Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

Smear Layer Evaluation in Root Dentin after Different Root Canal Instrumentation Techniques – An *In vitro* Study

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Abstract

Aim: The aim of the study was to evaluate smear layer (SL) at 1, 3, and 5 mm from apex after instrumentation with various file systems such as Hand K-files, Protaper Gold (PTG), OneShape (OS), and WaveOne Gold (WOG).

Methodology: Forty extracted human mandibular premolars are selected and radiographically assessed. The specimens were transversely sectioned and length was standardized to 13 mm. Apical patency was confirmed with 10 K file, working length was determined and root canals were initially flushed with 2 mL of 5.25% NaOCl. Specimens were randomly divided into four groups each with 10 specimens: Group 1 – canals were instrumented using hand K files, Group 2– canals were instrumented using PTG file system, Group 3) – canals were instrumented using OS file system, and Group 4 – canals were instrumented using WOG file system. All the canals were irrigated with 5 mL of 17% ethylene di-amine tetra acetic acid followed by 5 mL of 5.25% NaOCl followed by 5 mL of Distilled water. Canal orifices were packed with cotton pellets and sealed with temporary restorative material. Samples were sectioned along long axis. One-half of each tooth was examined under a scanning electron microscope at 1000× magnification.

Results: PTG, OS, and WOG produced a comparable amount of SL with the least amount formed in the Hand K-file group.

Conclusion: SL formation is an inevitable consequence of root canal preparation. PTG, OS, and WOG produced a comparable amount of SL with the least amount formed in the Hand K-file group. SL formation was least in the region 5 mm from the apex when compared to 1 mm and 3 mm from the apex for all the groups.

Key words: Hand K files, Oneshape, Protaper gold, Scanning electron microscope, Smear layer, WaveOne gold

INTRODUCTION

Success in endodontic treatment depends on adequate preparation of the root canal space, reduction in the number of microorganisms, and obturation of the root canal system.[1] The main purpose of root canal instrumentation is to shape and clean the root canal, which includes the removal of infected dentin and organic tissue by instrumentation and irrigation system.[2] During physical instrumentation, an irregular matter known as smear layer (SL) will be produced by the accumulation of organic pulpal materials and inorganic dentinal debris.[3] Eick *et al.* were the first who identified the SL using a scanning electron microscope (SEM) and found that SL is made from different sizes of particles ranging from <0.5 to 15 μm. The presence of SL on instrumented root canals was first reported by McComb and Smith in 1975.[4]

In general, it is considered and desired to remove the SL because of its potential deleterious effects. At present, chelating agents like ethylene di-amine tetra acetic acid (EDTA) are extensively being used to remove the SL formed during the chemomechanical preparation of the root canals.[2]

SL elimination can allow NaOCl to penetrate more easily into the dentinal tubules, thus enhancing its bactericidal

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Month of Submission : 01-2024
Month of Peer Review : 02-2024
Month of Acceptance : 03-2024
Month of Publishing : 03-2024

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action. Moreover, the sealing efficiency of root canal obturation may be affected by the SL that acts as a physical barrier interfering with the adhesion of sealers to canal walls.[5] Although the influence of SL on the success rate of endodontic treatment has not yet been definitely determined, it is currently considered important to promote techniques and products that can prevent the formation of layer or eliminate this layer.[1]

Endodontic K-files are the major tools used for cleaning and shaping of the root canal systems. The specifications of a hand file such as the number of flutes, the space between the flutes, the shape of the tip, and the symmetry of the tip have a significant effect on root cleaning. Not only the working length, but also the reactivity of the metal in the working environment should also be considered as the criteria for the selection of endodontic instruments. An appropriately selected file will improve the speed and efficiency of the root canal treatment.[6]

Protaper gold (PTG) is a new rotary nickel-titanium (NiTi) file system introduced as a modified version of the famous Protaper Universal and developed with proprietary advanced metallurgy through the heat treatment. PTG has all the features as the well-known Protaper Universal including the convex triangular cross-section design, progressive taper, and non-cutting tip.[7] OneShape (OS) file is made of a conventional austenite 55- NiTi alloy. It is used in a full clockwise rotating motion. There is no need to have an additional specific motor during the preparation with OS file. It can be attached to any endodontic motor with continuous rotation or traditional Endo handpiece. This may be suggested as an advantage in clinical practice.[8]

WaveOne Gold (WOG) is a new reciprocating single file NiTi file system introduced as a modified version of WaveOne and developed with advanced metallurgy through heat treatment called Gold-wire. WOG has a significant gold color.[7] It has a parallelogram cross-section that permits the file to engage the dentin in only one point along the canal wall providing a space around the instrument for better debris accumulation and then better coronal debris removal, this unique design could be one reason for the better performance.[9] There is a great tendency among clinicians to use single-file systems because they can reduce the time of the preparation. Furthermore, reciprocation extends the life span of the NiTi file, improves their resistance to cyclic fatigue, and does not reduce their cutting efficiency.[7]

METHODOLOGY

Forty extracted human mandibular premolars are selected. Teeth with cracks, caries, previous restoration, and canal calcifications were excluded from the study. Teeth were radiographed to assess canal morphology and were stored in normal saline until use. The specimens were transversely sectioned to obtain a standardized length of 13 mm. Apical patency of the canals was confirmed using 10 K-file and working length was determined. Root canals are initially flushed with 2 mL of 5.25% NaOCl. The teeth were divided into four groups each with ten samples based on the various file systems used for instrumentation as follows: Hand K-files (HKF) group – Canals were instrumented using the HKF. PTG group – Canals were instrumented using the PTG file system. OS group – Canals were instrumented using OS file system in full rotation. WOG group – Canals were instrumented using WOG file system in reciprocation.

After instrumentation irrigation of the root canals was done by continuous delivery of solutions for 1 min as follows: 5 mL of 17% EDTA followed by 5 mL of 5.25% NaOCl and then with 5 mL of distilled water. Canal orifices were packed with cotton pellets and sealed with temporary restorative material to prevent penetration of debris during sectioning. The samples were sectioned along the long axis. The sectioned tooth was assigned into various groups and each group having (n = 10). One-half of each sectioned tooth was used and scored in the present study while the other half was discarded. The samples were mounted on a metallic disc to be examined under SEM at 1000× magnification.

Statistical Analysis

Statistical analysis was performed using one-way analysis of variance analysis to evaluate the SL formation in groups with different instrumentation techniques. Comparison of groups was done by Kruskal–Wallis test ($P < 0.05$) and pair-wise comparison of groups was done by Mann–Whitney U test ($P < 0.05$).

RESULTS

The specimens were assessed for SL under SEM at 1000× magnification for HKF group [Figure 1], PTG group [Figure 2], OS group [Figure 3], and WOG group [Figure 4].

SEM images were scored for the presence or absence of SL region at 1 mm, 3 mm, and 5 mm of each sample according to a 5-score index system described by Hulssman *et al.* (1997).[7] SL formation was least in the region 5 mm from the apex when compared to 1 mm and 3 mm from the apex for all the groups. SL formation was highest in the region 1 mm from the apex when compared to 3 mm and 5 mm from the apex for all the groups.

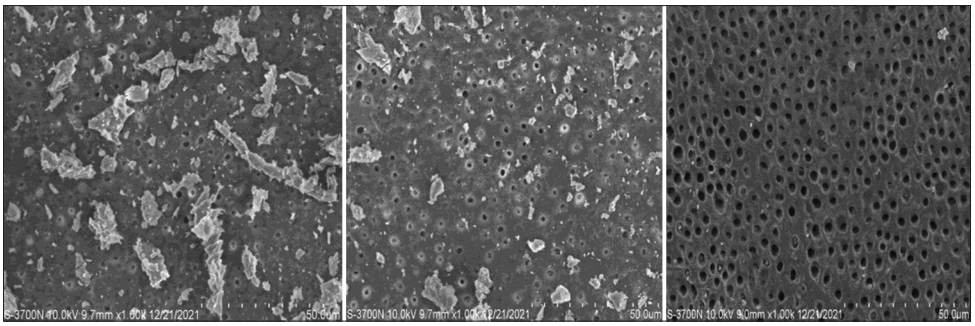


Figure 1: Scanning electron microscope image of Hand K-files group sample at 1, 3, and 5 mm from apex

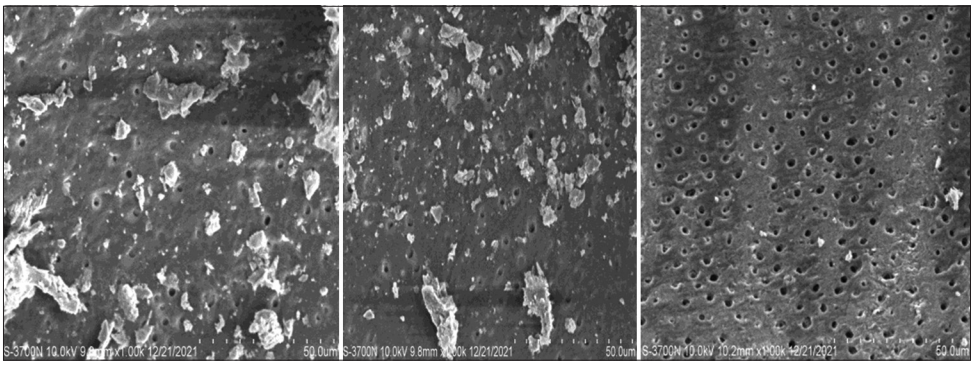


Figure 2: Scanning electron microscope image of Protaper Gold group sample at 1, 3, and 5 mm from apex

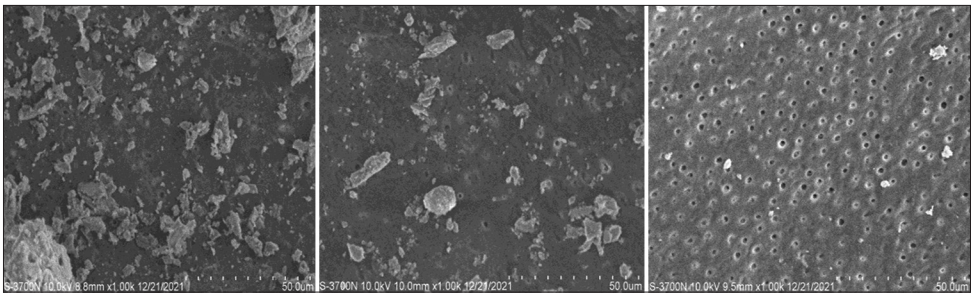


Figure 3: Scanning electron microscope image of OneShape group sample at 1, 3, and 5 mm from apex

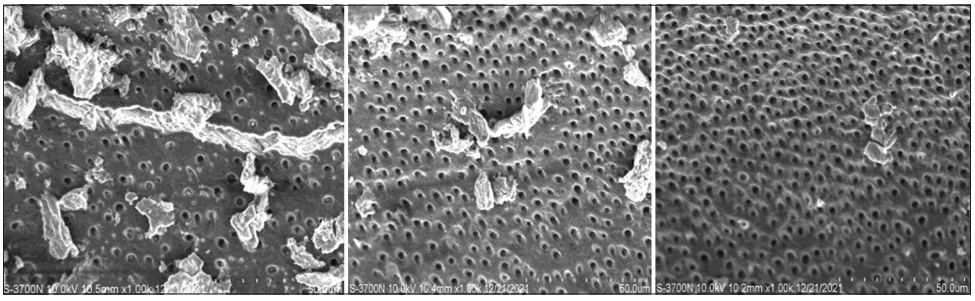
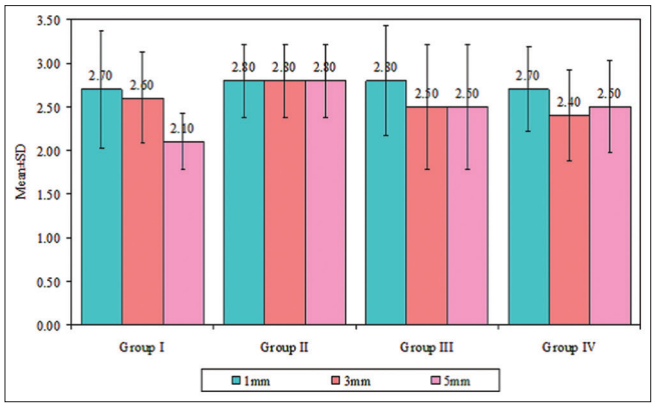
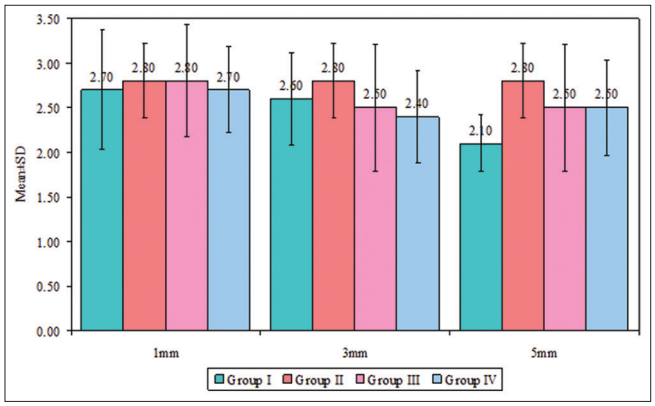


Figure 4: Scanning electron microscope image of WaveOne Gold group sample at 1, 3, and 5 mm from apex

Graph 1 represents the mean SL formed by HKF, PTG, OS, and WOG groups at 1 mm, 3 mm, and 5 mm from the apex. PTG, OS, and WOG produced a comparable amount of SL with the least amount formed in the Hand K-file group. Graph 2 represents the mean SL formed at 1 mm, 3 mm, and 5 mm from the apex by hand k-file, PTG, OS, and WOG groups. SL formation was least in the region 5 mm from the apex when compared to 1 mm and 3 mm from the apex for all the groups. SL formation was highest in the region 1 mm from the apex when compared to 3 mm and 5 mm from the apex for all the groups [Tables 1 and 2].



Graph 1: Comparisons of dentin surfaces (1 mm, 3 mm, and 5 mm) from the apex with smear layer scores in four groups (Hand K-files, Protaper gold, OneShape, and WaveOne gold)



Graph 2: Comparisons of four groups (Hand K-files, Protaper Gold, OneShape, and WaveOne Gold) with smear layer scores at dentin surface at 1, 3, and 5 mm from the apex

DISCUSSION

Cleaning, shaping, and sealing of the root canal system are mandatory for successful root canal treatment. A SL is formed in the instrumented areas despite the type of the instrument used to prepare the root canal. The SL consists of inorganic and organic parts that include remnants of pulp tissues, dentin chips, microorganism, and necrotic materials.[7] The effectiveness of endodontic files, rotary instrumentation, irrigating solutions, and chelating agents to clean, shape, and disinfect root canals promote the success, longevity, and reliability of modern endodontic treatments. A controversy still exists regarding the effectiveness of a myriad of file systems, irrigating solutions, ultrasonic irrigation, and chelating agents needed to accomplish the chemomechanical cleansing of the root canal system.[10]

SL removal is essential because it could allow NaOCl to penetrate into the dentinal tubules and to improve its bactericidal action. The existence of the SL along dentinal walls may reduce the adhesion of the sealers.[11] The tissue

Table 1: Comparisons of dentin surfaces (1mm, 3 mm, and 5 mm) from the apex with smear layer scores in four groups (HKF, PTG, OS, and WOG) by Kruskal–Wallis ANOVA

Dentin surfaces	Group I		Group II		Group III		Group IV	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1 mm	2.70	0.67	2.80	0.42	2.80	0.63	2.70	0.48
3 mm	2.60	0.52	2.80	0.42	2.50	0.71	2.40	0.52
5 mm	2.10	0.32	2.80	0.42	2.50	0.71	2.50	0.53
H-value	6.5750		0.0000		1.7400		1.8120	
P-value	0.0370*		1.0000		0.4190		0.4040	

*$P<0.05$. HKF: Hand K-files, PTG: Protaper gold, OS: OneShape, WOG: WaveOne gold, ANOVA: Analysis of variance

dissolving capacity and microbial activity of NaOCl make it an excellent irrigating solution but it has only limited effect on the dissolution of SL. For the elimination of SL, acid solutions have been recommended including sodium salt of EDTA, most active at a concentration of 15–17% and pH of 7–8; orthophosphoric acid at concentrations of 10, 32, and 37% and citric acid solutions at concentrations of 10, 25, and 50% are used.[2]

According to Goldman *et al.* (1982) and Yamada *et al.* (1983), the use of a high-volume final flush with 17% EDTA followed by NaOCl removed the SL effectively. They speculated that the combination of NaOCl and EDTA effectively removes the organic and inorganic components of the SL, respectively.[12] During the root canal preparation, the use of 17% EDTA and 5.25% NaOCl enhances the elimination of SL; nevertheless, it also results in the excessive demineralization of dentinal tubules and impaired surface morphology.[13]

Similarly, higher concentrations of NaOCl solution (5.25%) may lead to localized irritation and inflammation of the periapical tissues. On the other hand, 17% EDTA is an organic acid that acts as a chelator to hold the calcium ions within hydroxyapatite. The inorganic components can be completely removed from the SL using EDTA solution and opening the dentinal tubules within 1 min. However, an extended treatment (>10 min) may lead to erosion of the intertubular and peritubular dentin.[13]

NaOCl is an effective endodontic irrigation solution in a variety of concentrations, ranging from 0.5% to 6%. However, it may cause serious complications because of incorrect use or mistakes. The accidental injection into the periapical tissues in teeth with immature apical foramina or when the apical constriction has been destroyed all along the root canal preparation or by resorption is the most common complication.[14] Pioneering instrument designs such as the altered cross-sections, helical angle, increased taper, non-cutting tip, and specific flute design

Table 2: Pair-wise comparisons of dentin surfaces (1 mm, 3 mm, and 5 mm) from the apex with smear layer scores in four groups (HKF, PTG, OS, and WOG) by Mann–Whitney U test

Dentin surfaces	Group I		Group II		Group III		Group IV	
	Z-value	*P*-value	*Z*-value	*P*-value	*Z*-value	*P*-value	*Z*-value	*P*-value
1 mm versus 3 mm	−0.2268	0.8206	0.0000	1.0000	−1.0205	0.3075	−1.1339	0.2568
1 mm versus 5 mm	−1.9276	0.0500	0.0000	1.0000	−1.0205	0.3075	−0.7559	0.4497
3 mm versus 5 mm	−1.8898	0.0588	0.0000	1.0000	0.0000	1.0000	−0.3780	0.7055

HKF: Hand K-files, PTG: Protaper gold, OS: OneShape, WOG: WaveOne gold

help to eliminate vital/necrotic tissue and infected dentin and debris but the cleaning effectiveness of the canal wall was affected.[15]

This study evaluated the cleaning efficacy of HKF, PTG, OS, and WOG file systems in terms of SL produced. This study compared HKF with PTG multiple file system in continuous rotatation, OS single file in continuous rotation, and WOG single file in reciprocating motion at 1 mm, 3 mm, and 5 mm from the apex.

To evaluate the SL on the dentinal surface, various techniques are available such as SEM and digital image analysis. However, in this study, we opted for SEM as it is a commonly available tool to evaluate the SL.

Endodontic K-files are fundamental tools for cleaning and shaping of the root canal systems. The requirements of any hand file such as shape of the tip, number of flutes, the symmetry of the tip, and the space between the flutes have a significant effect on root cleaning. Working characteristics should not be the only point of reference in the selection of endodontic instruments, but the reactivity of the metal in the working environment should also be taken into consideration.[6] PTG has a modified triangular cross-section presenting no active cutting edge with a neutral rake angle. A positive rake angle permits the instrument to cut more aggressively whereas a negative or neutral rake angle will only grind the root canal wall.[7]

OS is a single-file system made for use in continuous rotation.[11] There is no need of an additional specific motor during the preparation with OS file. It can be attached to traditional endo handpiece or any endodontic motor with continuous rotation. This may be suggested as an advantage in clinical practice.[8] According to Dagna *et al.* (2016), the continuous rotating systems showed better results than the reciprocating ones. They produced less debris and SL.[11] WOG has a parallelogram cross-section which permits the file to engage the dentin in only one point along the canal wall providing a space around the instrument for better debris accumulation and then better coronal debris removal, this unique design could be one reason for the better performance.[7]

Both of PTG and WOG systems are produced with using different alloys and a new proprietary thermal process named Gold wire in which the ground NiTi files are heat-treated and slowly cooled to obtain super-elastic NiTi files. It could be associated to the 2-stage transformation behavior and the high temperatures from which PTG and WOG are produced; as this material has pronounced flexibility with an elastic modulus lower than that of the austenitic phase. According to Zan *et al.* (2016), gold systems may be preferred as safer to reduce the apically extruded bacteria during endodontic treatments.[16] WOG works on the principle of reciprocating motion and is claimed to be able to completely clean and shape root canals with only one single-use instrument. These files are made of a special NiTialloy called GWire which is created by an innovative thermal treatment process. The benefits of this GWire NiTi are increased flexibility of the instruments and improved resistance to cyclic fatigue. According to Shalini Singh *et al.* (2019), WOG had better original canal anatomy with less aggressive dentin cutting and minimal canal transportation as compared to PTG file system.[17]

Reverse helix, semiactive and modified guiding tip, and offset parallelogramshaped crosssection limit the engagement zone. Reciprocating movement reduces torsional and flexural stresses, increases the centering ability of canal, and reduces the taper lock of the instrument within the canal.[18]

According to Dagna *et al.* (2016), each backward motion of the reciprocating files compacts the debris along dentinal walls and pushes them into lateral canals and over the apex while the continuous rotating systems showed better results than the reciprocating ones. The continuous motion of the rotary files favors upward removal of debris along the flutes of the file.[11] However, a significant decrease in preparation time by usage of single-file systems may be an advantage in clinical practice. Ability to efficiently clean the endodontic space is reliant on both irrigation and instrumentation. The use of torque-control handpiece may reduce the cutting efficiency of the instrument, and the progression of file into the apical third becomes difficult.[1]

According to Khademi *et al.* (2015), the engine-driven systems produce more SL than the traditional hand

instruments.[3] SL formation is an inevitable consequence of root canal preparation. According to results of our study, PTG, OS, and WOG produced a comparable amount of SL with the least amount formed in the hand K-file group. SL formation was least in the region 5 mm from the apex when compared to 1 mm and 3 mm from the apex for all the groups. On an average, more effective cleanliness was obtained in the region 5 mm from the apex, followed by the 3 mm from the apex then the region 1 mm from the apex which showed the highest SL formation score regardless of the instrument used. This finding is in agreement with many previous studies.[8,7] Furthermore, this finding may be more important than the result of the comparison between the four file systems in which the apical part scored with the highest amount of SL, it means that microorganisms remain in the apical parts and further measures should be taken to deliver the antibacterial solution in the apical part to prevent reinfection of the canal and the subsequent need for retreatment.

CONCLUSION

SL formation is an inevitable consequence of root canal preparation. PTG, OS, and WOG produced a comparable amount of SL with the least amount formed in the Hand K-file group.

SL formation was least in the region 5 mm from the apex when compared to 1 mm and 3 mm from the apex for all the groups.

SL formation was highest in the region 1 mm from the apex when compared to 3 mm and 5 mm from the apex for all the groups.

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How to cite this article: Rao SA, Muralidhar T, Pushpavathi R. Smear Layer Evaluation in Root Dentin after Different Root Canal Instrumentation Techniques – An *In vitro* Study. Int J Sci Stud 2024;11(12):20-25.

Source of Support: Nil, **Conflicts of Interest:** None declared.