

A Scanning electron microscopic evaluation of intracanal smear layer removal by two different final irrigation activation systems

DEEPTI DUA, ANKUR DUA¹, VEERENDRA M. UPPIN²

Abstract

Aim: The aim of this study was to compare smear layer removal at apical 1 mm level after final irrigation activation with an EndoVac system and Max-I probe. **Materials and Methods:** Fifty freshly extracted maxillary central incisors were randomly divided into two groups after completing cleaning and shaping with ProTaper rotary files. In one group, final irrigation was performed with an EndoVac system while in the other group final irrigation was performed with a 30 gauge Max-I probe. 3% sodium hypochlorite and 17% ethylenediaminetetraacetic acid were used as final irrigants in all teeth. After instrumentation and irrigation, the teeth were sectioned longitudinally into buccal and palatal halves and viewed under a scanning electron microscope for evaluation of the smear layer. Statistical analysis was performed using the Kruskal Wallis and Mann-Whitney U tests. **Results:** The EndoVac group showed significantly better smear layer removal compared with the Max-I probe at the apical 1 mm level. **Conclusion:** An apical negative pressure system (EndoVac) results in better debridement at apical 1 mm when compared with side-vented closed ended needle irrigation (Max-I probe).

Keywords: EndoVac, max-I probe, root canal irrigation, scanning electron microscope, smear layer

Introduction

Successful endodontic treatment depends on the effective removal of smear layer from root canals through chemo-mechanical instrumentation. Various root canal irrigants have been introduced, and most of them have satisfactory properties. Past studies have shown that a combination of 5.25% sodium hypochlorite and 17% ethylenediaminetetraacetic acid is quite effective in flushing out debris and smear layer from the root canals.^[1,2] However, none of the irrigants with the conventional irrigation system are effective in cleaning the apical 1 mm of the root canal, which has maximum anatomical areas that are the most difficult and critical to debride.^[3-6]

Many problems are associated with the conventional irrigation systems used. The irrigant is delivered with a syringe and

needle and is expressed under positive pressure into the canals. It has been shown that the irrigant does not go more than 1 mm beyond the needle tip and therefore the apical few millimeters are never irrigated.^[7,8] To make the irrigant reach the apical 1-2 mm, the needle should go close to the working length,^[9] which in turn increases the risk of apical extrusion of irrigant. The commonly used irrigant, sodium hypochlorite, is very toxic to the surrounding tissues and causes acute symptoms if forced beyond the apex.^[10]

The mechanical cleaning and shaping has also improved with rotary Ni-Ti files. However, it was found that debris is always present in the apical 1 mm.^[11,12] This is because the irrigant never reaches the apical most few millimeters.

Various newer irrigation systems have been introduced to increase the mechanical flushing action of irrigants for better removal of smear layer, which was not possible with conventional syringe irrigation with needles and cannulas. Recently, a 30 G irrigation needle covered with a brush (NaviTip FX) was introduced. There have been machine-assisted agitation systems (CanalBrush), the Quantec-E irrigation system, that allow for continuous irrigation agitation during rotary instrumentation. However, the literature shows no significant difference with these systems when compared with syringe needle irrigation.

The Max-I probe is a needle with a closed end and a side port that is said to deliver the irrigant in the apical third without the risk of perfusion beyond the apex.^[9]

The EndoVac system is another new irrigation system that uses negative pressure to draw the irrigant down the canal to the apex. This system claims to deliver the irrigant in the

¹Departments of Conservative Dentistry and Endodontics, Private Practice, New Delhi, Maulana Azad Institute of Dental Sciences, ²KLE VK Institute of Dental Sciences, Belgaum, Karnataka, India

Correspondence: Dr. Ankur Dua, Departments of Conservative Dentistry and Endodontics, Maulana Azad Institute of Dental Sciences, Bahadur Shah Zafar Marg, New Delhi - 110 002, India. E-mail: ankurdua@gmail.com

Access this article online	
Quick Response Code: 	Website: www.contempclindent.org
	DOI: 10.4103/0976-237X.128661

apical 1-2 mm without any risk of perfusion of irrigant beyond the apex.^[13]

The present *in vitro* study is an attempt to compare the efficacy in intracanal smear layer removal at 1 mm from working length after final irrigation with an EndoVac irrigation system and side-vented closed ended needle (Max-I probe).

Materials and Methods

Fifty freshly extracted intact, non-carious, human permanent maxillary incisor teeth were selected for the study. Teeth with straight and single patent root canal and without any anatomical variations, no visible root caries, no signs of external or internal resorption and with completely formed apices were used in the study. Pre-operative radiographs were taken, which were screened, and any teeth that did not meet the required criteria were excluded from the study. The external surfaces of the teeth were debrided using ultrasonic scalers and stored in sterile saline solution at room temperature. Each tooth was numbered on the buccal and palatal surfaces of the root. A flat occlusal surface was made as a reference for determining working length, and pulp chamber of each tooth was accessed. A #15 K-file (Kendo, VDW, Germany) was then introduced into the root canal until its tip was just visible at the apical foramen. The working length for the preparation was determined by deducting 1 mm from the length recorded when the file was just visible at the apex of the root. Root apices were covered with sticky wax. Cleaning and shaping of all teeth was performed by using Gates Glidden drills and ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) rotary files. The coronal portion of the canal was flared using Gates- Glidden drills 1 to 3. ProTaper rotary files were used for preparation of middle and apical third. All teeth were enlarged to the master apical file size of 50/.06 to minimize the confounding factor of differences in the remaining tissue after mechanical preparation. To ensure patency, recapitulation to working length was performed after each rotary instrument with a #10 K file. During instrumentation, 1 mL of 3% NaOCl (Vishal Dentocare, Ahmedabad, India) was used at each change of file. Samples were randomly divided into three groups depending on the type of irrigation system used for final irrigation.

Group A (Positive control): No final irrigation was performed after instrumentation was completed ($n = 10$).

Group B: Final irrigation was performed using an MAX-I probe (Dentsply Rinn, York, PA, USA) and a syringe. After instrumentation was completed, 30 s of irrigation was performed with 17% EDTA (Canalarge, Ammdent, Chandigarh, India) keeping the needle just short of binding point but no closer than 2 mm from the working length. Then, three cycles of irrigation was performed using 3% NaOCl, 17% EDTA and 3% NaOCl. The irrigation needle was placed at working length and irrigation with NaOCl for 30 s was accomplished. The

irrigant was then left undisturbed in the canal for 60 s. This was followed by irrigation with EDTA for 30 s and then left undisturbed for 60 s. The last irrigant was NaOCl, using the same method for the same amount of time. A small (1-2 mm), constant apico-coronal movement of the needle was maintained during expression of irrigant ($n = 20$).

Group C: Final irrigation was performed using an EndoVac (Discus Dental Smart Endodontics, Higuera Street, Culver City, CA, USA) irrigation system. After instrumentation was completed, 30 s of irrigation was performed with 1 mL of 17% EDTA using a macrocannula. This was performed by using the EndoVac delivery/evacuation tip at the canal orifice while the macrocannula was constantly moved up and down in the canal from the point where it started to bind to the point just below the canal orifice. Then, three cycles of microirrigation were performed using 3 mL each of 3% NaOCl, 17% EDTA and 3% NaOCl. During a cycle of microirrigation, the pulp chamber was maintained full of irrigant while the microcannula was placed at the working length for 6 s and then moved in the apico-coronal direction until 30 s had elapsed. The irrigant was then left undisturbed for 60 s. This completed one microirrigation cycle. Similarly, the other two cycles of microirrigation were performed ($n = 20$).

The canals were dried with absorbent paper points and the entrance to each of the canals was protected with a cotton pellet to prevent penetration of the dentinal debris into the canals during decoronation. A #15 K-file with rubber stopper set at working length was placed on the external surface of the tooth and working length was marked with a scalpel. Teeth were then marked at 1 mm from the working length with a scalpel. Using diamond discs with water, the crown was removed at the cement-enamel junction and deep grooves were made on the buccal and palatal surfaces of the roots without perforating the canal. The roots were then split longitudinally using a chisel. One half of each root was selected for examination under a scanning electron microscope.

After assembly on coded stubs, the specimens were gold sputtered and examined under a scanning electron microscope. The dentinal wall of the apical 1 mm was observed for the presence/absence of smear layer. Photomicrographs were taken of the canal walls at 1 mm from the working length of each specimen at 1000X magnification. These photomicrographs were evaluated individually by an examiner who was blind to the irrigation regimens and scores were attributed according to the following scoring criteria developed by Mayer *et al.* in 2003.^[7]

Smear layer

- Score 1 - All dentinal tubules are open and no smear layer is present
- Score 2 - Some dentinal tubules are open and others covered by thin smear layer

- Score 3 - A few dentinal tubules are open and others covered by thin homogenous smear layer
- Score 4 - All dentinal tubules are covered by a homogenous smear layer without any open tubules visible
- Score 5 - Thick homogenous layer completely covering the canal walls.

Attributed scores were tabulated and submitted to statistical analysis. The Mann–Whitney U test and non-parametric tests such as Kruskal Wallis test were used for comparisons between the various groups.

Results

Table 1 shows the mean and standard deviation for three groups at the 1 mm level. At the 1 mm level, the EndoVac system showed significantly cleaner root canals when compared with the Max-I probe irrigation ($P = 0.0001$) [Table 2]. Figures 1-3 show representative scanning electron micrograph photographs for groups A, B and C, respectively, at the 1 mm level.

Discussion

The ultimate goal of root canal preparation is canal debridement to promote apical healing.^[14] After biomechanical preparation, a layer of debris composed of organic and inorganic material is formed on the root canal walls, obliterating the dentinal tubule entrances and root canal ramifications.^[15] The smear layer may prevent or delay considerably the penetration of

antimicrobial agents into the dentinal tubules^[16] as well as interfere with the adhesion of root canal sealers to the canal walls thus compromising the quality of obturation.^[17,18] Various methods have been employed to eliminate debris and smear

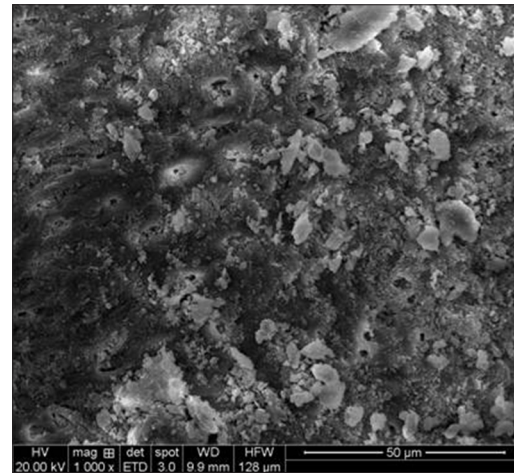


Figure 1: Group A (positive control) at 1 mm from working length

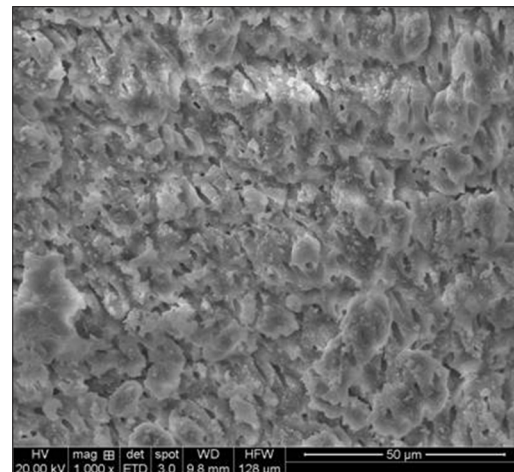


Figure 2: Group B (Max-I probe) at 1 mm from working length

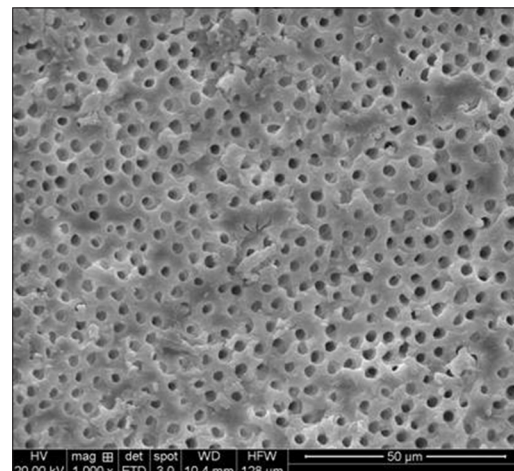


Figure 3: Group C (EndoVac system) at 1 mm from working length

Table 1: Mean, SD and median values in the three groups (A, B and C) for smear layer

Groups	1 mm		
	Means	Std. dev.	Median
A	5.00	0.00	5
B	3.80	0.79	4
C	1.20	0.42	1

SD: Standard deviation

Table 2: Pair-wise comparison of the three groups (A, B and C) with respect to smear layer scores at 1 mm by the Mann-Whitney U test

Groups	Means	Std. dev.	Median	Sum of ranks	U-value	Z-value	Pvalue
A	5.00	0.00	5.00	60.00	5.00	-2.6348	0.0084*
B	3.80	0.79	4.00	60.00			
A	5.00	0.00	5.00	65.00	0.00	-3.3968	0.0007*
C	1.20	0.42	1.00	55.00			
B	3.80	0.79	4.00	155.00	0.00	-3.9399	0.0001*
C	1.20	0.42	1.00	55.00			

* $P < 0.05$

layer from the root canal; however, none of the methods employed completely eliminate bacteria from the apical 1 mm of the root canal.^[19,20]

Sodium hypochlorite is the most widely used chemical solution in the biomechanical preparation of the root canal system.^[21] However, despite its excellent antimicrobial activity and capacity of dissolving organic materials, this solution alone does not effectively remove the smear layer.^[21,22] The association of EDTA and NaOCl solutions has proven to be effective in removing the smear layer.^[3] EDTA acts upon the inorganic components of the smear layer while NaOCl dissolves the collagen, leaving the entrances to the dentinal tubules more open and exposed. Studies have shown that the use of a high-volume final flush with 17% EDTA followed by NaOCl effectively removes the smear layer.^[23] However, none of the irrigants with the conventional irrigation system are effective in cleaning the apical one-third of the root canal.^[2]

Various irrigation systems have been developed that claim to work effectively in the apical third of the root canal.^[24]

In the current study, root canal instrumentation was performed with rotary nickel–titanium instruments that create a significant smear layer and hence are more challenging for irrigation systems. Apical preparations were extended to size 50/0.06 file to allow adequate penetration of solutions to the apical third of each root canal. A closed system of root canal was created to simulate *in vivo* situations, in which there is possible gas entrapment inside the root canal. The results of our study showed that the EndoVac system produced significantly cleaner canals at 1 mm from working length compared with the Max-I probe. This can be attributed to the design of the EndoVac microcannula and the placement of the 12 suction holes along the side of the last 0.07 mm of the microcannula. As the apical size increases, there are decreased chances of these holes contacting the root canal wall and becoming blocked. The larger area surrounding the microcannula also allows for increased volume of irrigant to the microcannula tip and a resulting increase in volume.^[25]

Another factor that supports the better cleaning efficacy of EndoVac in the apical 1 mm when compared with the Max-I probe is the vapor lock effect. The presence of apical vapor lock created by the organic decomposition of NaOCl into a bubble of carbon dioxide and ammonium adversely affects debridement efficacy when using a positive pressure system.^[26] In the closed system, irrigant extrusion beyond 1-1.5 mm of a side-venting needle could generate a liquid film along the air bubble–canal wall interface.^[27] The fluid stagnation in this “dead water zone” (apical area where the solutions are not exchanged by irrigation) fails to provide adequate irrigant replacement, resulting in gross debris retention in this region. Also, irrigation with an acidic or calcium chelating agent creates a demineralized collagen matrix on the surface of the radicular dentin on removal

of the smear layer.^[28,29] In the absence of strong turbulent fluid flow, debris particles could be trapped by this porous interlacing fibrillar network as they were displaced by the irrigant toward the orifice.^[26] The design of the microcannula however eliminates this vapor-lock effect thus allowing apical exchange of irrigants. Moreover, macrocannula removes as much debris as possible before a microcannula is used thus allowing better action of the latter and preventing the chances of blockage of the microcannula.

The results of our study are in accordance with the studies of Nielsen *et al.*^[13] and Mohan Abarajithan *et al.*,^[30] with the EndoVac irrigation system showing better debridement than conventional needle irrigation at the apical level of root canal. Our study showed that the EndoVac irrigation system is an effective root canal irrigation system for the removal of intracanal smear layer in the apical area. Nevertheless, these *in vitro* results cannot be extrapolated to *in vivo* situations. Hence, further research is required and more *in vivo* studies need to be performed to evaluate this method of irrigation.

Conclusion

Within the limitations of the present study, it could be concluded that the apical negative pressure system (EndoVac) used in the study is significantly more effective than the side-vented closed ended needle (Max-I probe) in removal of smear layer at the apical 1 mm level.

Acknowledgment

The authors deny any conflicts of interest. The authors would like to thank Dr. Beena Rani Goel for providing the EndoVac system for this study. They would also like to thank Mr. Gurulingam, Indian Institute of Science, Bangalore, for technical assistance and Mr. Shivalingappa Javali for assistance in statistical analysis.

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How to cite this article: Dua D, Dua A, Uppin VM. A Scanning electron microscopic evaluation of intracanal smear layer removal by two different final irrigation activation systems. *Contemp Clin Dent* 2014;5:37-41.

Source of Support: Nil. **Conflict of Interest:** None declared.