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Cleaning Efficiency of Root Canals using Different Rotary Instrumentation Systems: A Comparative *In vitro* Study

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ABSTRACT

Background: *Smear layer is always formed during the instrumentation process due to the action of endodontic instruments during the shaping process and it should be removed as it might decrease the overall success of endodontic therapy.* ***Aim of the study:*** *To compare the cleaning efficiency of different rotary Ni-Ti systems: ProTaper Next, Xp-endo Shaper and WaveOne Gold by assessing their ability to remove the smear layer from root canals walls.* ***Methods and materials:*** *A total of 24 palatal roots of maxillary molars were used in this study and randomly assigned into 3 groups (n=8) as follows: Group 1: instrumentation with ProTaper Next system (Dentsply Maillefer, Switzerland), Group 2: instrumentation with Xp-endo Shaper system (FKG Dentaire, Switzerland) and Group 3: instrumentation with WaveOne Gold system (Dentsply Maillefer, Switzerland). The samples were irrigated with 5.25% NaOCl. All samples were then examined by scanning electron microscope (SEM) at the center of the coronal, middle and apical thirds. The data was statistically analyzed using Kruskal Wallis and Mann-Whitney U tests.* ***Results:*** *ProTaper Next files showed a lower average mean of smear layer when compared to WaveOne Gold and Xp-endo Shaper files at the coronal third. No significant differences between the average means of smear layer were found at the middle and apical thirds.* ***Conclusion:*** *None of the tested groups showed a completely smear layer free root canal walls. In general, ProTaper Next files showed the best performance at the coronal third. All the files showed comparable performance at the middle and apical thirds.*

Keywords: Root canals, Smear, Necrotic tissue, Coronal area

INTRODUCTION

The major aim of the endodontic treatment is to remove infected and necrotic tissue and debris, shape the root canals and provide an adequate seal of the root canals system [1]. Smear layer is always formed as a result of dentin cutting no matter what type of instrument is used [2]. The smear layer consists of dentin, remnants of odontoblastic processes, pulp tissue, and bacteria. Packing of smear debris in the tubules may reach a depth of 40 μm [3].

The smear layer can harbor bacteria and their products, reduce the permeability of dentin to irrigants and medical dressing, and compromise the fluid-tight seal of canals after root filling. Thus, it is recommended to remove this smear layer before processing the root canal obturation [4].

There have been significant advancements in the development of Ni-Ti rotary instruments in recent years. This continuous improvement in the manufacturing processes aims to produce more efficient files, possessing features such as flexibility, efficiency, safety, and simplicity [5].

ProTaper Next system is considered as an important representative for the fifth generation of Ni-Ti files. Files were designed so that the center of mass and/or the center of rotation are off-set. This feature generates a mechanical wave of motion that travels along the active length of the file and provides a better reduction of the engagement between the file and dentin [6].

WaveOne Gold system combines a single file technique in conjunction with reciprocating movement and unique heat treatment that has improved its strength and flexibility [7].

XP-endo Shaper introduced a proprietary thermomechanically treated NiTi alloy named MaxWire that combines both shape memory effect and superelasticity in clinical application. The booster tip has 6 cutting edges that respect the geometry of the canal, whilst removing more material with each pass [8].

PATIENTS AND METHODS

Preparation of the Samples

A total of 24 human maxillary first and second molar teeth freshly extracted were selected for this study and stored in distilled water at room temperature immediately after extraction. The teeth were selected according to the following criteria: absence of root decay, no previous endodontic treatment, mature and closed apices, the absence of internal resorption, root length of at least 15 mm, the maximum apical diameter of ISO size #20 and No visible cracks in the roots.

All teeth were cleaned with cumin scaler to remove calculus and soft tissue debris and then washed under tap water and kept in distilled water solution [9]. The crown of each tooth was removed at the level of the cementum-enamel junction (CEJ) (any sample with root length less than 15 mm was discarded and replaced), to facilitate instrumentation and avoid any bias associated with access opening procedure [10].

Each root canal was initially negotiated with #10 stainless steel K-file until the file was barely visible through the apex, then 0.5 mm was subtracted to establish the working length. The samples with initial apical foramen size more than the size of a 20 K-file were discarded and replaced with other samples.

The samples were randomly divided into 3 groups (n=8) as follows:

Group 1: Samples were instrumented with ProTaper Next system (PTN).

Group 2: Samples were instrumented with Xp-endo shaper system (XP).

Group 3: Samples were instrumented with WaveOne Gold system (WOG).

Each sample was irrigated with 5.25% NaOCl. The total volume of NaOCl used for the irrigation of each sample was 5 ml divided according to the steps of instrumentation [11]. The samples were rinsed with 5 ml of distilled water after finishing the instrumentation. The samples were instrumented following the manufacturer's instructions for each system included in the study. The X-Smart IQ endomotor (Dentsplymaillefer, Switzerland) was used for canals shaping. The irrigation solutions were introduced in the canals utilizing NaviTip®31ga Double Sideport Irrigator Tip (21 mm, Yellow) (Ultradent, USA).

SEM Examination

The roots were split longitudinally in a buccolingual direction using a rotating diamond disc after instrumentation. To avoid creating artificial debris, the disc was not allowed to penetrate the canal space. The internal surfaces of each root canal were very clean and clear [12].

Samples were dehydrated using a series of graded ethanol solutions (70%, 80%, 90%, and 100%). After assembly on coded stubs, the specimens were prepared in a vacuum chamber and sputter coated with a 300Å Gold-Palladium layer and viewed under SEM (Te scan, Vega III, Czech Republic) under 5000X magnification [13,14]. Three pictures were obtained from each tooth, one for each third, to give a total of 72 pictures at the center of each third.

The images of SEM examination for each sample were obtained and analyzed according to the scale defined by Hulsmann: 1=No smear layer, dentinal tubules open, 2=Small amount of smear layer, most dentinal tubules open, 3=Homogenous smear layer covering the root canal wall, few dentinal tubules open, 4=Complete root canal wall covered by a homogenous smear layer, no open dentinal tubules, 5=Heavy, non-homogenous smear layer covering the complete root canal wall. The data were statistically analyzed, by using Kruskal Wallis and Mann-Whitney U test. The level of significance was set at 0.05.

RESULTS

The results of the descriptive statistics for each group, which include the mean, average mean, standard deviation, standard error, minimum and maximum values are shown in Table 1.

Table 1 Descriptive statistics of SEM results for all groups

Group	Area	n	Mean	Average mean	S.D.	S.E	Min	Max
PTN	Coronal	8	3.25	3.54	0.70	0.25	2	4
	Middle	8	3.62		0.74	0.26	2	4
	Apical	8	3.75		0.46	0.16	3	4
XP	Coronal	8	4.62	4.04	0.51	0.18	4	5
	Middle	8	3.75		0.88	0.31	2	5
	Apical	8	3.75		0.88	0.31	2	5
WOG	Coronal	8	3.75	3.7	0.70	0.25	3	5
	Middle	8	3.25		0.70	0.25	2	4
	Apical	8	4.12		0.64	0.22	3	5

The lowest mean of smear layer level among Group 1 was found at the coronal area (3.25 ± 0.70) while the highest mean for the same group was at the apical area (3.75 ± 0.46). For Group 2 the lowest mean of smear layer level was recorded at the middle and apical areas (3.75 ± 0.88) and the highest mean was at the coronal area (4.62 ± 0.51). In Group 3 the lowest mean of smear layer level was at the middle area (3.25 ± 0.70) and the highest mean was recorded at the apical area (4.12 ± 0.64) (Figure 1).

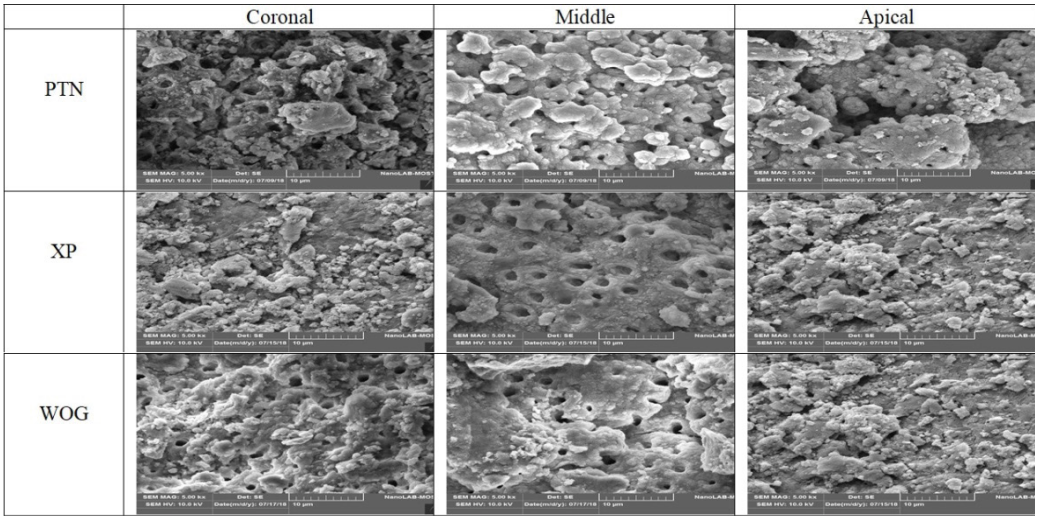

Figure 1 SEM images of the tested groups at 5000X magnification

To identify the presence of statistically significant difference among the means of the smear layer of all groups, Kruskal Wallis test was performed as shown in Table 2. The level of significance was set at 0.05.

There was a statistically significant difference between groups at the coronal areas ($p \leq 0.05$). No significant differences were found in the middle and apical thirds ($p<0.05$). Further analysis of all data was needed to examine the difference between every 2 groups; so the Mann-Whitney U test was performed for multiple comparisons between groups as shown in Table 2. The level of significance was set at 0.05.

The results of the Mann-Whitney U test among the groups showed that PTN group resulted in better smear layer removal at the coronal third when compared to WOG and Xp-endo groups ($p \leq 0.05$). WOG produced less smear layer when compared to Xp-endo ($p \leq 0.05$). However, there was no significant difference between PTN and WOG groups ($p<0.05$).

Table 2 Kruskal Wallis and Mann-Whitney U tests of smear layer among the tested groups

Area of root canal	Kruskal Wallis	Significance	Mann-Whitney U		
			ptn vs xp	ptn vs wog	Xp vs wog
Coronal	0.004	S	0.002	0.206	0.02
Middle	0.285	NS	-	-	-
Apical	0.440	NS	-	-	-

DISCUSSION

This study compared the cleaning efficiency of various endodontic rotary instruments by comparing the means of the smear layer that remains on the root canals following mechanical instrumentation. Only sodium hypochlorite was used in the irrigation protocol to avoid the influence of various irrigation solution [15]. The scanning electron microscope method that was in this study provided excellent details of the surface of the root canal walls but has limited ability to reveal the penetration of debris into the dentinal tubules [16].

None of the instrumentation groups showed a completely cleaned root canal surface. This finding is in agreement with some previous studies [17,18]. When comparing the cleaning efficiency of the rotary instruments at the coronal third, ProTaper Next showed less average means of smear layer as compared to WaveOne Gold and Xp-endo Shaper. This may be related to its unique swaggering motion in which the file always contacts the canal walls in 2 places. This provides more space for debris removal [15,19].

At the middle third, WaveOne Gold showed the best performance in smear layer removal in comparison to other instruments. This could be explained by the kinematics of the instruments used. WaveOne Gold operates in reciprocation movement and continuous rotation was shown to produce more smear layer when compared to reciprocation movement [20-22]. However, there was no significant difference between the means of smear layer between the instruments at the middle third.

At the apical third, WOG showed higher results of smear layer mean when compared to other instruments. This can be related to the kinematics of the instrument. This finding is in agreement with a previous finding by Rubinson, et al., who found more debris in the apical areas of root canals prepared by reciprocating instruments when compared to instruments operated in continuous rotation [23].

CONCLUSION

None of the tested groups showed a completely smear layer free root canal walls. In general, ProTaper Next files showed the best performance at the coronal third. All the files showed comparable performance at the middle and apical thirds.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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