closed end produces a vapor lock effect preventing the irrigant from effectively reaching the working length.[22]

Compared to conventional needle irrigation, EndoVac irrigation system is based on hydrodynamic activation of the irrigant using pressure-alternating mechanism.[23] This method facilitates irrigant delivery to the fullest of the working length without risk of periapical disturbances due to the irrigant, at the same time efficiently moving the debris more coronally.[24] EndoVac has shown to be a meticulous method to deliver irrigant to the most apical part of the root canal system.[2,25,26] Parente *et al.* showed that the challenges in fluid movement in a closed root canal system can be efficiently tackled with apical negative pressure.[27] Heilborn *et al.*, have shown a higher root canal cleansing effect by EndoVac system than compared to conventional irrigation, in the apical part of root canal, with lesser time of exposure.[28,29]

Agitation of the irrigant by the negative pressure could be the most probable cause of improved efficacy in cleansing root canals throughout the length though the volume of EDTA remained constant with all groups. Furthermore, the path of the fluid movement is in a corono apical direction with EndoVac, whereas it is from the apicocoronal direction in traditional needle irrigation.[1]

Earlier studies have shown that an improvement in canal debridement and irrigant flow was achieved with an increase in the apical size preparation and instrument taper.[15] Brunson *et al.*, have also shown for the use of EndoVac an increase in canal enlargement from ISO #35 to ISO#40 led to a 44% increase in the volume of irrigant at the apical region of the root.[30] Furthermore, an increase in apical preparation led to the unrestricted functioning of the orifices of the microcannula from the canal walls. The better space obtained around the microcannula at the tip results in increased volume of irrigant at the apical part providing enhanced removal of smear layer.[1] To improve the flow at the apex, a standardized apical preparation of ISO size 40 was incorporated in the study.

Agitation of an irrigant is carried out by placing an instrument into the root canal and moving it in a rotating, oscillating, or reciprocating motion. The agitation can be carried out with several methods including manual reciprocation, a mechanically driven rotary instrument, and sonic or ultrasonic devices.[31] The EndoActivator (Advanced Endodontics, Santa Barbara, CA) is marketed as a sonic device that is battery operated and functions at cycles 2,000, 6,000, and 10,000 cycles per minute.

The effect of the EndoActivator on irrigant penetration has been evaluated by several investigators. De Gregorio compared the effect of EndoActivator, needle irrigation, and ultrasonic activation on irrigant penetration in simulated lateral canals in cleared extracted teeth. Agitation was carried out for 1 min at a distance of 2 mm from the apex. The amount of colored dye entering the lateral canals was compared. It was observed that there was no significant difference between the EndoActivator and ultrasonic activation; however, both were more effective than conventional needle irrigation.

In the present study, EndoActivator was compared with EndoVac and conventional needle irrigation in removing the smear layer, and it was found that EndoActivator showed comparable results with that of EndoVac group without statistically significant difference at coronal, middle, and apical thirds of the root canal system.

Mechanism of action involved in disrupting the debris and smear layer for sonic activation using EndoActivator is due to acoustic streaming and cavitation. Acoustic streaming is defined as the swift movement of fluid in a vortex-like motion about a vibrating object.[32] It creates small, strong, and current of fluid (i.e., eddy flow) around the instruments. This eddying occurs toward the tip rather than at the coronal part of the file. Acoustic streaming improves the cleaning effect of the irrigant in the pulp space through hydrodynamic shear stress. In the root canal, this fluid movement may be caused by a vibrating file; however, it can be associated with small gas bubbles set into oscillation by the fluctuating pressure field generated by the file. With this in mind, stable cavitation can be included when describing acoustic streaming.[33]

During oscillation in a fluid, a positive pressure subsequent to a negative pressure is created. If the file's tensile strength is exceeded during the oscillation of pressure gradients, a cavity is formed in the fluid in the negative phase. During the next positive pressure phase, the cavity collapses inward with great force; this is cavitation. It occurs when the file vibrates in a liquid to produce alternating compressions and rarefactions of pressure.[19]

The studies have shown that using a small file size with minimum contact to the root canal wall provides optimal cleaning conditions. The streaming was found to be evenly distributed around the sonic file, which produced a large disturbance when freely oscillating and was unaffected by constraint. The majority of activity was found to occur around the file tip and decrease toward the hub.

Conclusion

Within the parameters of this *in vitro* study it was concluded that:

1. All the three experimental irrigating systems removed the smear layer from different levels of the root canal (coronal, middle, and apical)
2. The EndoActivator (Group II) and EndoVac (Group III) showed effective smear layer removal from the coronal, middle, and apical thirds without statistical significance between the groups
3. Needle irrigation group (Group I) showed the least smear layer removal and was statistically significant compared to EndoActivator (Group II) and EndoVac (Group III).

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