DOI: 10.7860/JCDR/2023/61774.17698

Original Article

Dentistry Section

Effectiveness of Ultrasonic, F-File, and NaviTip FX Needle Agitation Techniques on Removal of Root Canal Debris and Smear Layer Using Two Different Irrigants: A Scanning Electron Microscopy Study

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ABSTRACT

Introduction: For successful endodontics, there should be proper cleaning and shaping of the canal before the obturation. Various agitation techniques help in the removal of the debris and smear layer. With the removal of this debris and smear layer, there will be a better opening of dentinal tubules and penetration of sealer in the tubule.

Aim: To evaluate the effectiveness of removal of debris and smear layer from prepared root canals by comparing ultrasonic agitation, F-file agitation, and NaviTip FX needle agitation using Sodium hypochlorite (NaOCl) and SmearClear as irrigants.

Materials and Methods: The present in-vitro study included 60 bilaterally matched pairs of extracted human premolar teeth with single canal and mature apices, were collected. All teeth were decoronated at the cementoenamel junction. The teeth were grooved longitudinally on the buccal and lingual surfaces. Instrumentation was done using K3 rotary files up to #40 and irrigation was carried out using 2 mL syringes mounted with Max-i-probe needles. Agitation procedure (n=10 for each group) was done as follows.

Group 1: Ultrasonic agitation of 2.5% NaOCl for 30 seconds.

Group 2: F-file agitation of 2.5% NaOCl for 30 seconds

Group 3: NaviTip FX agitation of 2.5% NaOCl for one minute continuously.

Group 4: Ultrasonic agitation of SmearClear for 30 seconds.

Group 5: F-file agitation of SmearClear for 30 seconds.

Group 6: NaviTip FX agitation of SmearClear for one minute continuously.

The roots were split into two halves using a chisel and mallet. The amount of debris and smear layer was assessed using SEM at 1000X magnification at each root canal's coronal, middle, and apical areas. Statistical analysis was done using Kruskal-Wallis and Mann-Whitney U test.

Results: Statistically significant difference was obtained in the reduction of debris and smear layer between 2.5% NaOCl and SmearClear. Ultrasonic agitation of SmearClear was better than F-file agitation and NaviTip FX. In both debris and smear layer removal (p-value <0.05).

Conclusion: Ultrasonic agitation of SmearClear was better than F-file agitation and NaviTip FX agitation. SmearClear produced better removal of debris and smear layer than 2.5% NaOCl.

Keywords: Cleanliness, Instrumentation, Irrigants, Sodium hypochlorite

INTRODUCTION

For endodontic success, the removal of infected pulp tissues, microorganisms, and microbial toxins from the root canal system is essential [1]. Hence, chemomechanical debridement plays an important role in endodontic treatment [2]. The currently available Nickel-Titanium (Ni-Ti) instruments work on the central body of the canal, leaving the canal untouched in several areas, after debridement of the canal [3]. Irrigation serves as a lubricant, facilitating the cleaning of the canal system by flushing debris and bactericidal agent [4].

Debris is made up of small pieces of dentin, along with remaining living or dead pulp tissue, that are loosely attached to the walls of the root canal. This debris is often infected [5]. Additionally, after the root canal instrumentation process, a thin film called the "smear layer" forms on the surface of the root canal walls. This layer, which is about 1-2 micrometers thick, is made up of a mixture of dentin particles, pulp tissue, bacteria and any remaining irrigation solutions. This smear layer can block the openings of the dentinal tubules [6].

Currently, in endodontic practice, the most commonly used irrigants for cleaning root canals are sodium hypochlorite (NaOCl), Ethylenediaminetetraacetic acid (EDTA) and a Chlorhexidine (CHX). These irritants are often used in combination to address the limitations of using a single irrigant alone [7]. It is crucial that these irrigants come into direct contact with all surfaces of the root canal, especially the apical one-third, in order to effectively clean the canal [1].

Contact of an irrigating solution on the root canal walls mainly depends on the wettability of the irrigating solution on root dentine, which is in turn dependent on a low surface tension [8]. The surface tension of an irrigating solution can be reduced with the addition of surfactants [9]. SmearClear is a product that was introduced for the removal of the smear layer and debris. It consists of a 17% EDTA solution which includes two proprietary surfactants namely, polyoxyethylene and iso-octylcyclohexyl ether [7].

Efforts are ongoing to develop better methods for delivering and agitating irrigants in root canals to improve their cleaning effectiveness [10]. Weller RN et al., introduced Passive Ultrasonic Irrigation (PUI) which results in the acoustic streaming effect of ultrasonics and these advancements can aid in transporting chelating agents to

the apical root canal to aid in the removal of the smear layer and improve cleaning in the apical root canal [11].

Innovations have been introduced as a proposed means of effectively cleaning the root canal system and potentially replacing ultrasonic agitation as a cleaning method [12]. An example of a new device for cleaning the root canal system is the F-file, a disposable, plastic rotary file with a diamond abrasive embedded in a non toxic polymer. It is designed to remove debris and agitate the irrigant without widening the canal. The file has a taper of 0.04 and the file tip is similar to a size #20 K-file [13]. Another new agitation device that works along the principle of brushing the canal walls is NaviTip FX, this brush was efficient to clean the root canal mechanically [14].

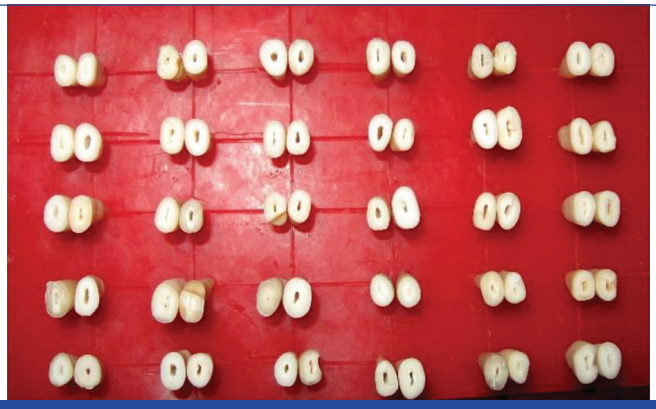
There were no studies in the medical literature about the effectiveness of debris and smear removal using NaOCl and SmearClear as irrigants with newer three techniques. Therefore, the present study aimed to evaluate the effectiveness of removal of debris and smear layer by Scanning Electron Microscope (SEM), from prepared root canals by comparing the techniques of ultrasonic agitation, F-file agitation, and NaviTip FX needle agitation using NaOCl and SmearClear as irrigants.

MATERIALS AND METHODS

The present in-vitro study was carried out for in the Department of Cpnservative Dentistry and Endodontics, Bapuji Dental College and Hospital, Davanagere, Bangalore, India, from June 2011 to September 2014. Ethical clearance was obtained from the Institutional Ethical Committee (BDCH IEC/09/2010).

In this study, 60 bilaterally matched pairs of single-rooted human premolars with a single canal and closed apex were collected and stored in normal saline. A tooth extracted for orthodontic reasons with crack-free, caries-free and no resorption was considered.

A digital radiograph was taken twice in a mesiodistal and buccolingual direction to confirm the presence of a single canal. The radicular portion was obtained by decoronating the cementoenamel junction with the help of a diamond disk [Table/Fig-1].



[Table/Fig-1]: Decoronated matched paired root canals of teeth.

Study Procedure

The patency of the canal was confirmed for each tooth by inserting a #10 K-file beyond the apical foramen. A longitudinal groove was placed at the buccal and lingual surfaces of the sample chisel and mallet was used for the vertical split. To prevent the creation of artificial debris, the disc was not inserted into the canal space.

Root canal instrumentation: Working length was recorded at the first visibility of #10 K-file at apical foramen and reducing it by 0.5 mm. Canal shaping was done using K3 rotary files up to #40 and irrigation was carried out using 2 mL syringes mounted with Max-i-probe needles of 25-and 30-gauge. For groups 1, 2 and 3, 2.5% NaOCl was the irrigant during instrumentation. For groups 4, 5 and 6, SmearClear was the irrigant during instrumentation.

Irrigant agitation protocol [Table/Fig-2]: After instrumentation, the matched pairs of teeth were divided as follows:

[Table/Fig-2]: Agitation tips: ultrasonic sonic tips, F files and Navi Tip files.

Group 1: Ten teeth from each matched pair underwent ultrasonic agitation of 2.5% NaOCl for 30 seconds 2 mm short of the apex in short cyclic axial motion in Satelec ultrasonic unit at slow speed.

Group 2: Ten teeth from each matched pair underwent F-file agitation of 2.5% NaOCl for 30 seconds in a short circumferential cyclic axial motion at 600 rpm in an electric slow-speed handpiece.

Group 3: Ten teeth from each matched set were cleaned using a manual combination of left and right rotary motion and up and down movements, using a brushing technique with the NaviTip FX for a continuous one-minute period while being irrigated with 2.5% NaOCl.

Group 4: Pairs of the 10 teeth underwent ultrasonic agitation of SmearClear for 30 seconds 2 mm short of the apex in short cyclic axial motion in Satelec ultrasonic unit at a slow speed.

Group 5: Ten pairs of teeth were cleaned using F-file agitation with SmearClear for 30 seconds in a short cyclic axial motion at 600 rotations per minute with an electric slow-speed handpiece.

Group 6: Ten pairs of teeth were cleaned using a manual combination of left and right rotary motion and up and down movements, using a brushing technique with the NaviTip FX for a continuous one-minute period while being irrigated with SmearClear.

All teeth of each group underwent a final rinse with 0.9% saline. The coronal and apical orifices were sealed with warm wax and all the samples were placed in the physiologic saline solution until proceeding with the teeth-splitting protocol.

Splitting of the teeth and SEM evaluation: The wax of the coronal and apical orifices of all the teeth were removed and the canals were dried with paper points. Chisel and mallet were used to split the tooth into two halves. All the specimens were dried, gold-sputtered, and SEM evaluation was done at coronal, middle, and apical one-third at the magnification of 1000X. The retained debris and smear layer were scored using a three-step scale using Zmener O et al., criteria [15].

To evaluate debris, the following scoring system was used:

Score-1: No debris or only a few isolated particles are present.

Score-2: Debris covers 50% or more of the canal walls.

Score-3: Debris covers the entire canal walls.

To evaluate the smear layer, the following scoring system was used:

Score-1: A regular pattern of open dentinal tubules with no smear layer present.

Score-2: Some open dentinal tubules are visible, while the rest are covered by a smear layer.

Score-3: A continuous smear layer covers the entire canal walls, and no dentinal tubules are visible.

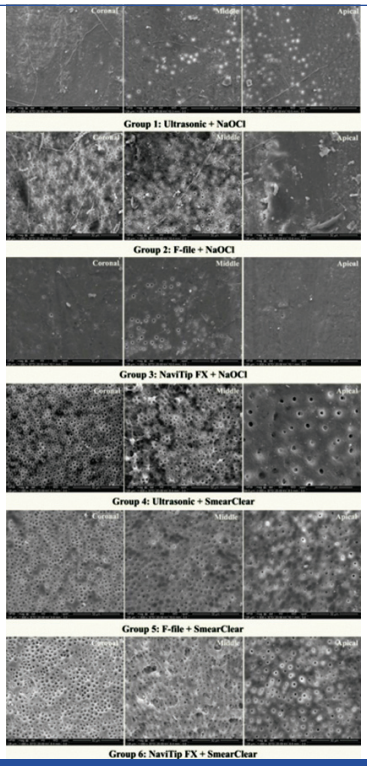
The debris and smear layer in the root canals of all groups were evaluated using a three-point scale. The average scores of the coronal, middle, and apical one-third of the root canal were calculated by adding the scores of each individual unit and dividing by the total number of evaluation units.

STATISTICAL ANALYSIS

The scores for debris and smear layer in the root canals of all groups were analysed using statistical methods, specifically the Kruskal-Wallis test and the Mann-Whitney U test. These tests were chosen due to the non normal distribution of the data and the presence of multiple groups. The results were then tabulated and recorded in an Microsoft (MS) Excel sheet and the level of significance was set at 95%. The Kruskal-Wallis test was used to compare the differences between groups and the Mann-Whitney U test was used for comparisons within each group. The p-value <0.05 was considered statistically significant.

RESULTS

The scores for debris and smear layer in each tooth and group were determined by analysing SEM microphotographs and calculating the mean scores [Table/Fig-3] revealing evidence of erosion of dentinal tubules.



[Table/Fig-3]: SEM microphotographs of coronal, middle and apical thirds of root canals of teeth in the experimental groups.

Group 4: showed better debris and smear layer removal when compared to other groups [Table/Fig-4,5].

Root portion	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Coronal	2.6	1.8	2.1	1.4	2.0	1.9
Middle	2.6	2.2	2.0	1.6	2.0	1.9
Apical	2.7	2.6	2.7	1.8	2.0	2.2

[Table/Fig-4]: Average score of debris in the root canals in each group.

Root portion	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Coronal	2.6	2.0	2.2	1.0	1.2	1.5
Middle	2.6	2.1	2.1	1.1	1.6	1.8
Apical	2.7	2.8	2.7	1.7	1.8	2.2

[Table/Fig-5]: Average score of smear layer in the root canals in each group.

Group 4: Ultrasonic+Smear Clear, showed the lowest mean debris score compared to the other groups and the difference between the groups were significant (p-value <0.01) [Table/Fig-6]. Multiple comparisons of debris scores were done using by Mann-Whitney U test. It was seen that the debris removal of group 4 was significantly lower than all the other groups (p-value <0.05) [Table/Fig-7].

Groups	Median	Mean	p-value
1	2.67	2.67	**<0.001**
2	2.17	2.20	
3	2.33	2.23	
4	1.67	1.60	
5	2.00	2.00	
6	2.00	2.00	

[Table/Fig-6]: Mean of debris scores in the root canals of each tooth in each group. *Kruskal-Wallis test

Groups	Variables	1	2	3	4	5	6
1	Mean	2.67	0.47	0.44	1.07	0.67	0.67
	p-value		**0.01**	**0.007**	**0.001**	**0.001**	**0.001**
2	Mean	0.47	2.20	0.03	0.6	0.2	0.2
	p-value	**0.01**		0.74	**0.004**	0.07	0.20
3	Mean	0.44	0.47	2.23	0.63	0.23	0.23
	p-value	**0.007**	**0.01**		**0.001**	**0.002**	**0.029**
4	Mean	1.07	0.6	0.63	1.60	0.4	0.4
	p-value	**0.001**	**0.004**	**0.001**		**0.007**	**0.019**
5	Mean	0.67	0.2	0.23	0.4	2.00	0.0
	p-value	**0.001**	0.07	**0.002**	**0.007**		0.61
6	Mean	0.67	0.2	0.23	0.4	0.0	2.00
	p-value	**0.001**	0.20	**0.029**	**0.019**	0.61	

[Table/Fig-7]: Multiple comparison of debris scores of each tooth in each group. Mann-Whitney U test

Group 4: Ultrasonic+SmearClear, showed the lowest mean smear layer score compared to the other groups where the level of significance was set at p-value <0.01 [Table/Fig-8] on multiple comparisons of smear layer scores between the groups, it was seen that the debris removal of group 4 was significantly lower than all the other groups (p-value <0.05) except group 5, F-file+SmearClear [Table/Fig-9].

Groups	Median	Mean	p-value
1	2.67	2.63	**0.001**
2	2.33	2.30	
3	2.33	2.33	
4	1.33	1.27	
5	1.67	1.53	
6	1.84	1.83	

[Table/Fig-8]: Mean of smear layer scores in the root canals of each tooth in each group. Kruskal-Wallis test

Groups	Variables	1	2	3	4	5	6
1	Mean	2.63	0.33	0.30	1.37	1.10	0.80
	p-value		0.03	0.08	0.001	0.001	0.001
2	Mean	0.33	2.30	0.03	1.04	0.77	0.47
	p-value	0.03		0.90	0.001	0.001	0.005
3	Mean	0.30	0.03	2.33	1.07	0.80	0.50
	p-value	0.08	0.90		0.001	0.001	0.005
4	Mean	1.37	1.04	1.07	1.27	0.26	0.56
	p-value	**0.001**	0.001	**0.001**		0.07	**0.002**
5	Mean	1.10	0.77	0.80	0.26	1.53	0.30
	p-value	0.001	0.001	0.001	0.07		0.11
6	Mean	0.80	0.47	0.50	0.56	0.30	1.83
	p-value	0.001	0.005	0.005	0.002	0.11	

[Table/Fig-9]: Multiple comparison of smear layer scores of each tooth in each group. Mann-Whitney U test

DISCUSSION

The aim of this study was to evaluate the effectiveness of removal of debris and smear layer using SEM, from prepared root canals by comparing the techniques of ultrasonic agitation, F-file agitation, and NaviTip FX needle agitation using NaOCl and SmearClear as irrigants. Debris and smear layer removal in the root canal using the agitation technique proved to be a better protocol to follow. One of the biggest challenges in endodontic treatment is effectively cleaning the root canal system and its branches, removing both organic and inorganic debris and the smear layer, in order to create a favourable environment for the tooth to heal optimally.

This study involved a sample of 60 pairs of human premolar teeth with a single root canal and mature apices, each pair being bilaterally matched. The teeth were split vertically with a chisel and mallet after being grooved longitudinally with a diamond disc on the buccal and lingual surfaces in order to facilitate the process.

This step was carried out before performing cleaning and shaping with the conviction that any artificial debris created during the decoration and placement of grooves would not contaminate the specimens. The studies reported in the literature vary from the aforementioned protocol in this regard as the grooves were placed after the instrumentation of root canals [5,8]. The possibility of contamination has not been addressed hitherto. Therefore, the present study's protocol may be considered a potential preventive to the risk of specimen contamination.

Prati C et al., conducted a study on the effect of different endodontic instruments (K3, Hero 642, RaCe, and K-file) on the amount of dentin and pulpal debris, the appearance of the smear layer, and the surface profile of the root canal. They found that the type of instrument used only had a partial impact on these factors [16]. Kum KY et al., found that the K3 rotary system resulted in less formation of a smear layer on the root canal walls in the selected apical third area of curved canals, compared to the ProFile system [17]. In the present study, root canal instrumentation was performed with K3 rotary Ni-Ti files in a crown-down manner.

A study by Khademi A et al., aimed to find the smallest instrument size needed for the effective removal of debris and smear layer from the apical third of the root canal. The results showed that a #30 K-file was sufficient for this purpose [18]. A study by Ram Z determined that the root canal must be enlarged to a size of 40 at the apex in order for the irrigant to effectively remove debris and smear layer [19]. Keeping the findings of these studies in mind, the apical preparation of #40 K-file selected in the present study is justified.

NaOCl is considered to be the best choice for cleaning root canals during endodontic treatment because it has superior antibacterial, tissue dissolving, and lubricating properties compared to other compounds [4]. Research has shown that using different concentrations of NaOCl (0.5%, 1.0%, 2.5% and 5.25%) is equally effective at removing necrotic pulp tissue in the root canal and cleaning away superficial debris, but it is not effective at removing the smear layer [3]. Hence, 2.5% NaOCl was used in this study as one of the main irrigants. NaOCl is not able to dissolve inorganic dentin particles, thus it fails to prevent the formation of a smear layer during instrumentation [20].

To solve the problem of NaOCl not being able to dissolve inorganic dentin particles, demineralising/chelating agents like EDTA have been used. SmearClear is a commercially available solution that contains 17% EDTA, cationic (cetrimide) and anionic surfactant. Studies have shown that SmearClear is as effective as different concentrations of EDTA in removing the smear layer [9]. Lui JN et al., showed that the surfactants in SmearClear did not improve its performance in smear layer removal compared to EDTA alone [21]. A study by Zehnder M et al., found that decreasing the surface tension of chelator solutions used in endodontics did not enhance their ability to chelate calcium and that adding a wetting agent to these solutions is unnecessary [22]. However, da Silva LAB et al., demonstrated that SmearClear was able to remove the smear layer from root canals as effectively as 14.3% EDTA, suggesting that both solutions may be used for such purpose [9]. Published data have indicated detrimental effects on dentin with the use of high volume combined with a higher application time of EDTA solutions [7]. The present study used 1 mL/minute volume of SmearClear when using it as the sole irrigant for three of the experimental groups. However, the time for which the chelating solution acted in the canals was greater than it would have been if used as a final flush. The SEM micrographs of group 4, 5 and 6 reveal evidence of erosion of dentinal tubules which is consistent with the findings in the literature [23].

The current study showed that using ultrasonics for agitation is more effective than other methods, regardless of the type of irrigant used, as per the results demonstrated in the study. SEM micrographs revealed the least debris and smear layer scores in the ultrasonic agitation compared to other groups. This finding has been corroborated in previous studies [23]. This protocol was followed in a study by Townsend C and Maki J, which showed the best results with ultrasonic agitation for removing bacteria from simulated root canals [24].

The F-file was hailed as a possible replacement for sonic and ultrasonic agitation of root canal irrigants [25]. NaviTip FX is a 30-gauge irrigation needle covered with a brush. Studies have shown that the use of NaviTip FX in a manual brushing action with simultaneous irrigant delivery shows greater efficacy in cleaning the root canal walls [14,26]. In this study, the NaviTip FX was employed for one minute while continuously irrigating with a combination of manual left and right rotary motion and up and down movements, using a brushing technique on the dentin walls.

The present study concluded that ultrasonic agitation showed this method was more effective, regardless of the type of irrigant used, when compared to other methods of agitation and the results were in conjunction with Chopra S et al., [27]. Goel S and Tewari S in one of the studies concluded that NaviTip FX and intermittent PUI were effective in the removal of the smear layer from the apical third [28].

Results also showed no significant difference between F-file and NaviTip FX with both NaOCl and SmearClear as irrigants. Shenvi S et al., concluded in their study found that there was no improvement in the removal of the smear layer when using F-file compared to the use of an ultrasonically activated K-file [13].

Limitation(s)

In-vitro study design was a major limitation of this study. Further in-vivo research in this area is needed to evaluate the antimicrobial effects of the tested methodologies in endodontic practice.

CONCLUSION(S)

Based on the limitations of the current study, it can be inferred that ultrasonic agitation produces the cleanest canal walls compared to F-file and NaviTip FX agitation and, F-file and NaviTip FX produce similar results and is equally suited for agitation techniques. Also, smear clear produced better removal of debris and smear layer from prepared root canals compared to 2.5% NaOCl.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Dec 12, 2022
- Manual Googling: Jan 27, 2023
- iThenticate Software: Feb 01, 2023 (14%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Nov 22, 2022**
Date of Peer Review: **Jan 10, 2023**
Date of Acceptance: **Feb 02, 2023**
Date of Publishing: **Apr 01, 2023**