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Comparison of WaveOne and ProTaper Universal Preparation Systems in the Amount of Smear Layer/Debris Production: an in-vitro SEM Study

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ABSTRACT

Background and Aim: Debris and the smear layer that remain after root canal preparations may result in failure of root canal therapies. The aim of this study was to compare the smear layer formation and the amount of residual debris following the use of WaveOne and ProTaper rotary files in mesiobuccal root canals of upper first molars by scanning electron microscopy (SEM).

Materials and Methods: In this experimental study, 34 mesiobuccal root canals of human maxillary first molars with 20°-40° curvatures (according to Schneider technique) were randomly distributed in two experimental groups (15 each) and two control groups. The canals in test groups were instrumented according to the manufacturers' instructions. Five ml of 5.25% sodium hypochlorite (NaOCl) and 5 ml of normal saline were used as irrigants. The roots were split longitudinally, and apical, middle, and coronal radicular sections were randomly scanned by an SEM at ×1000 magnification. Two endodontists scored the data according to Schäfer and Schlingemann scoring system. Data of the amount of debris and smear layer were separately analyzed by Kruskal-Wallis test.

Results: Although there was a slight difference in mean scores between the two groups (3.28 for WaveOne and 3.6 for ProTaper), no significant differences in debris amount were noted. The overall mean smear layer formation was not significantly different between the two groups (4.11 for WaveOne and 3.95 for ProTaper).

Conclusion: There was no significant difference in remaining debris and smear layer in coronal, middle, and apical parts of root canals. However, ProTaper system appeared to produce less debris during preparation.

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Original Article

Introduction:

Smear layers remained within the canal walls after root canal preparations may lead to failure of root canal therapies (RCTs).[1] Studies have shown that a smear layer with the thickness of 2.1 µm covers the root canal walls following root canal preparations.[2] This thin layer with small crystalline structures consists of organic and inorganic pulpal tissues such as inorganic dentinal debris, and bacteria and their by-products.[3] Remnants of the smear layer may act as a barrier which prevents the beneficial effects of intracanal irrigants and drugs on dentinal walls, compromising the cleaning procedure.[4] The main objective of cleaning and shaping of the root canal system is the removal of pulpal remnants, bacteria and their by-products, and finally, sealing the canals. [5] Rotary instruments, used in root canal preparations, often lay a large amount of smear layer and debris on root canal walls.[6] Many hand and rotary endodontic files and instruments are used to create a space for irrigation and disinfection during the root canal preparation. Since the 1980s, nickel-titanium (NiTi) files have been introduced into the market, which due to their superior elasticity, they facilitate efficient canal preparations with reduced procedural errors. However, these instruments have several disadvantages such as the necessity of using several instruments to enlarge the canal, which is time-consuming and expensive because of the use of several rotary files. [7,8] Among NiTi rotary instruments, ProTaper Universal (Dentsply Maillefer, Switzerland) with its system-based efficiency in flexibility and precision renders an exceptional performance.[9] ProTaper system includes three shaping files (Sx, S1, and S2) and three finishing files (F1, F2, and F3), with two additional new files for larger canals (F4 and F5). Their progressive taper design and a convex triangular cross-section are of the main features which improve the flexibility and cutting efficiency while reducing torsional loading and file fatigue. According to the manufacturer's instruction, a slow-speed handpiece and an electromotor are required for applying rotary files with 150-300 rpm (revolutions per minute). [9] The latest system is the single-file system with reciprocating motions. The aim of reducing the number of several rotary files into one is to limit the time and to reduce the cost. [8,10,11]. As a single-use file for canal preparation, WaveOne file (Dentsply Maillefer, Switzerland) has been designed and manufactured by using M-Wire technology which improves the flexibility, strength, and resistance to cyclic fatigue by up to nearly four times in comparison with other brands of rotary NiTi files.[12]

The counterclockwise engaging angle is five times the clockwise disengaging angle.[1] At present, there are three files in WaveOne single-file reciprocating system with tip sizes of 0.21 mm (Small file), 0.25 mm (Primary file), 0.4 mm (Large file), and with apical tapering of 0.6%, 0.8%, and 0.8%, respectively.[12] The reciprocating motions consist of 150° counterclockwise and 30° clockwise movements.[13]

Owing to the fact that there are few studies on how canal debridement and smear layer cleaning can be thoroughly achieved with this new reciprocating single-file technology compared to other rotary systems, this research has been carried out to compare ProTaper and WaveOne files with regard to the amount of the remaining smear layer and dentinal debris after canal preparation in the mesiobuccal root canals of maxillary first molars.

Materials and Methods:

In this experimental study, extracted human maxillary first molars were collected. After debriding the root surface, the specimens were immersed in 5.25% sodium hypochlorite (NaOCl; Clorox bleach, Clorox Co., Oakland, CA, USA) for one hour, and then, they were stored in normal saline until root canal preparation.[14]

Dental roots with cracks, fractures, caries, or external resorption were excluded from this study. The crowns of the teeth were cut at the cementoenamel junction (CEJ) by a diamond disk (918 BF, DZ, Lemgo, Germany), and the patency was checked by using a #10 K-file (Dentsply Maillefer, Ballerinas, Switzerland). For apical stop, the initial file was considered to be a #15 K-file as it did not pass through the apical foramen.

The specimens with lateral apical foramina were excluded from this study.

Preoperative radiographs were taken from the teeth via parallel technique and by using a digital radiographic device (Trophy Radiology S.A., Paris, France) with exposure parameters of 75 kilovoltage peak (kVp), 10 milliamperes (mA), and exposure time of one second with a 16-mm-long cylindrical cone and by using a digital intraoral imaging plate (Digora® Optime PSP System, Soredex, Orion Corp. Helsinki, Finland), and the images were processed and archived. Based on initial radiographic images, only the teeth without any internal resorption, calcification, prior endodontic treatments, and those with a fully formed apex were included in this research.

To measure the working length (WL) of the mesiobuccal canal, a radiograph was taken with a #15 K-file in the canal via parallel technique and by using a digital intraoral imaging plate (Digora® Optime PSP System, Soredex, Orion Corp. Helsinki, Finland) and a radiographic cone of 29.9-mm length and 6-cm diameter, with exposure time of 0.22 seconds in buccolingual and mesiodistal directions. Next, the images were processed and archived. Afterwards, the angle of canal curvature in each image was assessed according to Schneider's method [15] in AutoCAD software at ×100 magnification. The teeth with 20-40° angles of curvature were selected, and finally, 34 maxillary first molars were included in this study.

At this point, the samples were numbered and were randomly (by using a random number table) divided into two groups of 15 with two positive and negative control groups. The WL in all the groups was obtained by measuring the length of a #10 K-file at the apical foramen of the mesiobuccal root canal minus 1 mm. Then, all the teeth were cut to reach the length of 12 mm. In each group, the canals were prepared by the use of WaveOne file (Dentsply Maillefer, Switzerland) and ProTaper Universal files (Dentsply Maillefer, Switzerland) and an electromotor (Switzerland) according to the speed and the torque recommended by the manufacturer.

In group A (WaveOne system), shaping was done with only a #25 file (8%) via the crown-down technique from the coronal one-third to the middle one-third, and finally, to the apical one-third of the canal according to the WL, and each step was checked by using a #10 K-file as patency.

In group B (ProTaper system), shaping was done to F2 ProTaper file [(S1-Sx) - (S1-S2-F1-F2)].

Canal scouting was performed by using a #10 K-file when the patency of the root canal was explored.

After each file, the canals were irrigated with 2ml of 5.25% NaOCl by using a 23-gauge needle (Dentsply-Tulsa Dental, Tulsa, OK, USA). The final irrigation was done with 5ml of 5.25% NaOCl, and subsequently with 5ml of normal saline (Baxter Healthcare, Deerfield, IL, USA) to neutralize the effect of the irrigant. In the positive control group, the canals were prepared according to the test groups, but no irrigation was done in order to create a smear layer on the canal walls. In the negative control group, the canals were not prepared but were irrigated with 5.25% NaOCl.

In the next step, the mesiobuccal root was cut from the furcation by a diamond disc (918 BF, DZ, Lemgo, Germany) under water cooling. Then, two grooves were made along the outer buccal and lingual surfaces without deeper penetration into the canal. Each root was cut buccolingually into two sections by a chisel in the longitudinal axis of the root. The teeth which were fractured at this step were excluded and replaced by new ones according to the research method. Then, the specimens were prepared for further evaluation under a scanning electron microscope (SEM; (TESCAN VEGA-TS5136, Czech Republic). First, the specimens were dried and gold coated. Then, images were randomly taken from three sections of coronal, middle, and apical under the SEM at ×1000 magnification, and the formation of a smear layer on the canal walls was evaluated (Figures 1 to 5).

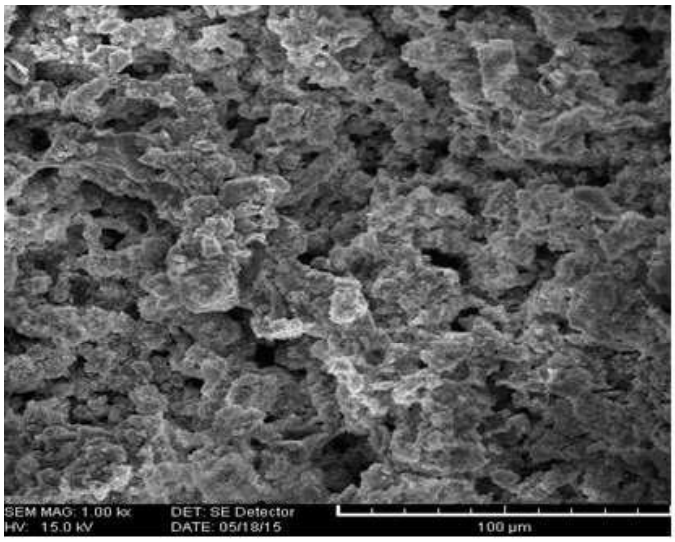

Figure 1. Negative control group: without filling material/irrigated by 5.25% sodium hypochlorite (NaOCl)

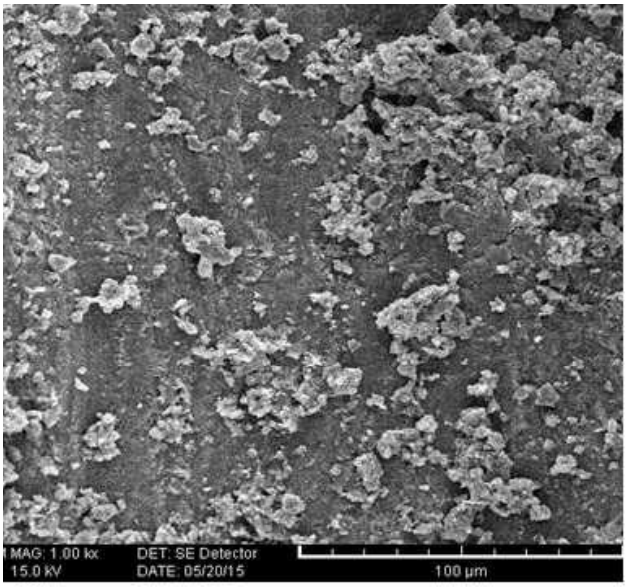

Figure 2. Positive control group prepared by ProTaper system: with filling material/ without irrigation

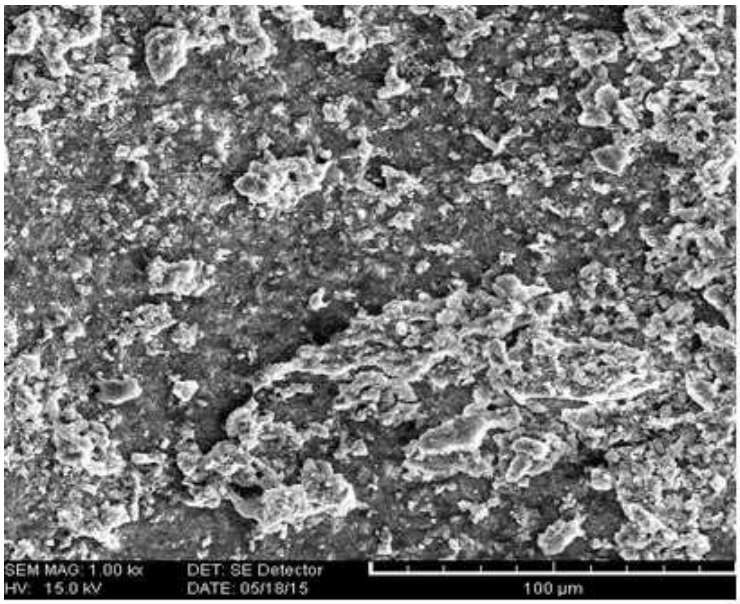

Figure 3. Positive control group prepared by WaveOne system: with filling material/without irrigation

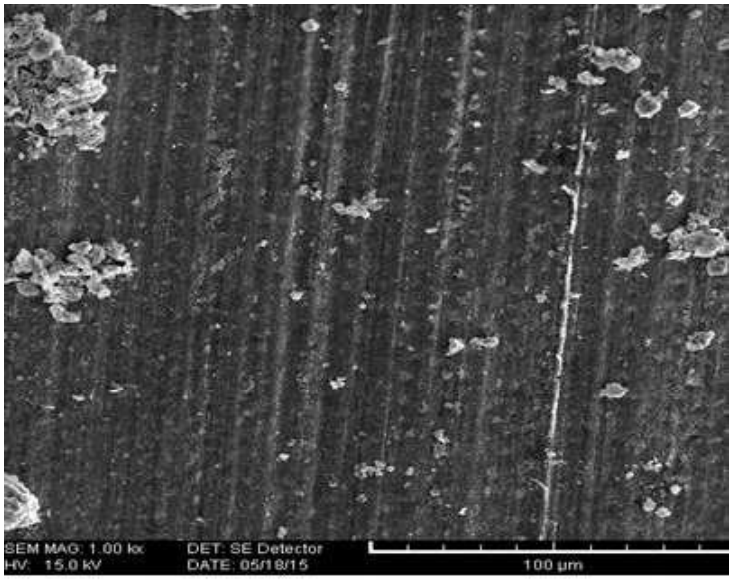

Figure 4. One of the specimens prepared by ProTaper system

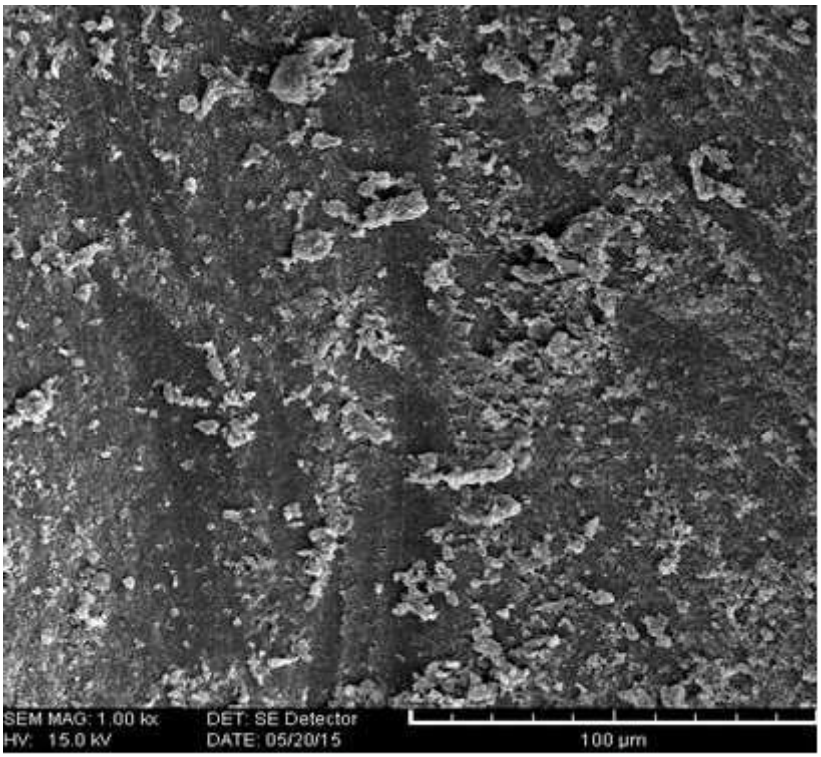

Figure 5. One of the specimens prepared by WaveOne system

The investigators were two endodontists who were trained according to Schäfer-Schlingemann scoring system and were calibrated as follows: typical images of Schäfer-Schlingemann system were shown to the endodontists at the moment and one week after. If the observers were in agreement based on Schäfer-Schlingemann scoring system, they were considered calibrated, and the images were separately evaluated and scored by the investigators (Tables 1 and 2). In cases in which the scores were not in accordance, the endodontists were asked to reevaluate the images for new scoring. After scoring the specimens, the evaluation of each sample, according to the tooth number, was recorded in the given data sheet.

Table 1: Schäfer-Schlingemann scoring system for scoring the observed debris

Score 1	Clean canal walls with only very few debris
Score 2	Few small conglomerations
Score 3	Many conglomerations; less than 50% of the canal wall covered
Score 4	More than 50% of the canal wall covered
Score 5	The complete or nearly complete coverage of the canal wall by debris

Table 2: Schäfer-Schlingemann scoring system for scoring the observed smear layer

Score 1	No smear layer
Score 2	A small amount of smear layer, some open dentinal tubules
Score 3	Homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules
Score 4	The entire root canal wall covered with a homogenous smear layer, no open dentinal tubules.
Score 5	A thick, homogenous smear layer covering the entire root canal wall

Results:

In this study, there were different levels of debris and smear layer formation along the walls of the prepared canals in both test groups. Remnants of pulpal tissues and red blood cells were observed in both negative control groups, which were characteristic of intact areas. Deposition of a smear layer was the main feature in both samples in the positive control group (Table 3).

Table 3. Evaluation of remaining debris and smear layer in positive and negative control groups based on Schäfer-Schlingemann scoring system

Area / Control	Coronal		Middle		Apical	
	Smear layer	Debris	Smear layer	Debris	Smear layer	Debris
C^-1	-	5	-	5	-	4
C^-2	-	4	-	5	-	5
C^+ ProTaper	5	4	5	5	5	3
C^+ WaveOne	5	5	5	5	5	4

There was no significant difference in debris and smear layer formation between the two systems and their method of application (P>0.05). However, the mean score of remaining debris was 3.6 for ProTaper, and 3.82 for WaveOne. The mean score of smear layer formation in total dentinal areas was 3.95 for ProTaper, and 4.11 for WaveOne.

The mean score related to the debris left in apical areas was 3.87 for ProTaper, and 3.87 for WaveOne; thus, no statistically significant difference was observed between the two groups (P=0.295).

In the middle region, the mean score of remaining debris was 3.47 for ProTaper, and 3.67 for WaveOne, with no statistically significant difference between the two groups (P=0.388).

In the coronal section, the mean score of remaining debris, without any significant difference, was 3.47 for ProTaper, and 3.93 for WaveOne (P=0.2; Table 4 and Figure 6).

Table 4. Evaluation of remaining debris based on Schäfer-Schlingemann scoring system

Area / File type	Coronal	Middle	Apical
ProTaper	3.47 ± 0.743	3.47 ± 0.834	3.87 ± 0.990
WaveOne	3.93 ± 1.033	3.67± 0.90	3.87 ± 0.834
P-value	0.2	0.388	0.295

In the evaluation of the smear layer formation after canal preparation, no significant difference was detected between the two groups in the three radicular areas. The mean score of smear layer formation in the apical area was 3.8 for ProTaper, and 4.2 for WaveOne, with no statistically significant differences (P=0.511). In the middle area, the mean score was 4.07 for ProTaper, and 4.13 for WaveOne, with no statistically significant difference between the two groups (P=0.116).

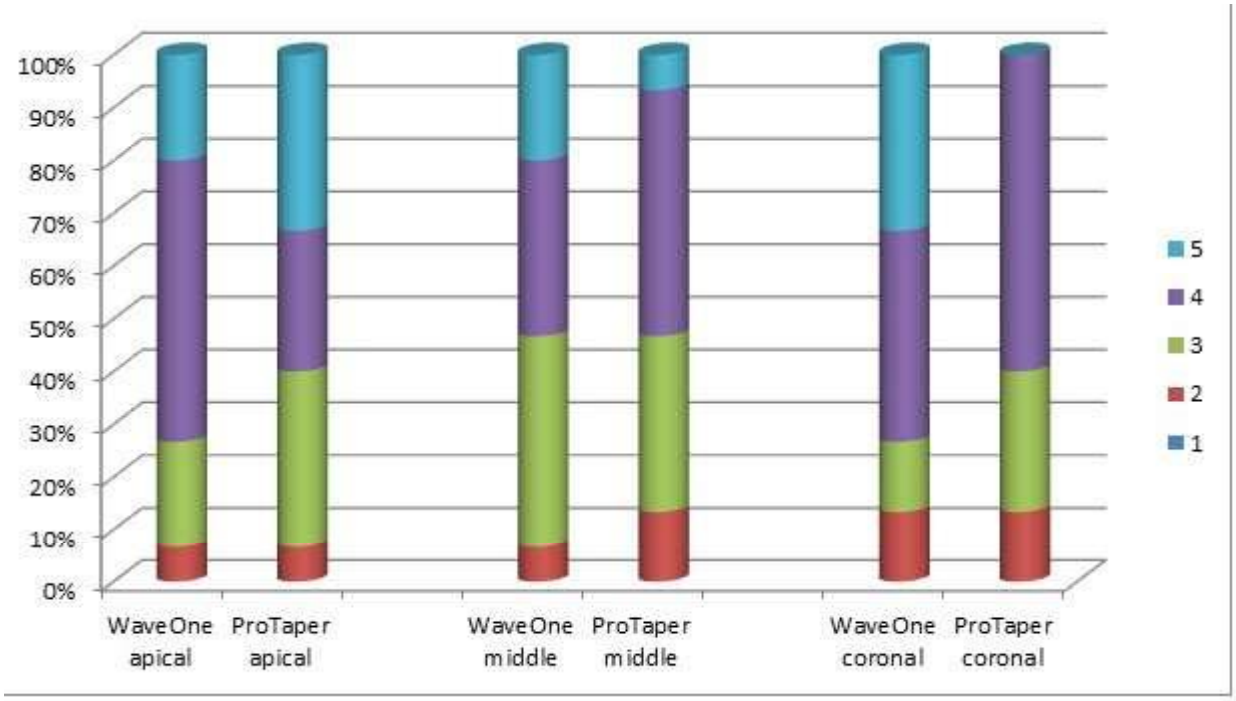

Figure 6. Debris level according to radicular areas and test groups

The mean score in the coronal area was 4 for both ProTaper and WaveOne, which showed no statistically significant difference (P=0.211; Table 5 and Figure 7).

Table 5. Evaluation of smear layer formation debris based on Schäfer-Schlingemann scoring system

File type \ Area	Coronal	Middle	Apical
ProTaper	4 ± 0.655	4.07 ± 0.799	3.8 ± 0.676
WaveOne	4 ± 0.756	4.13 ± 0.743	4.2 ± 0.676
P-value	0.211	0.116	0.511

Table 4 shows the remaining debris in different areas according to the systems, which indicates that there is no statistically significant difference in the remaining debris in coronal, middle, and apical radicular areas (P>0.05).

Table 5 shows the smear layer formation in different areas according to the systems, which indicates that there is no statistically significant difference in the smaer layer formation debris in coronal, middle, and apical radicular areas (P>0.05).

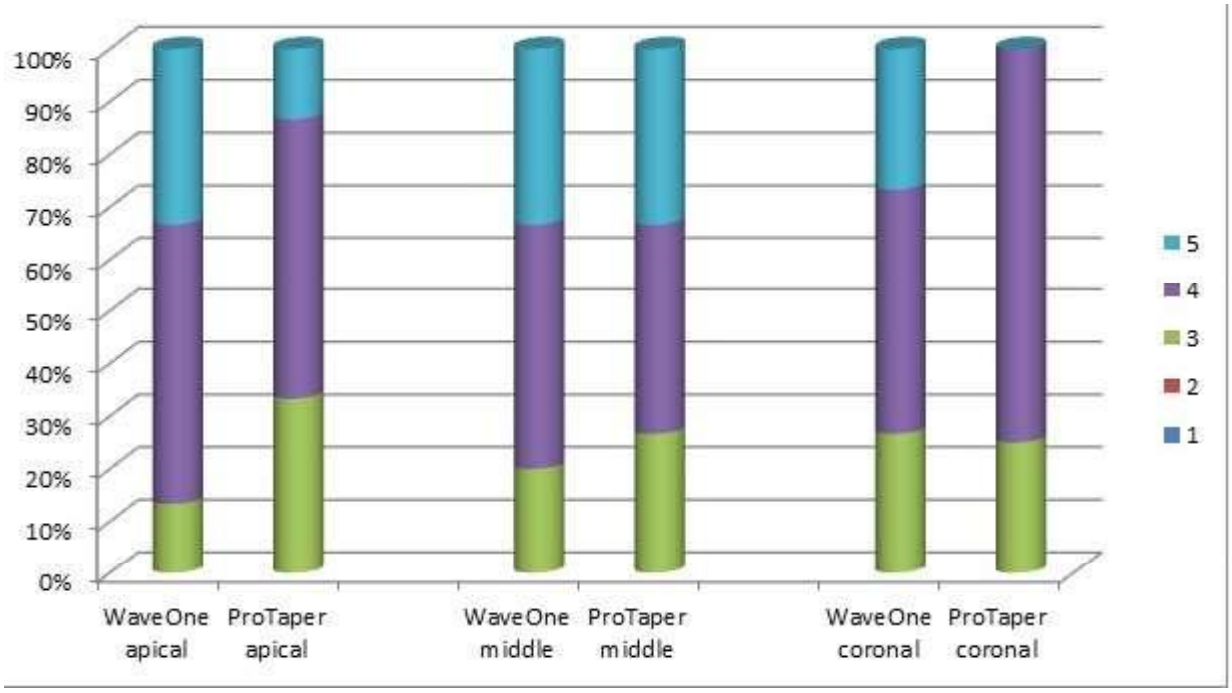

Figure 7. Smear layer formation according to radicular areas and test groups

Discussion:

The main objective of RCT is cleaning and shaping of root canals, removing the pulpal tissue and bacteria and their by-products, and finally, sealing the canal.[5] The aim of this study was to compare the smear layer formation and the amount of residual debris following the use of WaveOne and ProTaper rotary files in the mesiobuccal root canals of upper first molars by SEM.

Two parameters of debris and smear layer were considered as the quality of cleaning. Debris consists of dentinal particles and vital and/or necrotic pulpal tissues, which are often infected and layered on the canal surface. Therefore, the presence of debris indicates the incomplete removal of microorganisms from the root canal.[11] Following the canal preparation, a smear layer with the thickness of 1-2 µm is created, which unevenly covers the canal walls after preparation.[2] This layer with crystalline structures consists of organic and inorganic pulpal tissues, such as inorganic dentinal debris and bacteria and their by-products.[3]

Although there has been controversy about the effect of the smear layer on the quality of canal preparation and obturation, the researchers have found that the smear layer, by itself, is a contaminated tissue which can protect bacteria within dentinal tubules.[2] Smear layer formation may obstruct and delay the flow of irrigating solutions, intracanal drugs, and disinfectants into dentinal tubules, which subsequently causes coronal and apical leakage.[3]

Moreover, it has been demonstrated that the smear layer may prevent the penetration of sealers into dentinal tubules, which will lead to leakage.[16,17]

Following the proven effects of the smear layer on the outcome of RCTs, the application of various materials capable of removing organic and inorganic parts of the smear layer have been confirmed;[2,16] from which, endodontic irrigants can be mentioned, which are the key to a successful canal preparation. It has been stated that 5.25% NaOCl is the best solution known for canal irrigation with antibacterial activities, which is capable of solving necrotic tissues.[18,19] Owing to the fact that NaOCl cannot remove the inorganic part of the smear layer, the application of

demineralizing (chelating) materials should be considered as well.[16]

The extent of the smear layer depends on the type or sharpness of the cutting bur and cutting of wet or dry dentin. In addition, the increase of centrifugal forces will integrate the rotary instrument's movement with dentinal walls and will result in more formation of the smear layer. Thus, the smear layer formation produced by rotary instruments will be by far larger compared to hand instruments.[20-22]

Several studies have been carried out to compare different rotary instruments and to introduce the more accepted system for a better canal preparation.

The result of the present study showed no statistically significant difference between the two groups with regard to the remaining debris and smear layer formation; this finding is in agreement with the results reported by Amaral et al. [21] They carried out a research to evaluate rotary and reciprocating systems in cleaning and removing of debris and smear layers. The specimens were prepared by three systems: Reciproc, WaveOne, and Mtwo. The smear layer scoring was determined by a three value scale. Amaral et al reported that the coronal and middle areas of the root canal showed a cleaner dentin in comparison with the apical third of the root canal.[21] However, in our study, there was no significant difference between coronal, middle, and apical regions. This difference can be attributed to the method of evaluation.

In a research by Poggio et al, two systems of Mtwo and Reciproc were compared to evaluate the amount of debris and the smear layer removed from the canal, which showed that Mtwo rotary system with 5.25% NaOCl and 17% Ethylenediaminetetraacetic acid (EDTA) could prepare cleaner canal walls compared to Reciproc. [23] However, cleaner walls with a higher cleaning efficacy were detected after the use of Mtwo rotary system in apical and middle areas. The difference between this study and our study can be attributed to the different types of rotary and reciprocating instruments.

Robinson et al conducted a research to investigate the debris accumulated in the canal, and debris density after canal preparation with the reciprocating motion of a single-use file compared to several files of rotary systems in 38 canals. [11] The result after canal preparation showed that the debris remained in the canal was 19.5% after the use of WaveOne, and10.6% after the use of ProTaper, with a statistically significant difference. The mean density of the remaining debris was 1.6 g/m^3 for WaveOne and 1.55g/m^3 for ProTaper, which indicated that the use of WaveOne file might cause debris packing. The majority of debris were often accumulated in uninstrumented regions such as isthmuses, fins, and projections of the main canals.[11] The main significant difference between the research by Robinson et al and our study is the method of evaluation (three-dimensional (3D) images taken by Micro CT versus 2D images taken by SEM). Another reason for this difference may be the high number of specimens; however, the amount of the smear layer was not investigated in this survey.

Another research was carried out by Burklein et al in order to investigate the shaping ability and cleaning efficacy in severely curved root canals by comparing two single-file systems: Reciproc and WaveOne versus Mtwo and ProTaper.[24] In debris removal, Mtwo and Reciproc instruments with 5.25% NaOCl and 17% EDTA achieved significantly better results than WaveOne and ProTaper in the apical third of root canals, with a statistically significant difference. In middle and coronal parts, Reciproc and WaveOne had no significant differences with Mtwo and ProTaper.[24] Similar to our results, WaveOne and ProTaper had an equivalent cleaning efficacy.

Conclusion:

Based on the aforementioned results, one can conclude that more smear accumulation might be expected in apical regions due to a better file-to-wall contact in the apical third; however, a lower amount of the smear layer does not indicate the cleanliness of the canal. However, regarding debris, the lesser is the amount of debris, the cleaner is the canal. Hence, in our study, the debris in coronal parts are by far fewer in comparison with the apical part. Most importantly, the amount of the debris left in the apical part of root canals is the same for both rotary and reciprocating systems.

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