

Evaluation of Smear Layer Removal Using Different Irrigation Methods In Root Canals

Keywords

Endodontics
Endosafe
Endoultra
Smear Layer Removal

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ABSTRACT

This study evaluated different irrigation methods in smear layer removal from the root canal walls using maleic acid (MA). Maxillary anterior teeth (N=30, n=10 per group) were decoronated, canals were enlarged with Protaper (size F4) and allocated to three groups: EndoUltra: 2.5 ml of 7% MA was irrigated for 30 s, followed by EndoUltra activation for 30 s; EndoSafe: EndoSafe irrigation system was used for 1 minute using 5 ml of 7% MA; Side-vented needle: 30 gauge needle irrigation was performed for 1 min using 5 ml of 7% MA. After SEM analysis, the inter-examiner reliability was verified using Kendall's Co-efficient and data were analyzed using Pearson Chi-Square test. No statistical significant differences were found between the two examiners ($p>0.05$). In intra-group comparison, needle and EndoSafe irrigation demonstrated significantly better smear layer removal at middle third of the root canal system ($p<0.05$) when compared to apical third. In inter-group comparison, smear layer was minimally removed with needle irrigation. In the apical third, EndoUltra group removed smear layer more effectively. Endosafe needle irrigation in combination with 7% MA removed the smear layer in the root canal at best, while the EndoUltra performed the best at the apical third of the root.

INTRODUCTION

During endodontic treatment of the tooth, one of the most essential steps is the debridement of the root canal system. This step might determine the success of the complete endodontic therapy. It has been previously reported that more than 35% of the canal walls remain untouched by the endodontic instrumentation.¹ These areas contain tissue remnants and biofilms that might lead to treatment failure as they provide the possibility for microorganisms to recolonise.² Hence, irrigation plays a vital role during the debridement of the root canal.³

Instrumentation of the root canal system produces smear layer which covers the dentinal tubules.⁴ Smear layer is made up of dentin debris pulp tissue, odontoblastic process, necrotic debris, microorganisms, and their metabolic products.⁵ It has been demonstrated that the removal of smear layer improves the fluid-tight seal of the root canal system^{6,7} Also, smear layer itself may be infected and may shield the bacteria within the dentinal tubules,⁵ hindering the penetration of intracanal medicaments, irrigating agents and sealers into the dentinal tubules.⁸

Received: 27.02.19

Accepted: 29.04.19

doi: 10.1922/EJPRD_01817Husain06

Commonly used irrigation solutions for the removal of smear layer is the combination of ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl).⁹⁻¹¹ However, EDTA has been shown to have reduced efficacy in removal of smear layer from the apical third of the root canal system.¹² It is also considered cytotoxic,¹³ reduces the adhesion of resin cements,¹⁴ decreases the active chlorine when combined with NaOCl¹⁵ and forms precipitate with chlorhexidine gluconate.¹⁶ Previous studies have demonstrated the superior efficacy of 7% maleic acid (MA) in removal of smear layer in the apical third of the root canal system when compared to 17% EDTA.^{12,17} MA has an advantage over 17% EDTA of being less cytotoxic.¹³ In fact, the effectiveness of an irrigating solution depends on the method of its delivery into the root canal system. Conventional irrigation involves dispensing an irrigant into the root canal through syringe and needles/cannulas of variable gauges. Even though needle irrigation is the widely used irrigation technique, it has some disadvantages such as penetration of the irrigant solution depending on the distance of the needle tip to the working length, the flow rate and the needle design. In order to overcome these difficulties and to prevent inadvertent injection beyond the apical foramen,¹⁸ the apical negative pressure (ANP) irrigation technique has been introduced to endodontics. ANP irrigation has shown to produce better debridement at 1 mm from the working length compared with the needle irrigation in single canals.^{19,20} EndoSafe is an ANP irrigation device (Vista Dental Inc) designed to simultaneously deliver and evacuate irrigant at the working length through its highly flexible, open-ended 30-G needle tip and its folding evacuation hood. Passive ultrasonic irrigation (PUI) in endodontics was first described by Weller *et al.*²¹ During PUI, energy is transmitted from a file or smooth oscillating wire to the irrigant by means of ultrasonic waves which induces acoustic streaming and cavitation of the irrigant.²²

Studies have shown that PUI promotes better removal of the smear layer in the apical region and isthmus regions.²²⁻²⁴ EndoUltra (Vista Dental) is the only cordless ultrasonic activator having a tip frequency of 40,000 Hz with a unique, multi-use activator tip. To date, the effectiveness of EndoUltra, EndoSafe and needle irrigation in removal of smear layer from the instrumented root canal system has not been evaluated.

The objective of this study therefore, was to evaluate the efficacy of EndoUltra, EndoSafe and needle irrigation in removal of smear layer from the root canal wall when used with 7% MA. The null hypothesis tested was that there would be no differences between the EndoUltra, EndoSafe and needle irrigation in removal of canal wall smear layer.

MATERIALS AND METHOD

SPECIMEN PREPARATION

Thirty extracted human single rooted non-carious maxillary anterior teeth with straight root and type I canal anatomy were selected. All the teeth were radiographed in mesio-distal and bucco-lingual direction to verify the presence of single, non-calcified canal with mature apex and the absence of any resorption or endodontic obturation. Superficial soft tissues were removed, and the teeth were stored in 0.2% sodium azide (Sigma Aldrich, Sigma Chemical Co, St. Louis, MO) at 4°C until the experiments. The teeth were decoronated at the cemento-enamel junction to standardize the root length to 16 mm, after which the pulp tissue was removed using barbed broach (Mani Inc., Tochigi Ken, Japan). The working length was established by inserting a no.10K file (Mani Inc.) into each root canal until it was just visible at the apical foramen (observed under magnifying loupes) and by subtracting 1 mm from this point. Apices were then sealed using sticky wax (City dental supplies, Stephen, South Australia) to mimic the closed end system. The canals were then enlarged to size F4 using pro-taper rotary files (Dentsply Maillefer, Ballaigues, Switzerland). As an irrigating agent between each instrument, 5 ml of 2.5% NaOCl (Vista Dental Products, LLC, Racine, WI) was used. Irrigant was delivered into the canal using 30-gauge side-vented needle (Vista Dental Products) which was placed 1-2 mm short of working length.

EXPERIMENTAL GROUPS

The specimens were then randomly divided into 3 groups (n=10) based on the irrigation regimen:

Group I: EndoUltra: 2.5 ml of 7% MA was irrigated using 30-gauge side-vented needle for 30 s followed which EndoUltra device was activated for 30 s within the canal (*Figure 1*). The same procedure was repeated once more so that the total irrigation time with 7% MA and activation time with EndoUltra was 1 min.



Figure 1: EndoSafe root canal irrigation system

Group II: EndoSafe: 5 ml of 7% MA was irrigated using EndoSafe irrigation system for 1 min (Figure 2).



Figure 2: Representative image of EndoUltra irrigation system.

Group III: Needle group (control): 5 ml of 7% MA was irrigated using 30 gauge side-vented needle for 1 min. The canals were then dried with sterile paper points (Dentsply, Maillefer) and longitudinal grooves were prepared on the buccal and lingual surfaces of each root using a diamond disc (Horico Dental) at a slow speed without penetrating the canal.

SEM ANALYSIS

The roots were then split into two halves using a straight chisel. Then, better half of each specimen from each respective group was subjected to Scanning Electron Microscope (SEM) analysis in order to evaluate for the presence or absence of smear layer.

The specimens were first dehydrated using ascending grades of ethyl alcohol (25, 50, 75 and 100%) for 15 min. The specimens were then mounted on metallic stubs, gold sputtered using an ion sputter, and examined under SEM. Several photomicrographs were taken to observe the surface morphology at x1500 and 10KV of the canal walls at the coronal (10-12 mm from apex), middle (6-7 mm from apex), and apical (1-2 mm from apex) thirds of each specimen. These areas were evaluated by two independent evaluators who were blinded to the experimental groups. The images were scored according to the criteria after Hülsmann *et al.*²⁵ as follows:

Score 1: No smear layer, dentinal tubuli open

Score 2: Small amount of smear layer, some dentinal tubuli open

Score 3: Homogenous smear layer covering the root canal wall, only few dentinal tubuli open

Score 4: Complete root canal wall covered by a homogenous smear layer, no open dentinal tubuli

Score 5: Heavy, non-homogenous smear layer covering the complete root canal wall

STATISTICAL ANALYSIS

Data were analyzed using a statistical software package (SPSS Software V.20, Chicago, IL, USA). The inter-examiner reliability for smear layer removal was verified by using the Kendall's Co-efficient test. The data of the scores for intragroup and intergroup

comparisons were statistically analyzed using Pearson Chi-Square test. $P < 0.05$ was considered to be statistically significant in all tests.

RESULTS

Kendall's Co-efficient test results demonstrated no statistical significant differences between the two examiners ($p > 0.05$). In the coronal third of the root canals, the Kendall's scores were 0.525 for EndoUltra, 0.651 for EndoSafe and 0.658 for needle group. In the middle third of the roots, scores were the highest with 0.603 for EndoUltra, 0.157 for EndoSafe and 0.078 for needle group. In the apical third, scores were 0.651 for EndoUltra, 0.361 for EndoSafe and 0.934 for needle group. The results of the smear layer scores in each experimental group at different thirds of the root canal system are presented in Table 1.

On intra-group comparison, in needle irrigation group, smear layer was removed better in the coronal and middle third when compared to the apical third ($p = 0.05$). Similar findings were observed with EndoSafe group, where no significant difference was found between the coronal and middle thirds compared to apical third ($p = 0.004$). However, in EndoUltra group, there was no significant difference between coronal, middle and apical thirds ($p = 0.240$). On inter-group comparison, there was a significant difference between all three groups. Needle irrigation group removed smear layer less efficiently when compared to EndoSafe and EndoUltra groups in all thirds of the root canal ($p < 0.05$). When EndoSafe group was compared to EndoUltra group, there was no significant difference in the coronal and middle thirds ($p > 0.05$). However, in the apical third, EndoUltra removed smear layer more effectively ($p < 0.018$). Representative SEM images of root canal walls treated with the different experimental groups are presented in Figures 3a-h.

DISCUSSION

Irrigant activation can enhance the irrigant to disperse in the root canal system and improve mechanical cleaning of the root canal by effective fluid flow dynamics.^{26,27} The present study compared the efficacy of EndoUltra, EndoSafe and needle irrigation in the removal of smear layer from the root canal system using 7% maleic acid. The results revealed that EndoUltra had better smear layer removing ability especially from the apical third of the root canal system when compared to EndoSafe and needle irrigation. Hence, the null hypothesis tested in this study was rejected.

The findings of this study corroborates with the results of other studies where PUI use has promoted better removal of the smear layer.^{24,28} The superior efficacy of EndoUltra in removal of smear layer from the apical third of the root canal system may be due to the vibration produced by its fine oscillating tip at a frequency of 40,000 Hz. It has been previously shown that the use of a small oscillating tip of the ultrasonics is able to transport irrigants into the apical parts of the root canal system.²⁹ Also, the volume of irrigating solutions used and the taper of the canal preparation employed in this study allowing for hydrodynamic flow, could also have contributed to the effective removal of smear layer by EndoUltra in the apical third of the root canal system.

Table 1. Scores of smear layer recorded in each experimental group at various thirds of the root canal system using different irrigations systems

			Experimental groups			Total
			Endosafe	EndoUltra	Needle Irrigation	
Coronal	1	Count (%)	5 (50)	8 (80)	1 (10)	14 (46.7)
	2	Count (%)	5 (50)	2 (20)	5 (50)	12 (40)
	3	Count (%)	0 (0)	0 (0)	4 (40)	4 (13.3)
Total		Count (%)	10 (100)	10 (100)	10 (100)	30 (100)
Middle	1	Count (%)	7 (70)	8 (80)	3 (30)	18 (60)
	2	Count (%)	3 (30)	2 (20)	5 (50)	10 (33.3)
	3	Count (%)	0 (0)	0 (0)	2 (20)	2 (6.7)
Total		Count (%)	10 (100)	10 (100)	10 (100)	30 (100)
Apical	1	Count (%)	0 (0)	5 (50)	0 (0)	5 (16.7)
	2	Count (%)	6 (60)	5 (50)	4 (40)	15 (50)
	3	Count (%)	4 (40)	0 (0)	4 (40)	8 (26.7)
	4	Count (%)	0 (0)	0 (0)	1 (10)	1 (3.3)
	5	Count (%)	0 (0)	0 (0)	1 (10)	1 (3.3)
Total		Count (%)	10 (100)	10 (100)	10 (100)	30 (100)

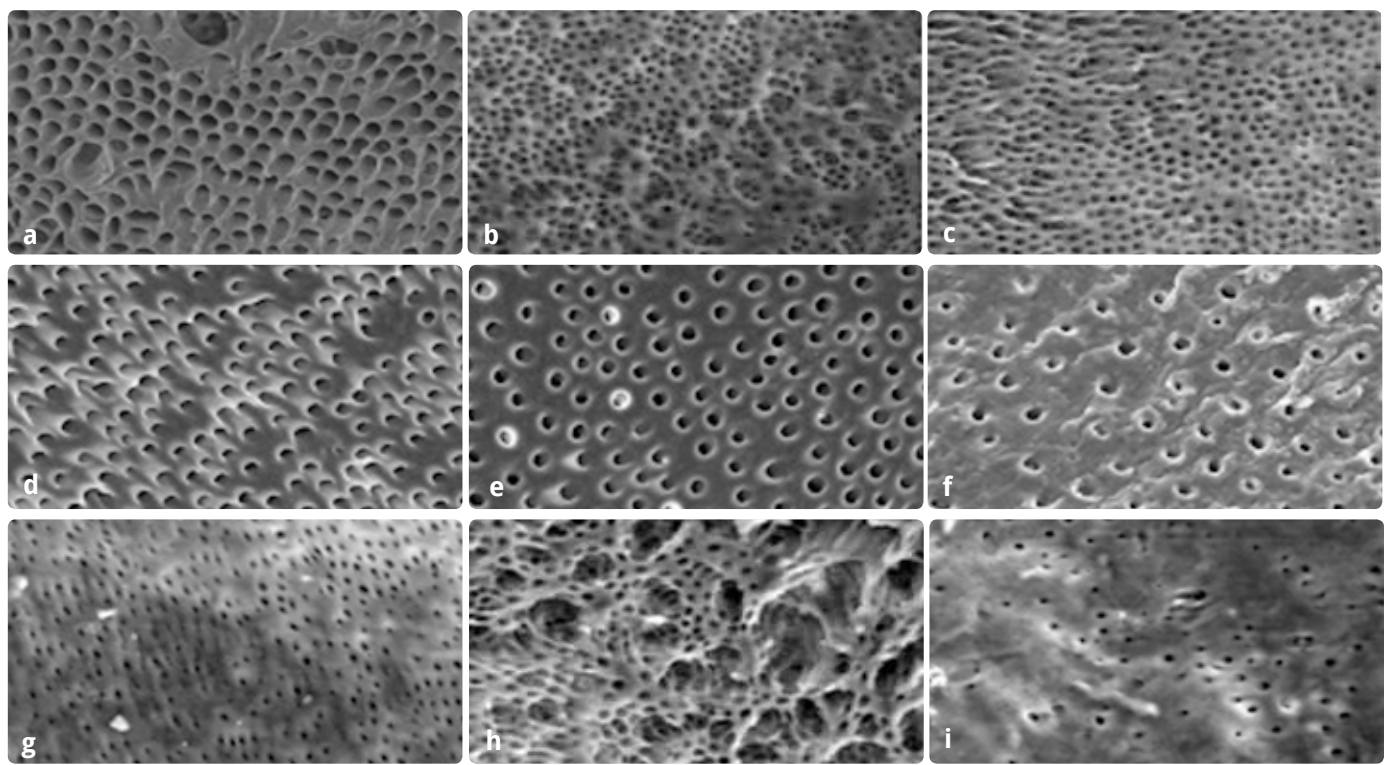


Figure 3a-i: Representative scanning electron microscopy images (SEM) of canal walls a) in the coronal root third irrigated with EndoUltra, b) in the middle root third irrigated with EndoUltra, c) in the apical root third irrigated with EndoUltra, d) in the coronal third irrigated with EndoSafe, e) in the middle third irrigated with EndoSafe, f) in the apical third irrigated with EndoSafe, g) in the coronal third irrigated with needle irrigation, h) in the middle third irrigated with needle irrigation, i) in the apical third irrigated with needle irrigation.

The ANP system (EndoSafe) used in this study was not as effective as EndoUltra in removal of smear layer from apical third of the root canal system. This result is in accordance with the study by Tay *et al.*³⁰ where EndoSafe was found to be equivalent to side-vented needle irrigation in debridement of apical thirds of mandibular molars. Its poor performance when compared to EndoUltra may be attributed to the insufficient volume of irrigating solution circulation and aspiration from the apical third of the root canal. Also, it has been stated that in EndoSafe system, irrigant is delivered from the needle tip apically and suctioned coronally via the evacuation hood unlike EndoVac where irrigant is delivered coronally and drawn apically through negative pressure.³⁰ However, in the present study, EndoSafe irrigation was found to be superior to conventional needle irrigation. Most likely, its better cleaning efficacy is due to the evacuation tube together with the extremely flexible needle, which enhances the reverse flow of the irrigant and consequently helps in flushing out of the debris. Needle irrigation (control group) on the other hand showed the least efficacy in removal of smear layer in all the thirds of the root canal system. This result is in accordance with previous studies which have reported the poor efficiency of needle irrigation.^{30,31}

Closed end canal model was used in this study for root canal irrigation in order to simulate the clinical situation and to evaluate the effect of vapor lock on the root canal debridement.³² Taper of the canal and the volume of the irrigating solution used helps in the proper fluid dynamics. The canals were prepared to Protaper size F4 with an apical diameter #40 to ensure that adequate space was present for the flow of irrigating solutions up to the working length of the root canal for the efficient debridement.³³ In addition, 5 ml of final rinse of MA was used for 1 min in the present study^{12,34} instead of other irrigants such as NaOCl. The reason for not using a negative control group was due to the fact that NaOCl inhibits resin adhesion in the root canal which is crucial especially for adhesively bonded root retained restorations.

SEM analysis allowed highly magnified view of the root canal walls to evaluate for the presence or absence of smear layer. However, SEM evaluation is prone to subjective bias because it is largely based on the comparison of the quantity of open dentinal tubules.³⁵ Furthermore, the gold sputtering process or the sectioning of teeth could influence the presence of smear layer and subjective scoring system relies on the concentration and density of the dentin tubules throughout the length of the root canal. All these factors may yield to detection bias in evaluating the smear layer. However, in the present study, Kendall's coefficient result revealed a good inter-examiner agreement. Since irrigations systems work in closed canal system, such inherent problem related to microscopical analysis could be circumvented after cutting the root into two halves and evaluating the middle portion from coronal to apical longitudinally. Future studies could also use NaOCl as an irrigant and verify the obtained results using other non-contact microscopy methods.

CONCLUSIONS

From this study, the following could be concluded:

The smear layer removal from the apical third of the root canal system was more efficient with EndoUltra compared to Endosafe and needle irrigation when used along with 7% maleic acid.

Endosafe needle irrigation in conjunction with 7% maleic acid removes smear in the root canal the best compared to all other methods tested.

DISCLOSURE

The authors declare that they have no conflict of interest.

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