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Original Article

Comparative Assessment of the Shaping and Cleaning Abilities of M-Pro and Revo-S versus ProTaper Next Rotary Ni-Ti Systems (An In Vitro study)

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Abstract

Objective: The aim of the present study was to compare the canal transportation, centering ratio, debris and smear layer score after using 3 rotary Ni-Ti systems, Revo-S (RS; Micro-Mega, Besancon Cedex, France) and ProTaper Next (PTN; Dentsply Tulsa Dental Specialties, Tulsa, OK) and M-Pro system(Guangdong, China, Mainland).
Material and methods: Thirty nine mesiobuccal root canals of extracted lower first molars with 20˚ to 45˚ angle of curvature and were divided randomly into 3 groups of 13 samples each: group RS, group M-Pro and group PTN. Root canal transportation and centering ratio were evaluated at 3, 6 and 9 mm from apex using i-CAT CBCT (Hatfield, pennsylvania ,USA) before and after preparation.Thirteen Roots from each group were split longitudinally using diamond disc, by making a groove on buccal and lingual side of root without reaching the lumen of the canal.The root halves were examined under Scan Electron Microscope (SEM) by magnification x 1000 and x 4000 for debris and smear layer respectively The significance level was set at $P \leq 0.05$.
Results: There was no statistically significant difference in canal transportation, canal centering ratio, debris and smear layer score between the three tested groups.
Conclusion: From the obtained results and within the limitations of this study, the following could be concluded:M-Pro Nickel Titanium rotary system had a negligible effect on root canal transportation which was similar to the ProTaper Next and Revo-S systems and no system was able to clean the root canal system completely.

Keywords: Shaping ability, cleaning ability, Canal transportation, smear layer, Debris.

Introduction

Root canal shaping and cleaning play a crucial role in the success of endodontic treatment. Ideally, canal shaping should create a continuous tapered preparation with increasing apico-coronal diameter while maintaining the original path of the canal.[1] In the past, root canals were prepared by stainless steel hand instruments with relatively high modulus of elasticity which caused difficulty in shaping small curved canals that resulted in undesirable aberrations such as zips, elbows, perforation and ledge, in addition to creating debris and a smear layer on the canal walls.[2,3]

Recently, with the introduction of various types of endodontic rotary instruments made of Nickel Titanium alloy, these drawbacks have been overcame. Where, the super-elastic behavior of conventional austenitic Ni-Ti and the controlled memory (CM) properties of martensitic rotary Nickel Titanium instruments succeeded to reduce the restoring forces and maintain the original canal shape even in severely curved canals with a lower risk.[3,4]

The rotary Nickel Titanium instruments available in market vary considerably in their design as cross-section, helical angle, pitch and taper. ProTaper Next rotary system (Dentsply Maillefer, Ballaigue, Switzerland) provides shaping advantage through off-centered rectangular cross section that gives the file a snake-like swaggering movement creating enlarged space for debris removal. Also, its metallurgy is based on the M-wire alloy that is claimed to improve file flexibility and cyclic fatigue resistance.[5,6] While, Revo-S rotary system (Micro Mega, Besancon, France) has asymmetrical cross section which provides less stress on the instrument and increases the available volume for upward debris elimination. Thought it is made of austenitic alloy; the smaller section allows more flexibility and offers a better ability to negotiate curves [7,8]

Recently, M-Pro rotary system (Guangdong, China, Mainland) has been introduced to the market from controlled memory (CM) wire that has pre-bending ability, increased flexibility and cyclic fatigue resistance.. It has convex triangular cross section to minimize contact with the canal wall and have rounded non cutting tip to avoid overcutting.[9]

Canal cleaning ability of endodontic files can be evaluated from its ability to remove debris and smear layer which is an essential prerequisite for the successful outcome of endodontic treatment [10]. The smear layer is a thin surface film (1-2µm) consisting mainly of inorganic material that is produced when a canal is instrumented [11]. Although there is a controversy about the effectiveness of smear layer removal in endodontic therapies, its removal seems desirable because it will increase dentin permeability, allowing better disinfection of deep layers of the infected root canal dentin[12].

Thus, this study was aimed to shed a light on the ability of ProTaper Next, Revo-S and M-Pro systems to maintain the main course of the canal and their cleaning ability.

The null hypothesis was that there would be no statistically significant difference between three systems regarding maintaining canal shape and cleaning ability.

Materials and Methods

Sample size Calculation

Based on a previous study by Bhaumik et al., 2017 [13] the difference in the apical transportation between at least 2 groups was 0.04 ± 0.035 mm. Using power 80% and 5% significance level, we needed 13 tooth in each group. Sample size calculation was achieved using PS: Power and sample size calculation software version 3.1. (Vanderbilt University, Nashville, Tennessee, USA).

I- Selection of Samples:

A total of 39 extracted human permanent first mandibular molars extracted for periodontal reasons, were collected from the Department of Oral and Maxillofacial surgery (Faculty of Dentistry, Cairo University). The teeth were cleaned from any hard or soft deposits using ultrasonic scaler and were immersed in 5.25% Sodium hypochlorite solution (NaOCl) for half an hour for disinfection and then stored in saline until use.

II Preparation of Samples:

A standard endodontic access cavity was performed in the all samples using high speed hand piece with a diamond round bur and EndoZ bur. A #10 K file was inserted in the mesiobuccal canal to check patency,With the file in the mesiobuccal canal adjusted to the apical foramen, radiograph was taken for each tooth (mesiodistal view) using direct digital radiography.

An x-ray machine with exposure parameters 70 KVP, 7mA and 0.04 sec exposure time was used. Digital images were captured using Digora imaging plate. Two samples were placed on imaging plate for each exposure.The digital images were analyzed using Digora software to determine the angle of curvature according to Schneider's method [14] and it ranged between 20˚- 40˚ in this study. After measuring the angle of curvature, all samples were decoranated at the cemento-enamel junction and distal roots were resected at the level of furcation from all teeth using diamond disk mounted on low speed straight hand piece under copious irrigation. The mesial roots length were measured to obtain a standardized root length of 16mm.

III -Samples Grouping:

The roots were randomly assigned into three equal groups (n= 13 per group) according to the Ni-Ti file used for root canal preparation; ProTaper Next, Revo-S and M-Pro systems. Random sequence was generated using random sequence generator internet site (https://www.random.org/sequences), on 3 groups that were being group A, B and C, Allocation concealment was done by one clinician by inserting each root in a separate envelope, followed by shuffling of the envelopes, then writing a number on each envelope from 1 to 39.

IV-Placement of the Samples in the Mould:

Three square blocks of 10×10cm were filled with acrylic resin mixed according to the manufacturer instructions. Each mould contained 13 mesial roots for each group. Vaseline was painted on the internal surface of the mold as a separating medium. Mesial roots were vertically placed in the acrylic resin before complete polymerization with the buccal surface of all teeth facing at the same directions and the apical foramen of each root were sealed with modeling wax. Amalgam filling inserted into the resin at one corner of the mold facing the buccal surfaces of the root to act as radioopacifier. Implementation was done by another clinician who put envelopes in each group, according to the table of the random sequence.

IV-Pre-Instrumentation Scanning:

Before canal preparation, each mold was scanned with I-Cat CBCT. The machine was operated at the following protocol for all the scans of the study ; 120 KV , 37.07 mA , voxel size 0.25 mm and scanning time 26.9 seconds.

V-Root Canal Instrumentation:

The teeth were randomly assigned into three equal groups (n=13) according to the rotary system used during root canal preparation as follow:

<u>Group A:</u>

Samples instrumented with ProTaper Next rotary system., in the following sequence:
-SX(19/4%taper) was used to 2\3of the working length.
-X1 (17/4% taper) then X2 (25/6%taper) were used to full working length.
-The X smart plus motor was used and the rotation speed was adjusted at speed 300 rpm and torque from 4- 5.2 N/cm according to manufacturer instructions.

<u>Group B:</u>

Samples instrumented with Revo-S rotary system, in the following sequence:
- SC1(25/6% taper) was used to 2\3of the working length.
- SC2(25/4%taper) then SU (25/ 6% taper) were used to full working length.
-The X smart plus motor was used and the rotation speed was adjusted at speed 400rpm and torque 0.8N/cm according to manufacturer instructions.

<u>Group C:</u>

Samples instrumented with M-Pro rotary system. in the following sequence:
- File (18/ 4% taper) was used till 2\3 working length.
-File (20/ 4% taper) then File (25 / taper 6%) were used to full working length
-The x smart plus motor was used and the rotation speed was adjusted at speed 450 rpm and torque 3N/cm for file18 and 1.5 N/cm for file (20, 25)according to manufacturer instructions
-The flutes of the instrument were cleaned after three in-and-out pecking motions and canal irrigation was done by 3 ml of 2.6%Sodium hypochloride (NaOCl) solution between each file for all systems using a 25 gauge plastic syringe introduced 2mm shorter than working length. This maneuver was continued till each file reached the working length. 1 ml of 17 % EDTA was used for 1min as a final irrigating solution.

-Each instrument of ProTaper Next, Revo-S and M-Pro was used to prepare six canals only, then discarded.

VI-Post Instrumentation Scanning:

After root canal instrumentation, CBCT images were taken with the same parameters as the pre-instrumentation images. The projections were reconstructed as cross-sectional images and measurements were taken at three levels: 3 mm, 6 mm, and 9 mm from the apex representing apical, middle and coronal third respectively. Pre and post-instrumentation scans were superimposed to evaluate post-instrumentation changes using a Software program (On Demand 3D).

Image Analysis of Centering ability and Root Canal Transportation:

The projections were reconstructed as cross-sectional images before and after canal instrumentation taken at three levels: 3 mm, 6 mm, and 9 mm from the apex representing apical, middle and coronal third respectively using the following formula [15] Mesiodistally: (M1-M2) / (D1-D2) or

(D1-D2) / (M1-M2) where M1 is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal, M2 is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, D1 is the shortest distance from the distal edge of the root to the distal edge of the uninstrumented canal and D2 is the shortest distance from the distal edge of the root to the distal edge of the instrumented canal and this formula used Buccolingually: (B1-B2) / (L1-L2) or (L1-L2) / (B1-B2) where B1 is the shortest distance from the buccal edge of the root to the buccal edge of the uninstrumented canal, B2 is the shortest distance from the buccal edge of the root to the buccal edge of the instrumented canal, L1 is the shortest distance from the lingual edge of the root to the lingual edge of the uninstrumented canal and L2 is the shortest distance from the Lingual edge of the root to the lingual edge of the instrumented canal. According to Gambill's formula[15],a value equal to 0.0 indicated the absence of transportation.

B-Assessment of Cleaning Ability:

Method of Evaluation:

The thirteen Roots from each group were split longitudinally using diamond disc, by making a groove on buccal and lingual side of root without reaching the lumen of the canal and then, chisel and mallet were used to split the root into two equal halves. The root halves were cleaned from grinding material using running water according to sabet et al[16] **.** For each specimen, the half with the most visible part of the apex was selected. The root halves were examined under Scan Electron Microscope (SEM) by magnification x 1000 and x 4000 for debris and smear layer respectively at three different level (apical, middle, coronal). Evaluation were performed by means of a numerical evaluation scale (Hulsman et al., 1997) [17] by two operator in endodontic department which were blind to each group and to each level of root canal.

1-Amount of Debris: (Dentin chips, Pulp remnants)
-The amount of Debris was graded as follow:
Score 1: little or no superficial debris covering up to 25% of the specimen.
Score 2: Little to moderate debris between 25% and 50%.
Score 3: Moderate to heavy debris covering between 50% and 75% of the specimen.
Score 4: Heavy amounts of aggregated or scattered debris over 75% of the specimen:
Score 5: Clumps of debris particles completely covered of the canal wall.

2-Smear layer Removal:

-The amount of smear layer was as follow :

Score 1: Little or no smear layer covering less than 25% of the specimen, tubules visible and patent.

Score 2: Little to moderate or patchy amount of smear layer covering between 25 and 50% specimen many tubules visible and patent.

Score 3: Moderate amounts of scattered or aggregated smear layer covering between 50% and 75% of the specimen , minimal to no tubule visibility or patency.

Score 4: Heavy smear layer layering covering over 75% of the specimen, no tubule orifice visible or patent.

Score 5: A thick , homogenous smear layer covering the entire root canal wall.

Statistical Analysis

Data were presented as mean and standard deviation values between three groups. Regarding transportation and centering ratio, comparison of the three groups within each level was performed through kruskal-wallis test and Friedman test used at different root levels within each system. While, the debris and smear layer score were analysed by ANOVA test and Kappa analysis for inter-observer reliability. Two tailed P value ≤ 0.05 was considered significant**.**

Results

Canal transportation:

Regarding comparison of the three groups within each level ;there was no statistically significant difference between three systems regarding canal transportation mesiodistally and buccolingually ($p > 0.05$). Regarding comparison of the three levels in each group; Mesiodistally: the PTN group recorded (0. 12 ±0.09, 0.14 ± 0.09, 0.17 ± 0.26) , Revo-S recorded (0.12 ± 0.11, 0.18 ± 0.14, 0.08 ± 0.06) and M-pro group recorded recorded (0.07 ± 0.06, 0.12 ± 0.08, 0.23 ± 0.26) at the 3, 6 and 9 mm levels respectively. While buccolingually: PTN group recorded (0. 08 ±0.07, 0.15 ± 0.22, 0.1 ± 0.1) , Revo-S recorded (0.13 ± 0.09, 0.15 ± 0.12, 0.24 ± 0.27) and M-pro group recorded (0.12 ± 0.22, 0.17 ± 0.12, 0.1 ± 0.08) at the 3,6 and 9 mm levels respectively.

All data are presented in Tables 1 and 2.

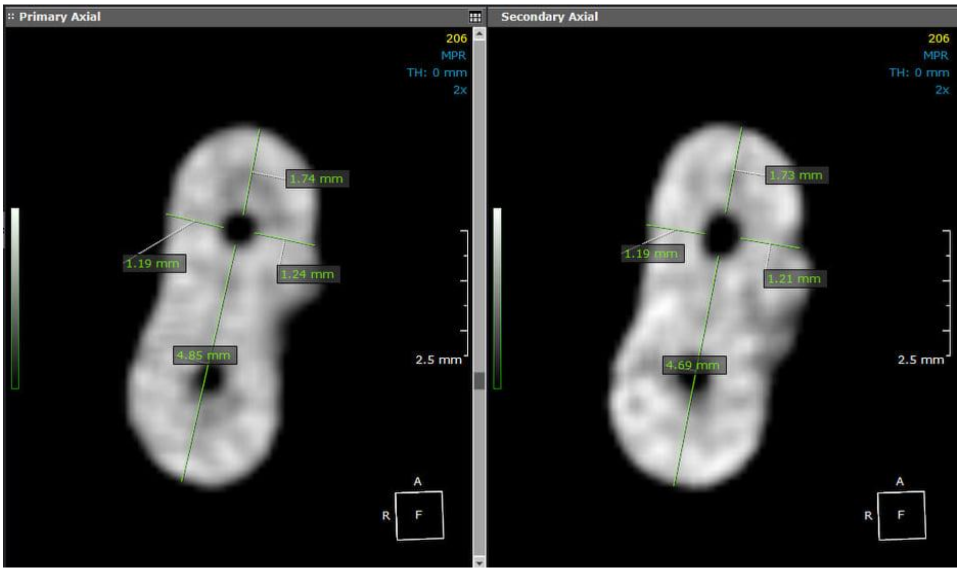


Figure (1): An image showing primary and secondary axial slices of CBCT showing dentin thickness at mesial,distal, buccal and lingual aspects of the canal lumen as representative sample.

Table (1): The mean, standard deviation (SD) and results of kruskal-wallis test for comparison between the canal transportation values (mm) after using the three file systems and results of Friedman test for comparison between the canal transportation values (mm) at different root levels within each system, in mesiodistal direction.

System / Root level	Group A: ProTaper Next		Group B: Revo-S		Group C: M-Pro		P value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
3 mm	0.12	0.09	0.12	0.11	0.07	0.06	0.658
6 mm	0.14	0.09	0.18	0.14	0.12	0.08	0.7
9 mm	0.17	0.26	0.08	0.06	0.23	0.29	0.517
P Value	0.9		0.57		0.24		

Table (2) The mean, standard deviation (SD) and results of kruskal-wallis test for comparison between the canal transportation values (mm) after using the three file systems and results of Friedman test for comparison between canal transportation values (mm) at different root levels within each systems, in buccolingual direction

System / Root level	Group A: ProTaper Next		Group B: Revo-S		Group C: M-Pro		P value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
3 mm	0.08	0.07	0.13	0.09	0.12	0.22	0.23
6 mm	0.15	0.22	0.15	0.12	0.17	0.12	0.53
9 mm	0.1	0.1	0.24	0.27	0.1	0.08	0.229
P value	0.87		0.77		0.47		

Centering ability

Regarding comparison of the three groups within each level; there was no statistically significant difference between three systems regarding centering ability mesiodistally and buccolingually ($p > 0.05$). Regarding comparison of the three levels in each group; Mesiodistally: the PTN group recorded (0. 18 ±0.18, 0.47 ± 0.25, 0.5 ± 0.32) , Revo-S recorded (0.36 ± 0.29, 0.31 ± 0.25, 0.43 ± 0.26) and M-pro group recorded recorded (0.41 ± 0.35, 0.43 ± 0.29, 0.47 ± 0.31) at the 3, 6 and 9 mm levels respectively. While buccolingually: PTN group recorded (0. 27 ±0.28, 0.32 ± 0.37, 0.41 ± 0.33) , Revo-S recorded (0.29 ± 0.29, 0.3 ± 0.32, 0.3 ± 0.24) and M-pro group recorded (0.33± 0.3, 0.16 ± 0.22, 0.53 ± 0.32) at the 3,6 and 9 mm levels respectively.
All data are presented in Tables 3 and 4.

cleaning ability

Regarding comparison of the three groups within each level; there was no statistically significant difference between three systems regarding debris score ($p > 0.05$). Regarding comparison of the three levels in each system; the PTN group recorded (3.46±1.26, 2.6± 1, 2.46 ± 0.96) , Revo-S recorded (3.46± 0.96, 3.15 ± 0.8, 2.7 ± 0.27) and M-pro group recorded (2.69 ± 1.18, 2.53 ± 0,87, 2.15 ± 0.89) at the apical, middle and coronal levels respectively .
All data are presented in Table 5.

Amount of smear layer:

Regarding comparison of the three groups within each level ;there was no statistically significant difference between PTN and Revo-S regarding smear layer score ($p > 0.05$). Regarding comparison of the three levels in each system; the PTN group recorded (3±0.7, 2.84± 0.89, 2.53 ± 1) , Revo-S recorded (3.9± 0.95, 3.3 ± 0.85, 3.38 ± 0.86) at the apical, middle and coronal levels respectively, while M-pro group was shown statistically significant difference between three levels (3.84 ± 1.4, 3 ± 1.3, 2.53 ± 0.77) at the apical, middle and coronal levels respectively
All data are presented in Table 6.

Kappa analysis for inter observer reliability of Scan Electron Microscope scoring of cleaning ability:

-The Cohen Kappa analyzed agreement among the two evaluators, values ranged between 0.85 to 1.

M- Pro system

- Regarding debris, there was perfect inter-observer agreement (reliability) regarding all levels and total values, Kappa statistic values = 1.00

- Regarding smear layer, there was perfect inter-observer agreement (reliability) regarding all levels Kappa statistic values ranging from 0.901 to 1.00 and 0.967 for total values

ProTaper Next system

- Regarding debris, there was perfect inter-observer agreement (reliability) regarding all levels Kappa statistic values ranging from 0.890to 1.00and 0.961 for total values.

- Regarding smear layer, there was perfect inter-observer agreement (reliability) regarding all levels Kappa statistic values ranging from 0.889 to 1.00and 0.964 for total values.

Revo-S system

- Regarding debris, there was perfect inter-observer agreement (reliability) regarding all levels Kappa statistic values ranging from 0.859 to 1.00 and 0.961 for total values.

- Regarding smear layer, there was perfect inter-observer agreement (reliability) regarding all levels Kappa statistic values ranging from 0.805 to 1.00 and 0.859 for total values.

Discussion

The main objective of root canal preparation is to achieve proper cleaning and shaping of the root canal system while maintaining the original canal curvature without altering its geometry [1, 18].To achieve this goal, many systems have been introduced to the market [19].

The selection of ProTaper Next and Revo-S in the present study, was due to the fact that both of them possess an asymmetric design which reduces the stresses on the instruments during canal preparation through minimizing the engagement between the files and dentin, and increase the available volume for upward debris removal.[5] While, the selection of M- Pro Nickel Titanium rotary system, was due to the fact that it was recently introduced into the market and there were no data available on its behavior in the canal .Thus, we needed to shed a light on its shaping and cleaning ability.

Table(3) The mean, standard deviation (SD) values and results of kruskal- wallis test for comparison between centering ratio after using the three file system and results of Friedman test for comparison between centering ratio at different root levels within each system, in mesiodistal direction

System / Root level	Group A: ProTaper Next		Group B: Revo-S		GroupC: M-Pro		P Value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
3 mm	0.18	0.18	0.36	0.29	0.41	0.35	0.258
6 mm	0.47	0.25	0.31	0.25	0.43	0.29	0.24
9 mm	0.5	0.32	0.43	0.26	0.47	0.31	0.67
P value	0.116		0.66		0.77		

Table (4) The mean, standard deviation (SD) values and results of kruskal- wallis for comparison between centering ratio after using the three file system and results of Friedman test for comparison between centering ratio at different root levels within each system, in buccolingual direction

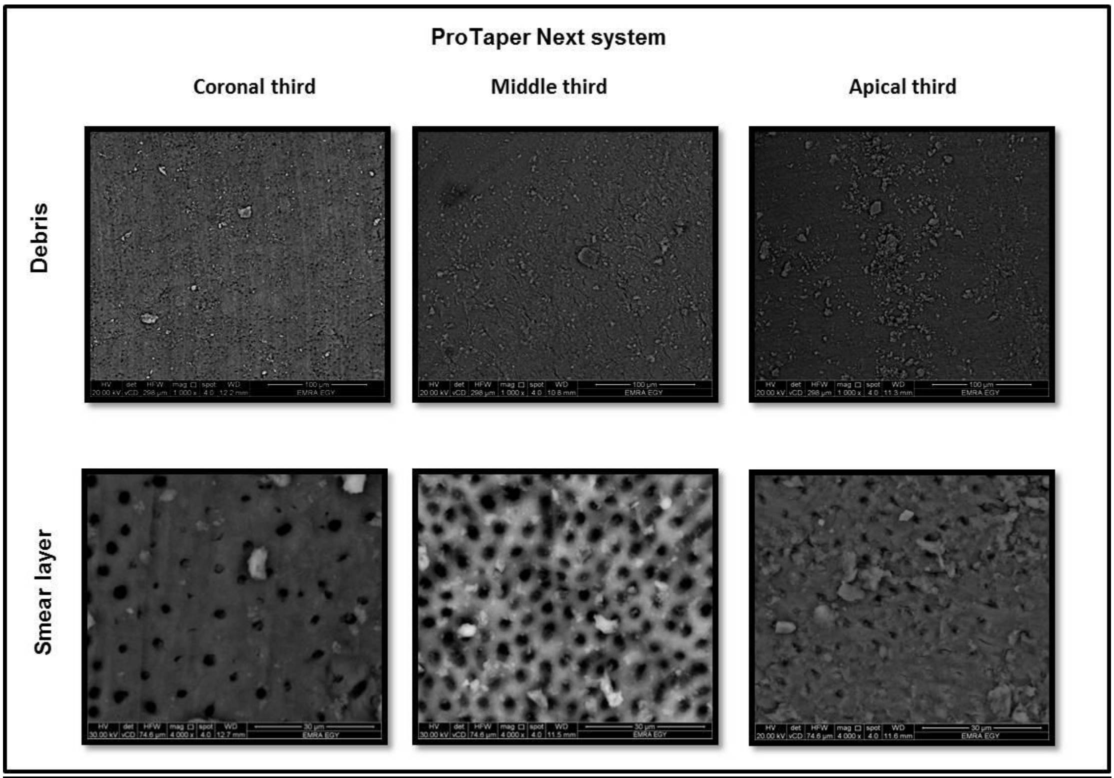
System / Root level	Group A: proTaper Next		Group B: Revo-S		GroupC: M-Pro		P Value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
3 mm	0.27	0.28	0.29	0.29	0.33	0.3	0.75
6 mm	0.32	0.37	0.3	0.32	0.16	0.22	0.478
9 mm	0.41	0.33	0.3	0.24	0.53	0.32	0.166
P value	0.21		0.73		0.28		

Table (5) The Mean and standard deviation (SD) values and results of debris between the three file system in the same root level and within the same file at different root levels by analysis of variance (ANOVA)

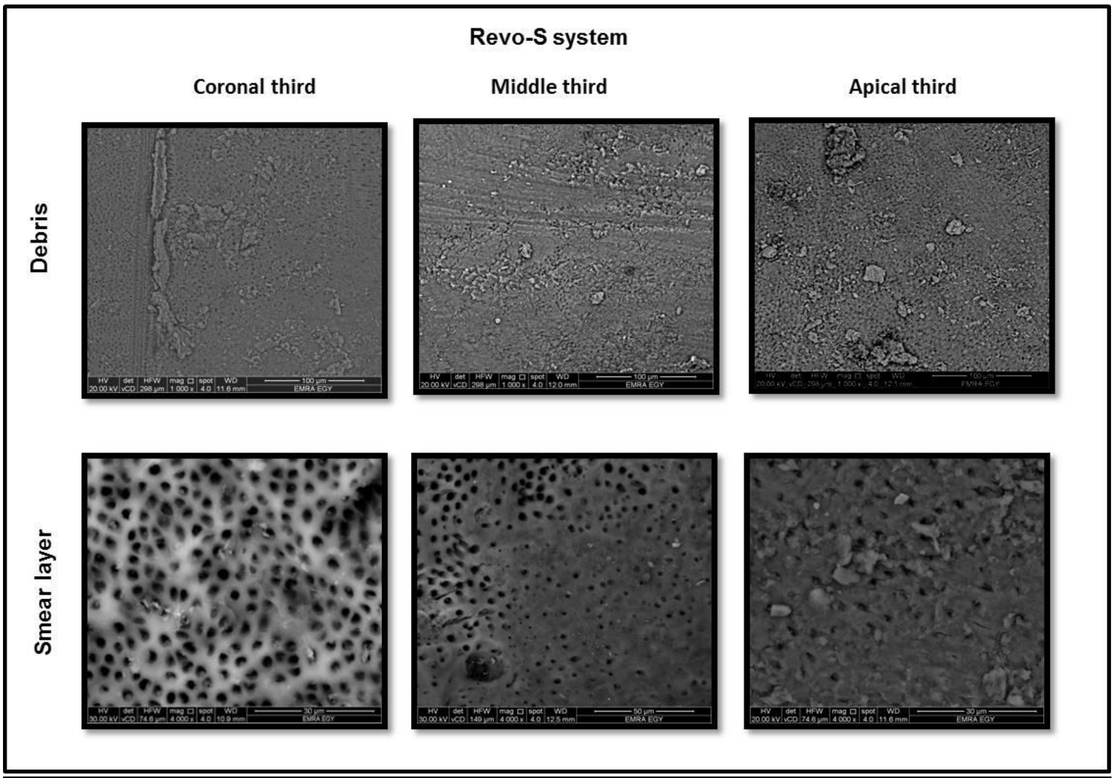
System / Root level	Group A: ProTaper Next		GroupB: Revo-S		Group C: M-Pro		P value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Apical	3.46	1.26	3.46	0.96	2.69	1.18	0.156
Middle	2.6	1	3.15	0.8	2. 53	0.87	0.188
Coronal	2.46	0.96	2.7	0.72	2.15	0.89	0.21
P value	0.056		0.122		0.375		

Table (6) Mean and standard deviation (SD) values and results of smear layer between the three file system in the same root level and within the same file at different root levels by analysis of variance (ANOVA)

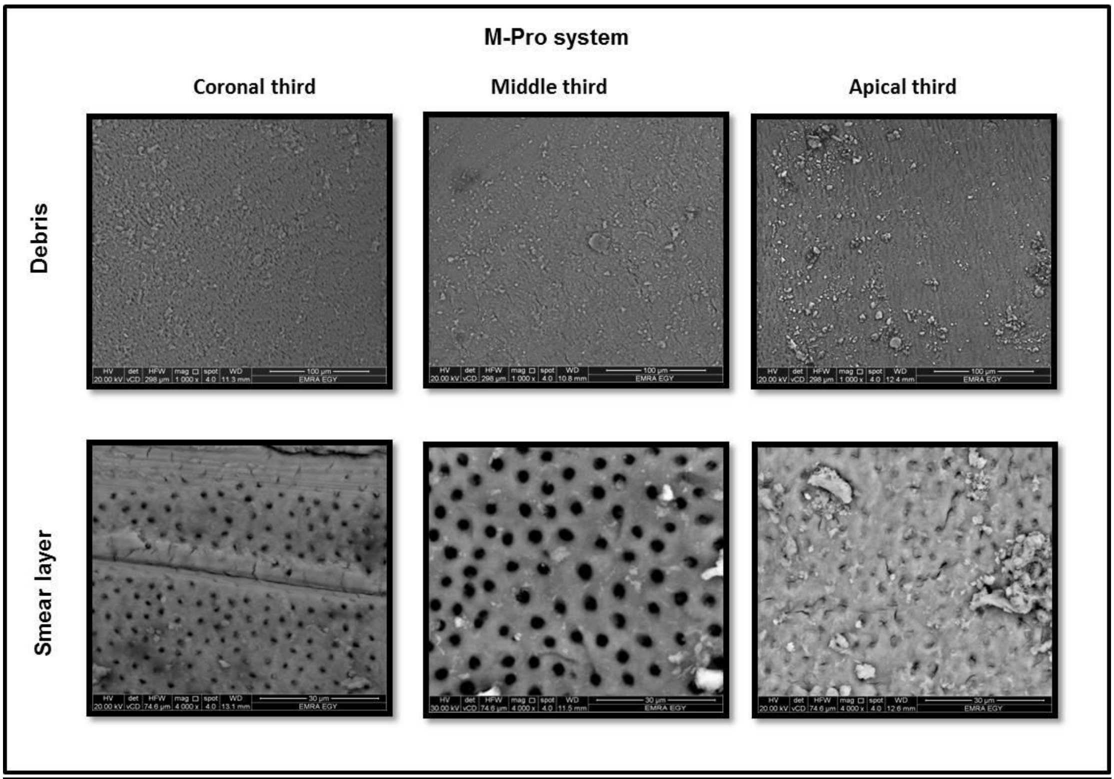
System	Group A: ProTaper Next		Group B: Revo-S		Group C: M-Pro		P value
Root level	Mean	SD	Mean	SD	Mean	SD	
Apical	3	0.7	3.9	0.95	3.84	1.4	0.06
Middle	2.84	0.89	3.3	0.85	3	1.3	0.534
Coronal	2.53	1	3.38	0.86	2.53	0.77	0.32
P value	0.418		0.175		0.03		



Figure(2) Scan Electron Microscope showing debris and smear layer at coronal, middle and apical third of the canal prepared by ProTaper Next system at magnification 1000x and 4000 for debris and smear layer respectively



Figure(3) Scan Electron Microscope showing debris and smear layer at coronal, middle and apical third of the canal prepared by Revo-S system at magnification 1000x and 4000 for debris and smear layer respectively.



Figure(4) Scan Electron Microscope showing debris and smear layer at coronal, middle and apical third of the canal prepared by M-Pro system at magnification 1000x and 4000 for debris and smear layer respectively

Shaping ability of the three system was assessed in terms of canal transportation and centering ability, since they significantly affect the final outcome of root canal treatment [3].

Where, canal transportation corresponds to the post- instrumentation deviation in the axis comparable to the original pre- instrumentation axis. [20, 21] While, centering ability refers to the ability of the file axis to be in line with canal axis, thereby avoiding canal zipping, ledging or perforation. [21] The formula introduced by Gambill et al., (1996) [15] was used in this study, as it is an effective method in measuring canal transportation and centering ability following previous studies [22, 23].

Scan Electron Microscope (SEM) was used as a method for evaluating the cleaning efficiency of the three systems because of its ability to differentiate between the areas of debris and smear layer. In addition, the SEM offer three-dimensional images with superior magnification and resolution [24].At low magnification (1000x) large amounts of debris could easily be seen, but details such as remnants of the smear layer or identification of dentinal tubules needed higher magnification (4000x) [25]. The score introduced by Hulsmann et al., (1997) [17] was used in this study, as it is an effective method in numerical evaluation of debris and smear layer score. Evaluation in this study used single reading for each of three levels (coronal, middle,apical) following previous study[26,27]

Human extracted teeth were selected to increase the reliability of the study and to replicate the clinical conditions than simulated canals made of acrylic resin in terms of hardness and surface texture [28]. Moreover, the heat generated by rotary instrument through friction softens the resin ,so that instrument's blade might bind or break [29].

Mesiobuccal root canals of extracted human permanent mandibular molars were implemented in the present study as they usually show more significant root canal transportation owing to the fact that they are narrow and curved in 2 planes. The angles of curvatures of the mesiobuccal canals included in the study ranged between 20˚- 40˚, since it is the mostly simulated clinical situation and following previous studies [30].

Direct digital radiography (Digora system) was used for evaluating the angle of curvatures of the samples as it offers many advantages comparable to conventional images as high image quality, low radiation dose , precision linear measurements ,manipulation of image quality, and the noise reduction by image processing [31]. These angles were measured according to Schneider´s method because it is considered simple, reliable, and most commonly used method for measuring the angle of curvature [32].

The crowns were resected at the cementoenamel junction to eliminate any coronal interference that may affect the operator authority over the file during instrumentation. All samples were flattened to a length of 16 mm for standardization [33].

The mesial roots were embedded in unset acrylic resin such that its long axis was parallel to the long axis of the mold. The buccal surfaces of all samples facing the same direction to ensure standardization of the specimens during tomographic scanning [34]. Moreover, an amalgam filling was inserted into the resin at one corner of the mold, facing the buccal surfaces of the roots; to enable its orientation during scanning. Each root tip was sealed with a small ball of wax to prevent the flow of resin through the apical foramen, and inside the canal, thus impairing its patency.

Though, several methodologies have been used to evaluate the final shape of the root canal preparations such as the Serial Sectioning technique, optical microscopy and Cone Beam Computed Tomography (CBCT) [35]. Cone Beam Computed Tomography (CBCT) was chosen for being an accurate, reliable method [36] as well as it offers reproducible data in three dimension planes; axial, sagital and coronal [37].

In the present study, the axial slice from CBCT image constituted an important tool to identify dentin thickness before and after preparation of the root canals to evaluate canal transportation and centering ability by subtraction of two images. Three root levels were chosen to be assessed: 3, 6, and 9 mm from the apex. These measurements represent the apical, middle, and coronal thirds of root canals respectively.

In order to enable accurate comparisons between different rotary systems, the final apical preparation diameter of all samples was terminated at size 25/0.06 [38].

The results of this study showed that the null hypothesis could be accepted. There were no statistically significant differences between the three systems.

Concerning the results of the shaping ability in this study, there was no statistically significant difference between three systems regarding canal transportation and centering ability ($p > 0.05$). Our findings comes in consistent with the results obtained by Saba et al., [39], Moe et al., [40] and Rubio et al., [41]) who showed there is no significant difference between ProTaper Next and Revo-S system . However, there is no published data regarding the shaping ability of M-Pro instruments. Thus, it was impossible to compare the present findings with previous results .Overall, it was noted that the newly developed instruments had a negligible effect on root canal transportation when were comparable with the ProTaper Next and Revo-S systems.

The absence of significant difference between the three systems regarding canal transportation and centering ratio could be attributed to several similarities between the three systems where they work in crown down technique, rotation motion, similar degree of taper of each system and terminated preparation with the same file tip diameter.

Though, apical transportation occurred with the three rotary systems but it didn't exceed the acceptable limit (0.12, 0.12, 0.07 for Revo-S, ProTaper Next, M- Pro systems, respectively at mesiodistal direction) and (0.13, 0.12, 0.08 for Revo-S, M Pro, ProTaper Next, respectively at buccolingual direction). According to Wu et al., (2000) [42] who reported that the apical seal of the endodontic treatment would be compromised if apical transportation of more than 0.3 mm occurred.

Concerning the results of debris, there was no statistically significant difference among the three levels of each system ($P = 0.056$, 0.122, 0.375 for ProTaper Next, Revo-S, M-Pro, respectively). Similarly, there was no statistically significant difference among the three system at each level ($p = 0.156$, 0.188, 0.21, for 3mm, 6mm, 9mm, respectively). Whereas, none of them showed a completely cleaned root canal surface. These findings were in agreement with some previous studies [27, 43]

Concerning the results of smear layer, there was no statistically significant difference among the three levels of ProTaper Next, Revo-S systems ($p=0.418$, 0.175 for ProTaper Next, Revo-S respectively). On the other hand, M-Pro system showed statistically significant difference among the three levels ($P = 0.03$). Whereas, there was no statistically significant difference among the three systems at each level ($p = 0.06$, 0.534, 0.32, for 3mm, 6mm, 9mm, respectively).

All the file systems showed their highest cleaning efficacy in the coronal thirds, followed by the middle thirds and exhibited maximum debris and smear layer in the apical thirds of the root canals. This might be attributed to the complex root canal apical morphology [24]and that the irrigants do not adequately penetrate the apical third which has a narrower diameter than the middle and coronal thirds [44], in agreement with Hulsmann et al., (2005) [3], Zouiten et al., (2015) [26]

The cutting efficiency of the root canal instruments is affected by a complex interaction of different parameters such as size, taper, cross-section, and the method of preparation (step back or crown down) and surface treatment of the instruments [1, 38].

Though, the difference in debris and smear layer scores were not statistically significant among the three groups ($P > 0.05$). Yet, SEM evaluation showed that the use of Revo-s rotary system have higher scores than ProTaper Next and M-Pro systems. A possible reason for this difference in the debris and smear layer removal is the different cross section [45].The cutting ability of Revo-S could be related to the asymmetric cross section which initiates a snake like motion along the length of the file enabling it to cut more dentin as claimed by the manufacturer and due to the fact that, it is made of conventional nickel titanium alloy which provide more cutting efficiency than instruments manufactured from M wire or CM wire.

On the other hand, ProTaper Next showed better debris and smear layer removal due to its offset mass of rotation which allowed the file to contact the canal at two points, thereby reducing the chances of lateral compaction of debris with improved canal cleaning ability (46).While, M- Pro system being made from CM wire, it has reduced cutting efficiency with a thick convex triangular core that lead to increase cutting ability when compared to the thinner core of the rectangular cross section of the ProTaper Next.

Conclusion

Within the limitations of this study, the following could be concluded;M-Pro Nickel Titanium rotary system had a negligible effect on root canal transportation which was similar to the ProTaper Next and Revo-S systems and no system was able to clean the root canal system completely.

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