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Comparative Evaluation of Smear Layer Removal Using Gutta Percha, Ultrasonic, Sonic, Plastic Finishing File and Canal Brush Methods: A Scanning Electron Microscope Study

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Abstract: ***Instrumentation of the root canal is associated with the formation of a smear layer. The presence of a smear layer prevents the penetration of intracanal disinfectant into the dentinal tubules and prevents complete adaptation of obturation materials to the dentinal walls. Additionally, bacteria remaining in dentinal tubules after root canal preparation may be sealed by the smear layer. The aim of the study was to compare the efficacy of gutta percha, ultrasonic, sonic, plastic finishing file and canal brush methods for the removal of the smear layer from the apical third of root canals. Sixty freshly extracted mandibular premolars were instrumented up to protaper file F3 and divided randomly into six groups (n = 10) according to the following final irrigation agitation techniques: group 1- no agitation (control), group 2- gutta percha , group 3- ultrasonic, group 4- sonic, group 5- plastic finishing file, group 6- canal brush. Specimens were then sectioned and observed under a scanning electron microscope and presence of smear layer was evaluated and scored. Under the testing condition it was concluded that the plastic finishing file method performed significantly better than the rest of the groups with respect to smear layer removal followed by the Canal Brush, sonic, gutta percha, ultrasonic methods.***

Keywords: canal brush, gutta percha, plastic finishing file, sonic, ultrasonic

1. Introduction

The success of root canal treatment primarily depends on proper cleaning and shaping to disrupt the microbial ecology, disinfecting the root canal system and finally sealing it to prevent microleakage. Although the treatment has a high success rate, failure still occurs.[1] Intricate nature of root canals, severe complexities and numerous variations in number and shape of canals poses serious challenges to chemomechanical debridement efforts.[2]

The biomechanical preparation lead to an amorphous, relatively smooth layer of microcrystalline debris known as smear layer. It consists of both organic and inorganic substances.[3] The advantages or disadvantages of the presence of smear layer are still controversial. Some authors suggest that maintaining the smear layer may block the dentinal tubules and limit bacterial or toxin penetration by altering dentinal permeability. Others believe that the smear layer being a loosely adherent structure should be completely removed from the surface of the root canal wall because it can harbour bacteria and provide an avenue for leakage. It may also limit the effective disinfection of dentinal tubules by preventing irrigants and other intracanal medicaments from penetrating the dentinal tubules. Systematic review and meta-analysis observed that the overall consensus has moved toward favouring the removal of the smear layer.[4, 5]

Irrigation is an essential part of root canal debridement because it allows for cleaning beyond what might be achieved by root canal instrumentation alone.[6] To date, no single irrigant has been demonstrated to be capable of dissolving both the organic and inorganic parts of dentin.[7] A combination of mechanical instrumentation and chemical irrigation has been found to accomplish reduction of the bacterial counts in infected root canals. Technological advances in recent times have led to the development of newer agitation devices that depend on various mechanisms for irrigant delivery and agitation.[2]

The aim of the study was to compare the efficacy of gutta percha, ultrasonic, sonic, plastic finishing file and canal brush methods for the removal of the smear layer from the apical third of root canals.

2. Materials and Methods

Preparation of the Samples

Sixty freshly extracted intact human mandibular premolars (length 20–21 mm, straight, with a single canal) checked by radiographs and with complete apex formation that were extracted for orthodontic reasons from patients aged 16–18 years was collected and stored in 10% formalin until use. Coronal access was achieved using a round bur. Working length was determined using a #15K-file that was inserted into the canal until it was visible at the apical foramen. The working length was measured 1 mm less than the length obtained with this initial file. To simulate the clinical situation, each apex was sealed with sticky wax.

Biomechanical Preparation of the Root Canals

All root canals were instrumented with the protaper universal system till F3 using an X-smart endo motor at 300 rpm. A single operator instrumented all root canals. The instruments were replaced after ten use. Freshly prepared 1% sodium hypochlorite (NaOCl) solution was used for root canal irrigation using a 5 ml syringe. After each instrument change, the root canals were rinsed with 3 ml of the irrigating solution. During the irrigation procedures, the irrigator tips were placed 1 mm from the working length and then moved forwards and backwards for 30 seconds. Subsequently, the root canals were irrigated with 10 ml distilled water to avoid the prolonged effects of the NaOCl solution.

Final Irrigation Procedures

After biomechanical preparation of the root canals, the specimens were divided randomly into six groups of ten teeth each. Except for the control group, the root canals were subjected to a final rinse with 1 mL 17% ethylenediaminetetraacetic acid (EDTA) using a 5ml syringe, which was placed 1 mm from the working length and then moved forwards and backwards for 30 seconds. The groups were as follows:

1) Group 1 (n = 10): Control; no final rinse and no additional agitation of the irrigant were performed.
2) Group 2 (n = 10): Gutta percha activation; the solution was activated with the F3 gutta percha.
3) Group 3 (n = 10): Ultrasonic activation; the solution was activated by an ultrasonic irrigation tip at a frequency of 30 KHz.
4) Group 4 (n = 10): Sonic activation; the solution was activated by sonic irrigation tip at frequency of 6 KHz.
5) Group 5 (n = 10): Plastic finishing file activation; the irrigant was activated by using a plastic finishing file placed in an endomotor at 600 rpm.
6) Group 6 (n = 10): Canal Brush activation; the irrigant was activated with a medium sized Canal Brush placed in an endomotor at 600 rpm.

After EDTA agitation, the specimens in all groups were irrigated for 60 seconds with 1ml 1% NaOCl followed by a final rinse with 5ml 0.9% sterile saline solution. The root canals were then dried with absorbent paper points and the specimens were stored in Eppendorf tubes.

Evaluation by Scanning Electron Microscopy

The teeth were grooved along the buccal and lingual surfaces by using a diamond disc at low speed and split longitudinally with a chisel and mallet into 2 halves. Further apical 5 mm was sectioned. For each specimen, the half containing the most visible part of the apex was placed in a 2% glutaraldehyde solution for 24 hours and dried. The other half of each tooth was discarded. Each specimens were mounted on an aluminum stub, coated with 25 mm gold palladium and examined under a scanning electron microscope and photomicrographs were taken. The photomicrographs were analyzed by three examiners who were specialists in endodontics and were blind to group status. Each examiner scored the presence or absence of a smear layer in the apical third following the method described by Torabinejad et al in which a score of 1 indicated no smear layer (no smear layer on the surface of the root canals; all tubules were clean and open), a score of 2 indicated a moderate smear layer (no smear layer on the surface of root canal, but tubules contained debris), and a score of 3 indicated a heavy smear layer (smear layer covered the root canal surface and the tubules). The results were tabulated and submitted to statistical analysis. The comparisons between groups were analysed statistically using the Kruskal Wallis and Mann Whitney U tests.

3. Result

The study was to compare the efficacy of gutta percha, ultrasonic, sonic, plastic finishing file and canal brush methods for the removal of the smear layer from the apical third of root canals. The reduction of smear layer after various agitation methods were scored using scanning electron microscopic images.

Statistical Package for Social Sciences [SPSS] for Windows, Version 22.0. Armonk, NY: IBM Corp., was used to perform statistical analyses. Descriptive analysis includes expression study variables in terms of mean and standard deviation. Inferential Statistics, the normality of the data was checked by using Shapiro Wilk test and it was observed that the data was not following a normal distribution. Hence all the inferential statistical tests were performed using relevant non parametric tests. Kruskal Wallis Test followed by Mann Whitney Post hoc Test was used to compare the mean smear layer scores between six groups. The level of significance [P-Value] was set at $P < 0.05$.

A comparison of mean smear layer scores between six groups using Kruskal Wallis test reveals that the mean smear layer scores among different study groups was statistically significant at $P < 0.001$. (Table 1, Graph 1)

A multiple comparison of mean difference in the smear layer scores between six groups using Mann Whitney Post hoc test revealed that plastic finishing file group showed significantly least smear layer score as compared to other groups. This was followed by canal brush group having significantly lesser smear layer scores. Similarly, both sonic & gutta percha groups also showed significantly lesser mean scores compared to no agitation group. However, the mean smear layer scores between no agitation & ultrasonic groups, gutta percha with ultrasonic & sonic groups, ultrasonic & sonic groups and finally plastic finishing file & Canal brush groups did not show any significant differences respectively. (Table 2)

The distribution of smear layer scores among study groups revealed that the smear layer scores in different groups were predominantly presented with score 2, varying between 60 – 80% in plastic finishing file, canal brush, sonic & gutta percha groups, whereas group ultrasonic & no agitation groups had score 3 varying between 70 – 100%. However, absence of smear layer was seen only in plastic finishing file with 40% and canal brush groups with 20%. (Table 3, Graph 2). Scanning electron microscopy photomicrographs of the evaluated area show that plastic finishing file was comparatively effective in removing the smear layer when compared with gutta percha, ultrasonic, sonic and canal brush agitation methods. (Fig 1)

Table 1: Comparison of mean smear layer scores between six groups using Kruskal Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
No Agitation	10	3.00	0.00	3	3	<0.001*
Gutta Percha	10	2.40	0.52	2	3	
Ultrasonic	10	2.70	0.48	2	3	
Sonic	10	2.30	0.48	2	3	
Plastic Finishing File	10	1.60	0.52	1	2	
Canal Brush	10	1.80	0.42	1	2	

*- Statistically Significant

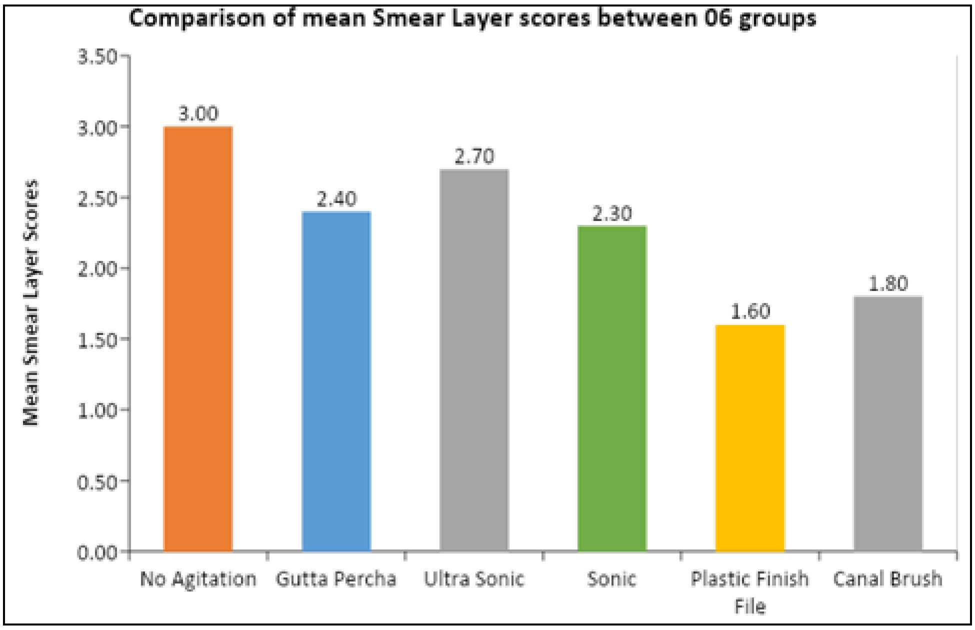
Table 2: Multiple Comparison of mean difference in the smear layer scores between six groups using mann whitney post HOC Test

Multiple Comparison Of Mean Difference In The Smear Layer Scores Between 06 Groups Using Mann Whitney POST HOC Test					
(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI of the Diff.		P-Value
			Lower	Upper	
No Agitation	Gutta Percha	0.60	0.01	1.19	0.004*
	Ultrasonic	0.30	-0.29	0.89	0.07
	Sonic	0.70	0.11	1.29	0.001*
	Plastic Finish File	1.40	0.81	1.99	<0.001*
	Canal Brush	1.20	0.61	1.79	<0.001*
Gutta Percha	Ultrasonic	-0.30	-0.89	0.29	0.19
	Sonic	0.10	-0.49	0.69	0.65
	Plastic Finish File	0.80	0.21	1.39	0.006*
	Canal Brush	0.60	0.01	1.19	0.02*
Ultrasonic	Sonic	0.40	-0.19	0.99	0.08
	Plastic Finish File	1.10	0.51	1.69	0.001*
	Canal Brush	0.90	0.31	1.49	0.001*
Sonic	Plastic Finish File	0.70	0.11	1.29	0.01*
	Canal Brush	0.50	-0.09	1.09	0.03*
Plastic Finish File	Canal Brush	-0.20	-0.79	0.39	0.34

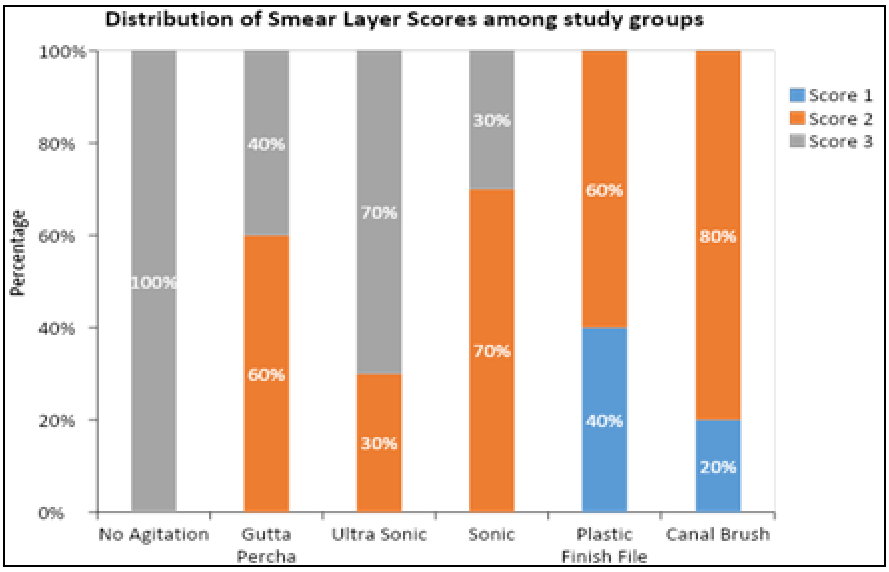
* - Statistically Significant

Table 3: Distribution of smear layer scores among study groups

Distribution of smear layer scores among study groups						
Groups	Score 1		Score 2		Score 3	
	n	%	n	%	N	%
No Agitation	0	0%	0	0%	10	100%
GP	0	0%	6	60%	4	40%
Ultrasonic	0	0%	3	30%	7	70%
Sonic	0	0%	7	70%	3	30%
Plastic Finish File	4	40%	6	60%	0	0%
Canal Brush	2	20%	8	80%	0	0%



Graph 1: Comparison of mean smear layer scores between six groups



Graph 2: Distribution of smear layer scores among study groups.

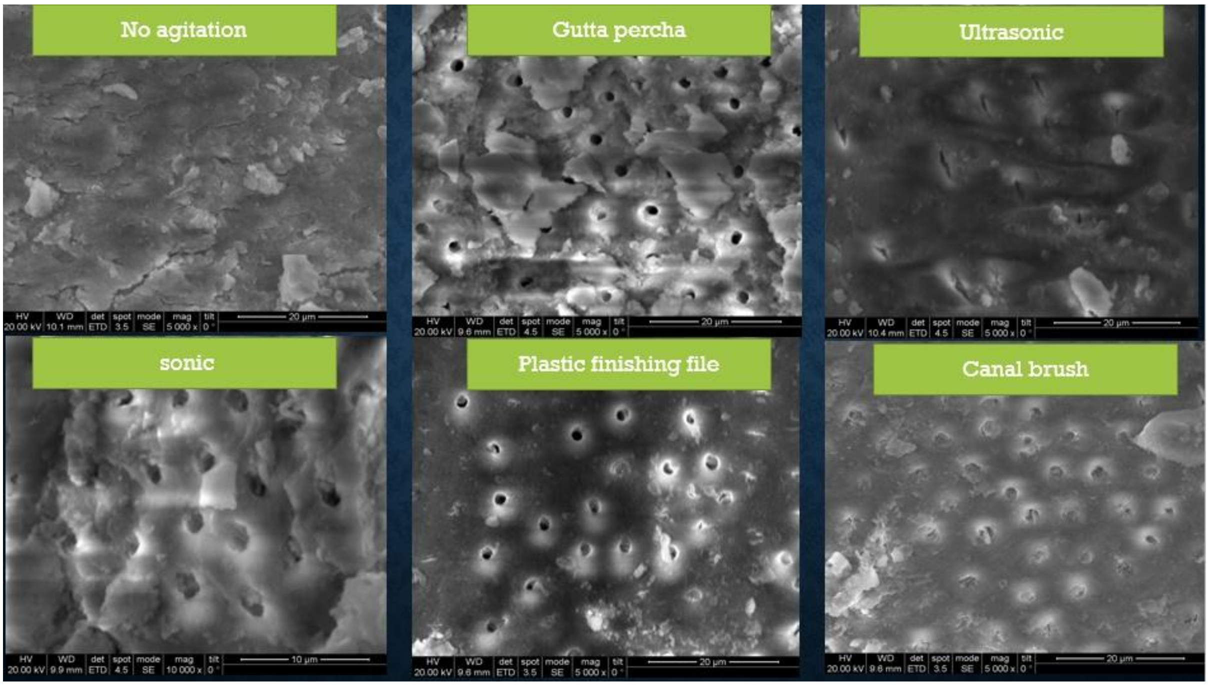


Figure 1: Scanning Electron Microscopy (SEM) photomicrographs

4. Discussion

The association of EDTA and NaOCl solutions has proven to be effective in removing the smear layer. 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.[8] Hence the efficacy of different concentrations of EDTA in combination with NaOCl is used for smear layer removal and currently, this is generally accepted as the most effective method, justifying its use in the present study.[9]

To enhance the effectiveness of irrigants, constant efforts are made to improve on irrigant delivery methods and different agitation protocols have been proposed. Research has shown that gently moving a well fitting gutta percha master cone up and down within an instrumented canal can produce an effective hydrodynamic effect and significantly improve the displacement and exchange of any given reagent. Study done by McGill et al and Huang et al confirmed that manual dynamic irrigation was significantly more effective than an automated dynamic irrigation system and static irrigation.[6]

In 1980, an ultrasonic unit designed by Martin et al became commercially available for endodontic use. The files are designed to oscillate at ultrasonic frequencies of 25–30 kHz, which are beyond the limit of human auditory perception (>20 kHz). They operate in a transverse vibration, setting up a characteristic pattern of nodes and antinodes along their length. This could be beneficial for transporting chelating agents and improving smear layer removal in the apical root canal.[6]

Sonic irrigation is different from ultrasonic irrigation in that it operates at a lower frequency (1–6 kHz) and produces smaller shear stresses. The sonic energy also generates significantly higher amplitude or greater back and-forth tip movement. Moreover, the oscillating patterns of the sonic devices are different compared with ultrasonically driven instruments. They have one node near the attachment of the file and one antinode at the tip of the file. When the movement of the sonic file is constrained, the sideway oscillation disappears. This results in a pure longitudinal file oscillation. This mode of vibration has been shown to be particularly efficient for root canal debridement, because it is largely unaffected by loading and exhibits large displacement amplitudes. Ultrasonic energy produces high frequencies but low amplitudes when compared with sonic energy.[6]

Ultrasonic showed poor results in the study which is in agreement with a study done by Kim et al, possibly because of the reduced time of activation (30 seconds) and the contact between the ultrasonic file and the canal walls. Some authors showed that ultrasonic activation are not efficient in removing the smear layer in straight root canals when using a final flush of 17% EDTA.[6,10]

The canal brush is a highly flexible microbrush and is molded entirely from polypropylene and might be used manually with a rotary action. However, it is more efficacious when attached to a contra angle handpiece running at 600 rpm. Garip et al evaluated the effectiveness of canal brush in removing the smear layer remaining on the root canal wall after endodontic instrumentation with the protaper universal system.[11] The authors observed irrigation with brushing tended to produce cleaner walls. In a recent study by Kamel and Kataia, agitation of the chelating agent with the rotary canal brush increased the efficacy of debris and smear layer removal.[12] The canal brush (Coltene, Germany) is available in three sizes (small, medium and large), which correspond to apical diameter of 25, 30 and 40 respectively, according to the ISO classification. The manufacturer recommends this brush to be used in conjunction with NaOCl at a maximum speed of 650 rpm for up to 30 seconds.[13]

Plastic finishing file efficiently cleans the canal walls and extracts the residual debris from the canal. The unique offset flute design of the finishing file enables the file to agitate sodium hypochlorite and remove remaining dentinal wall debris without further enlarging the canal. The advantage of plastic finishing file over other system is that, they can only help in agitation whereas the finishing file is a device that agitates and extracts the debris out of a canal.[14] This pre sterilized single use plastic rotary file has a unique design with a diamond abrasive embedded into a nontoxic polymer.[15]

5. Conclusion

Within the limitations of this study, it can be concluded that none of the agitation methods evaluated in this research completely removed the smear layer. The plastic finishing file method performed significantly better than the rest of the groups with respect to smear layer removal followed by the canal brush, sonic, gutta percha an ultrasonic methods. Overall, agitation of the irrigant improved smear layer removal in the apical third of the canal significantly and this protocol can be used in clinical practice.

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