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Comparison of Effectiveness of Different Irrigant Agitation Techniques on Smear Layer Removal: A SEM Study

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ABSTRACT

Introduction: The smear layer formed during root canal instrumentation hinders the penetration of intracanal medicaments and root canal sealers into the dentinal tubules. Using irrigants like sodium hypochlorite, citric acid, EDTA, and chlorhexidine effectively removes microorganisms and the smear layer from the root canal space. Various manual and machine agitation techniques can be used to improve the distribution and flow of irrigation solutions.

Materials and Methods: Conventional access opening was performed in premolars with a single canal followed by root canal instrumentation to the working length using ProTaper Universal rotary files (Dentsply), stopping when the ProTaper F3 file reached the desired length. A uniform irrigation protocol was followed in all samples. The samples were then divided into four groups: Control group (no activation), Group 1 (Manual agitation), Group 2 (EndoActivator), and Group 3 (Self-adjusting file). Then the samples were examined for smear layer removal.

Results: Conventional irrigation resulted in a greater number of samples exhibiting a smear layer score of 4 in the control group. In the middle third of the root canal, the endoactivator group and the self-adjusting file demonstrated superior results. The average smear layer score was notably higher in the control and manual agitation groups in the coronal third of the canal.

Conclusion: The use of self-adjusting files may serve as a complementary method to root canal irrigation for the removal of the smear layer. However, none of the irrigation activation techniques we examined were able to completely eliminate the smear layer.

INTRODUCTION

One of the most important phases of root canal therapy is said to be root canal system preparation which involves removing of vital and necrotic tissues, infected root dentine from the root canal system, and, metallic and non-metallic obturating materials in retreatment cases.[1]The instrumentation of root canal creates a smear layer that includes organic and inorganic substances such as dentinal debris, pulpal tissue, odontoblastic processes, microorganisms, and their metabolic products.[2] Presence of this layer prevents the penetration of intracanal medicaments, root canal sealers into dentinal tubules, and influences the adaptation of filling materials to canal walls.[3] Irrigants such as sodium hypochlorite, 10% citric acid, 17% ethylenediaminetetraacetic acid (EDTA) and chlorhexidine have been used to remove the microorganisms and smear layer from the root canal space.[4]
Sodium hypochlorite (NaOCl)is considered the gold standard irrigating solution during an endodontic treatment eventhough it cannot completely dissolve the inorganic components of dentin debris. Therefore, simultaneous use of NaOCl and ethylenediaminetetraacetc acid (EDTA) has been recommended for smear layer removal.[5] The manual irrigation technique is insufficient for thoroughly cleaning the intricate structure of the root canal system, which includes the apical third, isthmus, fins, and both lateral and accessory canals.[6] as it extends 1.5 to 2.0 mm beyond the needle tip. To ensure that these irrigating

solutions contact the entire surface of the root canal walls, intracanal agitation or activation of the irrigants is required.[7] There are various techniques and irrigant delivery systems available to enhance the distribution and flow of irrigating solutions inside the root canal system.[8]

These systems can be broadly categorized into two groups: machine-assisted agitation devices and manual agitation approaches. Manual technique involves irrigation with needles, endobrush and well fitting gutta percha whereas machine-assisted agitation involves use of rotary brushes,sonic, ultrasonic and pressure alternation devices.[9] The EndoActivator System (Dentsply Tulsa Dental Specialties, Tulsa, OK) is a sonically-driven canal irrigation system that includes a portable handpiece and three different sizes of disposable flexible polymer tips[10].Self adjusting file is a three-dimensional canal adaption system developed by ReDent-Nova which has a hollow lattice that enables consistent dentin layer removal and simultaneous irrigation.[11]

The study aims to compare the effectiveness of manual irrigant agitation, EndoActivator, and self-adjusting file on the removal of the smear layer.

Materials and Methods: Fifty premolars with a single canal were used in this study.

Exclusion criteria: The teeth with root caries, fractures, internal or external resorption, immature apexes, extensive restorations and dilacerated roots were excluded from the study.

Sample Preparation: Conventional access opening was done and the canal was negotiated with a #15K file and working length was established 0.5mm short of this measurement. The apex of all teeth was sealed with utility wax to simulate the clinical situation. The glide path was prepared with a #10 K file and the root canals were instrumented using ProTaper Universal rotary files (Dentsply) until ProTaper F3 file reached the working length. During instrumentation, each tooth was irrigated with 3ml of 4% NaOCl and recapitulation was done after each instrument used in the canal by inserting a smaller sized file to the working length.

Final Irrigation Protocol: Upon the completion of the canal preparation, each specimen was irrigated with 3ml of 4% NaOCl for 3 minutes, 3 mL saline for 1 minute, and 3 mL of 17% EDTA for 3 minutes.

The irrigant was delivered by means of a side vented needle -30 gauge inserted passively 2mm short of working length with back and forth motion of 2-3 mm. Based on the mode of irrigant activation, the samples were randomly assigned to 4 groups (n=15)

Control group: n= 15 (no activation): After final irrigation, the samples were left undisturbed without subjecting the irrigant to agitation.

Group 1: n=15 (Manual agitation) Specimens were irrigated with 3ml of 4% NaOCl for 3 minutes, 3 mL saline for 1 minute, and 3 mL of 17% EDTA for 3 minute. Irrigant agitation was done with a well-fitting Gutta Percha Master cone for 1 minute per canal at a frequency of 100 push-pull motions/minute

Group 2: n= 15 (EndoActivator, Dentsply): Specimens were irrigated with 3ml of 4% NaOCl for 3 minutes, 3 mL saline for 1 minute, and 3 mL of 17% EDTA for 3 minute. Intracanal irrigant activation was done for 1 minute with a 25/04 noncutting polymer tip of the EndoActivator placed 1 mm short of working length at 10,000 cycles per minute

Group 3: n=15 (Self-adjusting file (SAF), (ReDent-Nova, Israel) Specimens were irrigated with 3ml of 4% NaOCl for 3 minutes, 3 mL saline for 1 minute, and 3 mL of 17% EDTA for 3 minute using an irrigation pump (VATEA; ReDent-Nova). The SAF was used with a pecking motion to working length at 5000 vibrations per minute.

The roots specimens were then longitudinally split using a serrated disc (Brasseler, Savannah, GA) into two halves. The specimens were then fixed in 2% glutaraldehyde and dehydrated using the sequential increase with ethyl alcohol 30%, 50%, 70%, 80%, 90%, and 100% respectively for 10 minutes each. They were examined under a scanning electron microscope (LEO Evo 40X VP; Carl Zeiss AG, Oberkochen, Germany. The digital photomicrographs (4000X) of the dentinal wall on centre of each third for smear layer evaluation. The scoring of the smear layer was done according to the criteria given by Hulsmann et al.[12]

Score 1: Complete absence of a smear layer; open dentinal tubules.

Score 2: Presence of a slight smear layer; most dentinal tubules open.

Score 3: Presence of a homogeneous smear layer covering the canal wall; a few dentinal tubules open

Score 4: A thick smear layer covering the complete canal wall; no open dentinal tubules

Score 5: An entire canal wall covered by a heavy smear layer

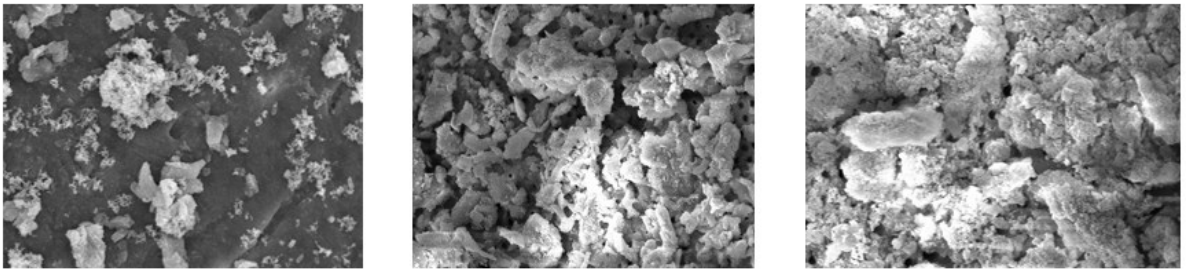

Fig1: Control group; A- coronal third; B- middle third; C- apical third

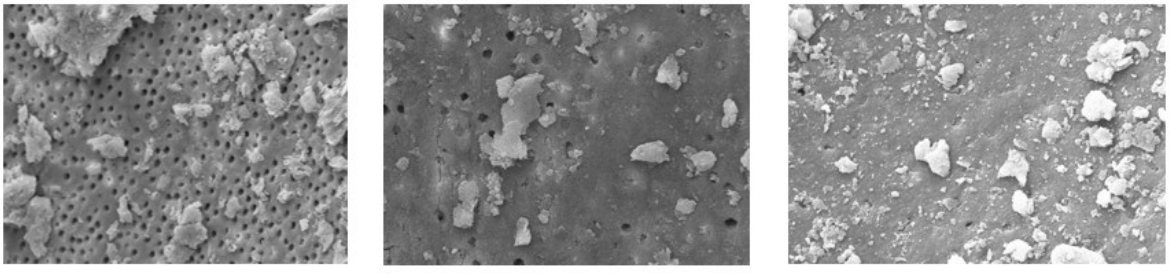

Fig 2: Manual agitation group; A-coronal third; B- middle third; C- apical third

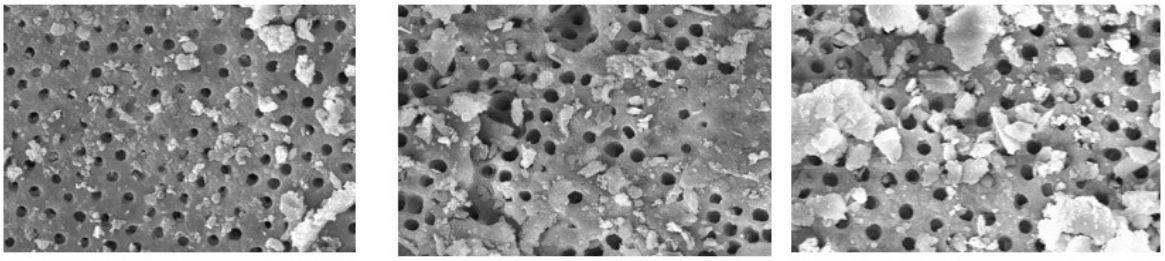

Fig 3: Endoactivator group; A-coronal third; B- middle third; C- apical third

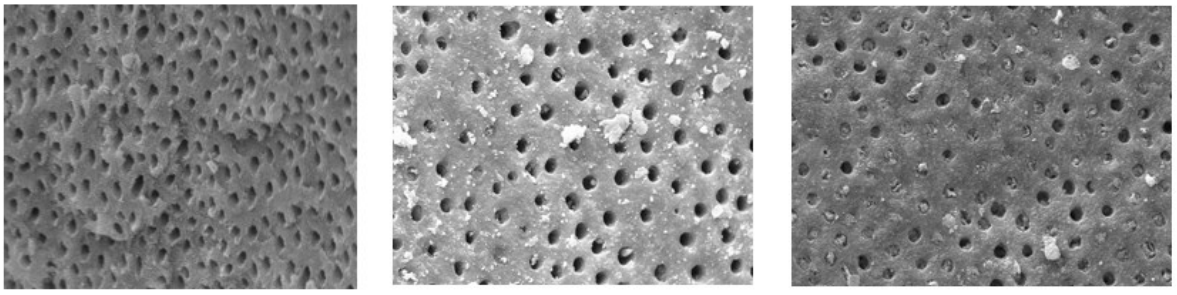

Fig 4: Self-adjusting file group; A-coronal third; B- middle third; C- apical third

Results: The chi-square test for smear layer scores confirmed significant differences between the Control, Manual Agitation, EndoActivator and Self-adjusting file groups. (Table -1)

Apical Third: In the control group, a thick smear layer covering the entire surface was observed, and there was a lack of open dentinal tubules suggestive of score 5 (Fig-1). Manual agitation group showed more samples with smear layer score of 4, whereas the endoactivator group and self-adjusting file group showed more samples with smear layer score of 2 and 3.

Middle Third: Smear layer scores of 4 and 5 were more significantly found in the control group and manual agitation (Fig 2) whereas the smear layer scores of 2 and 3 was more among the endoactivator group and self-adjusting file.

Coronal Third: Smear layer scores 1 and 2 were significantly found in the endoactivator (Fig 3) and self-adjusting file (Fig 4) and scores 3 and 4 were found in control group and gutta percha group.

Mann-Whitney U test was done for the inter-group comparison of mean smear layer removal at the apical, middle and coronal thirds.

The mean smear layer score was significantly higher among the control and manual agitation groups than the EndoActivator and self adjusting file groups at the coronal third.

The mean smear layer score was significantly more among the control and manual agitation groups than the EndoActivator group which was significantly more than SAF group at the middle third.

The mean smear layer score was significantly more among the control group and the manual agitation group than the EndoActivator group and SAF group at the apical third.

The inter-group comparison of the mean smear layer score was done using the Wilcoxon signed-rank test. The mean smear layer score was significantly more at the apical third in comparison to the middle third which was more than the coronal third.

Wilcoxon signed-rank test was done for the inter-group comparison of the mean smear layer score. The mean smear layer score was significantly more at the apical third in comparison to the middle third which was more than the coronal third in all the specimens.

Table 1: Mean Smear layer removal Score

Sample	Control Group			Manual Agitation			Endoactivator			Self-Adjusting file		
	Apical	Middle	Coronal	Apical	Middle	Coronal	Apical	Middle	Coronal	Apical	Middle	Coronal
1	3	3	3	4	4	3	3	2	2	2	2	2
2	4	5	4	4	3	3	4	3	2	3	3	2
3	4	3	3	3	3	3	3	3	3	3	2	2
4	5	5	3	3	3	3	3	2	3	3	2	2
5	4	3	4	3	4	3	4	3	3	3	2	2
6	0	0	0	5	3	3	4	2	2	3	3	1
7	0	0	0	3	3	3	3	3	2	3	2	2
8	0	0	0	4	3	3	4	4	3	2	2	2
9	0	0	0	3	4	3	5	2	3	3	1	2
10	0	0	0	3	3	3	2	2	2	2	2	2
11	0	0	0	3	4	3	2	3	3	3	3	2
12	0	0	0	5	3	3	3	3	2	3	3	2
13	0	0	0	3	3	3	2	2	3	3	2	2
14	0	0	0	3	3	3	3	4	3	3	3	2
15	0	0	0	4	3	3	3	2	2	3	2	2
Mean	4	3.7	3.4	3.5	3.27	3.00	3.20	2.67	2.53	2.77	2.27	2.13

DISCUSSION

Cleaning and disinfecting the root canal system is the major goal of endodontics in order to promote healing and preserve the health of periradicular tissue.[13] To prevent reinfection, root canals are cleaned before obturation through mechanical instrumentation, irrigants, and intracanal medicaments[14]. Failure to remove the smear layer during root canal treatment can lead to negative outcomes. The root canal instrumentation creates a smear layer containing dentin debris, pulp tissue, odontoblastic processes, necrotic debris, and microorganisms and their metabolic products.[15] To accomplish this, an effective irrigation method that ensures adequate irrigant delivery and flow particularly at the apical third of the root canal is required in order to debride the canal system.[16]

Studies have concluded that syringe irrigation is ineffective in the apical part of the root canal even though it is considered as a standard procedure.[17,18]During conventional syringe irrigation air is trapped in the apical third of root canal leading to vapor lock which might limit irrigant exchange and reduce debridement ability.[19] In order to increase the effectiveness of irrigation solutions, final-rinse activation techniques have been proposed which include agitation using hand files, gutta-percha cones sonic and ultrasonic devices.[20,21]

Manual dynamic irrigation (MDI) involves gently moving a well-fitted master gutta-percha cone in a up and down motion on an instrumented canal, can greatly enhance the displacement and exchange of any given reagent while also producing an efficient hydrodynamic effect.[22] Studies have demonstrated that manual dynamic irrigation was considerably more effective than both auto dynamic and conventional irrigation.[23]

The EndoActivator System (EA) (Dentsply Tulsa Dental Specialties, Tulsa, OK) is a sonic activation system which works on a hydrodynamic phenomenon that produces vigorous intracanal fluid agitation. In this study endoactivator performed significantly better than the MDI and the control group which is in accordance with the previous study conducted by David Uroz-Torres et al.[10]

The SAF system is the first endodontic file with an asymmetrical tip and no traditional central solid metal core. The metal core is a hollow cylinder with thin walls composed of NiTi lattice which enables file compression.[24]To better adapt to the cross-sectional morphology of the canal, the SAF instrument has a nontraditional hollow and flexible form. During treatment or retreatment, its somewhat abrasive surface scrapes dentine like sandpaper and can enhance canal cleaning.[25]According to a study, SAF when used with continuous irrigation with NaOCl and EDTA resulted in better removal of intracanal smear layer.[26]

The coronal third was cleaner than the apical third in all the specimens irrespective of the type of activation devices used which is similar to the findings of study done by Albrecht et al which could be due to wider diameter at the coronal third which exposes more volume and enhanced irrigant flow there, improving the effectiveness of smear layer removal.[27,28]The present study used a closed apical system to reproduce clinical conditions to simulate gas entrapment into the root canal.

The limitation of this study is that only the teeth with straight canals were considered. Future studies on the effectiveness of the different irrigant activation methods in root canal debridement in curved canals are possible.

CONCLUSION

Within the experimental protocol of this study, self-adjusting file can be considered as an adjunct to root canal irrigation in removing the smear layer. Self-adjusting file removed the smear layer more effectively than other techniques in the apical third of the root canal system. The coronal dentinal canal walls were significantly cleaner than the apical canal walls, irrespective of the irrigant activation method used. None of the irrigation activation methods we studied were able to remove the smear layer completely.

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