Original Article

Efficacy of SmearOFF, maleic acid, and ethylenediaminetetraacetic acid combined with sodium hypochlorite in removal of smear layer from curved root canals: *In vitro* study

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Abstract

Introduction: Mechanical instrumentation of the root canal system produces an amorphous smear layer. The aim of the present research was to assess the effect of SmearOFF, 7% maleic acid (MA) and 17% ethylenediaminetetraacetic acid (EDTA) when combined with sodium hypochlorite (NaOCl) in removal of smear layer from curved root canals.

Materials and Methods: Forty mandibular molars were selected of which only the mesial roots were prepared biomechanically and categorized into four equal groups on the basis of the irrigation protocol: (1) SmearOFF, (2) 7% MA, (3) 17% EDTA, and (4) 0.9% saline. Teeth were then decoronated; mesial roots were cleaved lengthwise and scanning electron microscopic analysis was performed for evaluation of existence of smear layer.

Results: On intergroup comparison, there has been found to be notable dissimilarity among the SmearOFF and MA groups in coronal, middle and apical thirds of the root canal system ($P > 0.05$). However, in EDTA group, there was no notable difference in coronal and middle third. However, in apical one-third, smear layer was cleared less effectively when compared to SmearOFF and MA ($P < 0.001$). In contrary, all of saline group specimens were extensively smeared in all the parts of the root canal system. On intergroup comparison, all the test irrigants removed smear layer effectively in coronal and middle third of the root canal. Nonetheless, in apical portion, SmearOFF, and MA effectuated significantly better compared to EDTA.

Conclusion: In combination with NaOCl, SmearOFF, and MA had superlative smear layer eradication efficacy in contrast to EDTA in apical third of the curved root canals.

Keywords: Ethylenediaminetetraacetic acid, maleic acid, scanning electron microscope, smear layer, SmearOFF

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INTRODUCTION

Proper instrumentation of the root canal system is the main factor for the positive outcome of endodontic treatment.[1] Nonetheless, a smear layer is created during mechanical preparation of the root canal which is known to cover the dentinal tubules.[2] Its constituents include organic components such as pulp tissue, odontoblastic processes, necrotic debris, microbes and their metabolic products and inorganic components like dentinal debris.[3] The fluid tight seal of the root canal system has been proven to ameliorate with the eradication of the smear layer.[4] In studies conducted earlier, it has been illustrated that the bacteria and microbes infect the smear layer and are contained within the dentinal tubules.[2] It can prevent the penetration of root canal irrigants, intracanal medicaments and sealers into the tubules,[5] and also being a loosely adherent structure, that can provide an avenue for leakage.[6] Numerous chelating agents such as ethylenediaminetetraacetic acid (EDTA), etidronic acid, MTAD, QMix, peracetic acid, phosphoric acid, and citric acid have been used for the elimination of the inorganic part of smear layer.[7-12] However, the combination of EDTA and sodium hypochlorite (NaOCl) is the commonly used protocol.[7] EDTA has been shown to have some shortcomings like, decreased effectiveness in elimination of smear layer from the apical third,[13,14] cytotoxic,[15] and reduction in the bond strength of resin cements.[16] Maleic acid (MA) is a mild organic acid which is also put to use as an acid conditioner in adhesive dentistry.[17] It has been illustrated in the earlier studies to be superior to 17% EDTA for the elimination of smear layer particularly in the apical thirds of root canals.[13] It has several other advantages when compared to 17% EDTA like, it increases the surface roughness of the intra-radicular dentin[18] which helps in bonding of obturating material, does not form precipitate when mixed with 2% CHX,[19] less cytotoxic and genotoxic,[15,20] and increases the wettability of sealers.[21] Recently, a new irrigating agent SmearOFF (Vista Dental Inc., Racine, WI, USA) has been introduced, which contains EDTA and CHX along with wetting agents and surface modifiers. The manufactures claim that it has superior chelation, better calcium suspension and will not form precipitate when used with NaOCl. The previous study on straight root canals demonstrated that, SmearOFF was efficient in smear layer removal when compared to EDTA.[22]

Many of the earlier smear layer elimination studies were conducted in straight roots with wide canals.[23] Nonetheless, when it comes to curved canals, hardly any literature exists concerning the elimination of smear layer after full biomechanical preparation of narrow canals. Hence, the aim of this study was to analyze the effectiveness of SmearOFF, 7% MA and 17% EDTA in the elimination of smear layer from curved root canals.

MATERIALS AND METHODS

After obtaining approval from the Institutional Review Board (712/2014), extracted human molar teeth were chosen for the study. Forty human noncarious mandibular molars with two separate mesial canals and completely formed apex were selected. Teeth which were restored, had more than 6°–8° of canal curvature, calcified or resorbed were excluded. After surface debridement with scaling instruments, samples were stored in 0.2% sodium azide (Millipore Sigma, St. Louis, MO, USA) at 4°C until use.

Specimen preparation

Individual tooth specimens were radiographed to visualize the root canal anatomy and confirm that each canal had a curvature of 6°–8° according to Schneider technique.[24] Tapering fissure flat-end diamond point (Horico, Berlin, Germany) was used under high speed to prepare four-walled access cavities until the two mesial canal orifices were located. Working length evaluation was done using a K-file (Mani Inc., Tochigi Ken, Japan) ISO size 10. After placing the file in the mesiobuccal canal, it was driven till the tip of the root when it could be confirmed visually, and working length was obtained after deduction of 1 mm from this length. For the purpose of the conditions of closed end system, apical ends of the roots were obliterated using sticky wax. Chemomechanical preparation of the mesiobuccal canals were done using HyFlex CM files (Coltène/Whaledent AG, Altstätten, Switzerland) and the canals were enlarged up to 04/40 (taper/size). Five ml of 2.5% of NaOCl (Vista Dental, USA) was used as an irrigant after each instrument change for 1 min to remove the organic part of the smear layer. Irrigation was performed using 29 gauge side vented needle (Vista Dental, USA) which was placed 2 mm short of the working length to prevent the extrusion of irrigating solution out of the canal and to stimulate the clinical situation.

Irrigation regimen

The irrigating solutions were stored in amber colored bottles for blinding. First bottle contained SmearOFF (Vista Dental, USA) solution and designated with the letter "A," second bottle contained 7% MA (Sigma Chemical Co, MO) and designated with the letter "B," third bottle contained 17% EDTA (Vista Dental, USA) and tagged with the letter "C" and the fourth bottle contained 0.9% saline and tagged

with letter "D." The investigator carrying out the irrigation procedure was blinded to the contents of these bottles.

The teeth were then arbitrarily categorized into three experimental groups and one control group (n = 10). Final irrigation was performed as follows: Group 1: 5 ml SmearOFF for 1 min followed by 5 ml 2.5% NaOCl for 1 min; Group 2: 5 ml 7% MA for 1 min followed by 5 ml 2.5% of NaOCl for 1 min; Group 3: 5 ml EDTA for 1 min followed by 5 ml 2.5% NaOCl for 1 min; and Group 4: 5 ml saline for 1 min followed by 5 ml of 2.5% NaOCl for 1 min (control group). The same operator performed all the procedures.

Scanning electron microscopic evaluation

After irrigation, the complete drying of the root canals was done using paper points (Dentsply, Maillefer, Ballaigues, China) and samples were decoronated at the cemento-enamel junction. A 40 size gutta-percha point was inserted into the mesial root canal to prevent the penetration of external debris. Subsequently, the mesiobuccal root was sectioned lengthwise buccolingually, producing 20 samples in each group. Of these, best 10 samples were taken for scanning electron microscopy (SEM) (JEOL, Tokyo, Japan analysis). The selected samples were then gold sputtered using an ion sputter by mounting them on metallic stubs, and were assessed under the SEM for existence of smear layer. Several photomicrographs at × 1500 magnification at 10 KV were taken to detect the surface morphology of the canal walls at coronal, middle and apical thirds of every specimen. These areas were examined by two independent investigators, totally unknown about the experimental groups of the samples being examined.

Scoring criteria

The images were scored in compliance to the criteria given by Torabinejad *et al.*[7]

One = no smear layer (no smear layer on the surface; all tubules were open and clean); 2 = moderate smear layer (no smear layer on the surface, but tubules contain debris); and 3 = heavy smear layer (smear layer covered the canal surface and tubules).

Statistical analysis

The inter-examiner's accuracy was rated by employing the Cohen's kappa coefficient test. The data of the score for intragroup comparison and intergroup comparison to evaluate the presence or absence of smear layer were statistically evaluated by Pearson Chi-square test. The level of significance was preset at $P < 0.05$.

RESULTS

The results of the Cohen's kappa coefficient test indicated that, there was no statistically substantial discrepancy among the observer's values for the scoring of the smear layer in all the thirds of root canal system for SmearOFF, MA, and EDTA groups. The kappa coefficient score for SmearOFF group, in the coronal third was 1, middle third was 0.060 and apical third was 0.178. For MA group in the coronal third was 0.264, the middle third was 0.068 and apical third was 1. For EDTA group, coronal third was 0.639, middle third was 0.178 and apical third was 0.150.

The observer values for each test irrigant group in the coronal, middle and apical thirds is represented in Table 1. On intragroup comparison, SmearOFF and MA groups had no statistically substantial variation between them in the coronal, middle and apical thirds of the root canal system ($P > 0.05$). However, in EDTA group, there was no statistically substantial variance in coronal and middle third but in the apical third, smear layer was cleared less effectively ($P < 0.001$). In saline group, all the specimens were extensively smeared over the entire surface of the root canal system.

On intergroup comparison, all the irrigants along with NaOCl eliminated the smear layer effectively in the coronal and middle third of the instrumented root canals. In the apical third, SmearOFF and MA performed significantly better when compared to EDTA. There was no significant difference between SmearOFF and MA ($P > 0.05$). Figure 1 illustrates the indicative scanning electron microscopic images of root canal walls treated with the experimental solutions at various thirds of the root canal system.

DISCUSSION

In general, the removal of smear layer was performed using 3 chelating agents and assisted using NaOCl which is used after each instrument change. These chelating agents removed the inorganic component of the smear layer while NaOCl removed the organic component. This fact supports the previous work performed by several investigators who revealed that this combination represented the most common irrigating protocol.[13,22] In the current study, the effectiveness of SmearOFF, 7% MA and 17% EDTA was compared as a final irrigants for the elimination of the smear layer from curved human root canals. The results revealed that SmearOFF, MA and EDTA had equal potential in smear layer elimination from the coronal and middle third of the curved root canal systems.

Table 1: Smear layer scores of experimental irrigants in coronal, middle, and apical thirds of the curved root canal system

				Group				Total
				Maleic acid	SmearOFF	EDTA	Saline	
Coronal	value	1.00	Count	7	8	6	0	21
			%	70.0%	80.0%	60.0%	0.0%	52.5%
		2.00	Count	3	2	4	5	14
			%	30.0%	20.0%	40.0%	50.0%	35.0%
		3.00	Count	0	0	0	5	5
			%	0.0%	0.0%	0.0%	50.0%	12.5%
	Total %		Count	10	10	10	10	40
			100.0%	100.0%	100.0%	100.0%	100.0%	
Middle	value	1.00	Count	8	10	6	0	24
			%	80.0%	100.0%	60.0%	0.0%	60.0%
		2.00	Count	2	0	4	3	9
			%	20.0%	0.0%	40.0%	30.0%	22.5%
		3.00	Count	0	0	0	7	7
			%	0.0%	0.0%	0.0%	70.0%	17.5%
	Total %		Count	10	10	10	10	40
			100.0%	100.0%	100.0%	100.0%	100.0%	
Apical	value	1.00	Count	6	6	2	0	14
			%	60.0%	60.0%	20.0%	0.0%	35.0%
		2.00	Count	4	4	4	1	13
			%	40.0%	40.0%	40.0%	10.0%	32.5%
		3.00	Count	0	0	4	9	13
			%	0.0%	0.0%	40.0%	90.0%	32.5%
	Total %		Count	10	10	10	10	40
			100.0%	100.0%	100.0%	100.0%	100.0%	

				Group				Total
				Maleic acid	SmearOFF	EDTA	Saline	
Coronal	value	1.00	Count	7	8	6	0	21
			%	70.0%	80.0%	60.0%	0.0%	52.5%
		2.00	Count	3	2	4	5	14
			%	30.0%	20.0%	40.0%	50.0%	35.0%
		3.00	Count	0	0	0	5	5
			%	0.0%	0.0%	0.0%	50.0%	12.5%
	Total %		Count	10	10	10	10	40
			100.0%	100.0%	100.0%	100.0%	100.0%	
Middle	value	1.00	Count	8	10	6	0	24
			%	80.0%	100.0%	60.0%	0.0%	60.0%
		2.00	Count	2	0	4	3	9
			%	20.0%	0.0%	40.0%	30.0%	22.5%
		3.00	Count	0	0	0	7	7
			%	0.0%	0.0%	0.0%	70.0%	17.5%
	Total %		Count	10	10	10	10	40
			100.0%	100.0%	100.0%	100.0%	100.0%	
Apical	value	1.00	Count	6	6	2	0	14
			%	60.0%	60.0%	20.0%	0.0%	35.0%
		2.00	Count	4	4	4	1	13
			%	40.0%	40.0%	40.0%	10.0%	32.5%
		3.00	Count	0	0	4	9	13
			%	0.0%	0.0%	40.0%	90.0%	32.5%
	Total %		Count	10	10	10	10	40
			100.0%	100.0%	100.0%	100.0%	100.0%	

However, in apical third, both SmearOFF and MA were equally effective than EDTA.

The results of this study are in compliance with the previous study that illustrated the superiority of MA and SmearOFF to EDTA in the elimination of smear layer.[22]

Complete elimination of smear layer was not accomplished with any of the irrigation regimens discussed in this study, which contemplates the complication linked to the cleaning the apical third of curved root canals.[25]

In the present study, MA showed better efficacy in the apical third as compared to EDTA which is in accordance with previous study.[13] This can be due to decrease in surface tension of 7% MA (0.06345 N/m) in contrast to that of 17% EDTA (0.0783 N/m). EDTA is efficacious at a neutral pH, hence accomplishes decalcification by being independent of the high hydrogen ion concentration

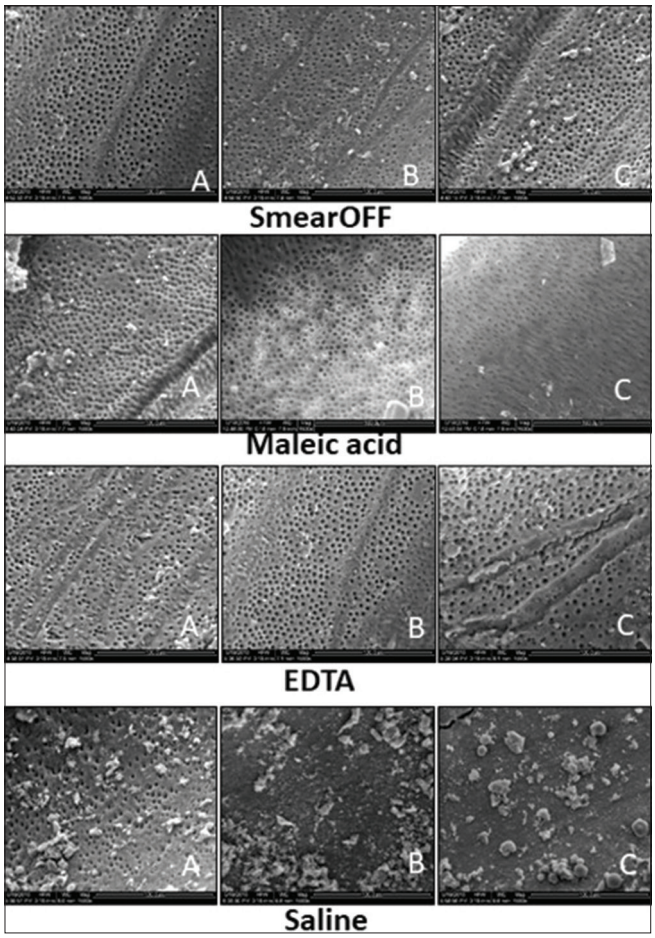

Figure 1: Representative scanning electron microscopic images of root canal walls irrigated with chelating agents SmearOFF, maleic acid, ethylenediaminetetraacetic acid, and saline (control) at the coronal third (A), middle third (B), and apical third (C) of curved root canal system

therefore works well as a chelating agent. The effectiveness of EDTA depletes over time with a reduction in pH caused by swapping of calcium from dentin by hydrogen.[26] Poor efficacy of EDTA in the apical third may be also attributed to its less pronounced action in the presence of sclerotic dentin in the apical third.[27] Also, it may be due to the reduction of mineral and noncollagenous proteins (NCPs) from dentin by neutral 17% EDTA, as it removes both free calcium ions and calcium bonded to NCPs. Therefore, degree of decalcification of 17% EDTA diminishes with the decrease in the content of NCPs from the apical third of canals.[26]

To the best of our knowledge, there has been no research conducted to assess the effectiveness of SmearOFF on the elimination of smear layer from the curved root canal system. The current study demonstrated the superior ability of SmearOFF to efface smear layer from the apical third as compared to 17% EDTA. This is in agreement with the manufacturer's claim of superior chelation. This superior effect of SmearOFF may be accredited to the additive effect of CHX and EDTA present in it. It may also be due to the surface active agent present in SmearOFF, which increases its wettability and lowers the surface tension thereby increasing its potency in eradication of smear layer from root canal system as reported previously by several investigators.[28]

The control group consisting of saline as an irrigant was completely ineffective on smear layer elimination. This result is parallel to the findings of the earlier investigations.[13]

Since the apical preparation size is still a topic of argument, larger apical preparation leads to a definite reduction of the bacterial count and amplifies the potency of irrigation in agreement with several studies.[29,30] In the current study, curved mesiobuccal root canals with a mean curvature of 7° were prepared with Hyflex rotary files. Sufficient apical preparation of the root canal was done by the master apical file size used (#40) and facilitated irrigation occurred due to the taper created during canal preparation. An enhancement in the elimination of smear layer is achieved with the flow/back flow of irrigating solutions which can be ascribed to the escalated taper in curved canals.[31] Contrarily, risks such as instrument separation, perforation or root fracture also increase with larger apical preparation.[29,32] In this study, an acceptable balance between apical enlargement, prevention of procedural mishaps and conservation of tooth structure was estimated to be represented by an apical preparation size of 40. In addition, the size of the root canal preparation in the current study facilitated insertion of the irrigating needle 2 mm short of working length. It has been reported that, debris removal and mechanical efficacy of irrigation is influenced by the depth of penetration of irrigation needle.[33]

In the current study, a 1 min time interval was used for the test irrigants since it has been reported that, the use of 17% EDTA beyond 1 min causes reduction in dentin microhardness and erosion of the dentinal tubules, and increases root fragility.[34] The suggested volume of EDTA for the elimination of smear layer varies from 3 to 20 mL per canal.[35] However, high-volume delivery using a fine needle is a hard task requiring an increased treatment time and operator fatigue. 5 mL of final rinse was utilized in the current study as suggested by Mello *et al*.[23] They proved that 5 mL EDTA was as a final rinse was as effective as 10 or 15 mL of EDTA for effective smear layer elimination.

The limitation of this study include the methodology used to assess smear layer using SEM model is not a

sound, reproducible, and valid one. Ideally, a longitudinal observation of the canal using microcomputed tomography (CT) is regarded a fundamental requirement to study the smear layer removal procedures. Thus, further studies should be performed to evaluate the effectiveness of SmearOFF in curved root canals using micro-CT.

CONCLUSION

Under the constraints of this *in vitro* study, it can be concluded that, SmearOFF, 7% MA and 17% EDTA, combined with NaOCl showed similar efficacy in eradication of smear layer from the coronal and middle thirds of curved root canals. However, in the apical third, SmearOFF and 7% MA had better efficacy than 17% EDTA.

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Conflicts of interest

There are no conflicts of interest.

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