EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 4027:4034, October, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 30-08-2024 • Accept Date : 23-09-2024 • Available online: 05-10-2024 • DOI : 10.21608/edj.2024.316689.3185

EVALUATION OF THE CLEANING ABILITY OF DIFFERENT ROTARY FILE SYSTEMS AN IN-VITRO SCANNING ELECTRON MICROSCOPIC STUDY

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ABSTRACT

Introduction: The present study aimed to compare the smear layer removal and cleaning abilities of the ProTaper Next (PTN), One Shape (OS), and XP Shaper rotary NiTi systems.

Materials and Methods: For this investigation, thirty recently extracted, single-rooted teeth were chosen. Three NiTi file systems were used for mechanical preparation: ProTaper Next files, one shape single file, and an XP Shaper file. The teeth were divided into three groups. In group 1, teeth were prepared with ProTaper Next files; in group 2, teeth were prepared using one shape file; and in group 3, teeth were prepared with XP Shaper file. Irrigation was carried out using 5.25% NaOCl and 17% ethylenediaminetetraacetic acid (EDTA). The teeth were longitudinally split into two halves and prepared for evaluation via Scanning Electron Microscope. The presence/absence of the smear layer and the presence/absence of debris at the coronal, middle, and apical thirds of each canal were evaluated via two 5-step scales for scoring. Numeric data were analyzed via the F-test (ANOVA) for normally distributed quantitative variables and the Post Hoc test (Tukey) for pairwise comparisons.

Results: A statistically significant difference was detected among the three groups. The XP-endo Shaper files showed the best debris and smear layer removal.

Conclusions: Comparing the XP Shaper files to those of the other two groups, the former showed superior debris removal and smear layer in the coronal, middle, and apical thirds of the root canal, within the confines of this investigation. Less smear layer reduction was achieved with one-shape single files compared with the ProTaper multiple file system.

KEYWORDS: Debris, Ni-Ti rotary instruments, SEM, Cleaning, Smear layer, Dentinal tubules.

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INTRODUCTION

Cleaning the root canal system with chemo mechanical preparation should successfully remove intracanal bacteria as well as debris to manage or prevent apical periodontitis.[1] Hermetic sealing, prevention of reinfection, and biological restoration of the periapical tissue must be supported by appropriate obturation.[2] Microorganisms can enter the dentinal tubules and spread the infection back to the root canal system when they become infected. Tools and techniques have been developed over the years to generate a debris-free and clean canal that is ideal for obturation.[3]

The ecosystem of microbes within the root canals is too large to be removed by mechanical instrumentation alone because it produces a smear layer and debris made up of inorganic as well as organic components, such as necrotic tissues, bacteria, and their byproducts produced from metabolic processes and remnants of odontoblastic processes (Tome's fibers). These parts of the tissue and debris restrict the access of irrigation solutions into the dentinal tubules, preventing root canal filling from properly bonding to the canal walls.[4]

During canal preparation, the mineralized tissues of the root canal are broken down producing a large amount of debris. A significant number of these particles, consisting of extremely minute particles of the mineralized collagen matrix, are dispersed across the surface to produce the smear layer.[5]

Smear layers are present only on the instrumented parts of canal walls. This layer may directly affect microleakage and prevent root canal filling materials from entering the dentinal tubules.[6]

Nickel-titanium (NiTi) rotary instruments have significantly enhanced canal shaping efficiency because they are more flexible, have higher cutting efficiency, and maintain canal geometry better than stainless steel files. However, NiTi files cannot achieve total canal cleaning, especially within the apical region. Cleaning oval canals is particularly difficult, mostly because of their round-cutting nature, which ultimately leaves an essential component of the canal wall intact. [1]

Few studies have been published on the cleaning capability of rotary Ni-Ti files. These rotary files include ProTaper Next files (multiple file system), One Shape files (single file system), and XP-endo Shapers (one file shaper system), which may aid in the elimination of the smear layer throughout endodontic therapy and thereby improve the quality of root canal treatment.[7]

The ProTaper Next (PTN) is a NiTi file system with three fundamental design characteristics: progressive tapers, M-wire technology, and an offset design that reduces the harmful taper lock and screw effect by reducing the contact zone between a file and dentin.[8]

Recently, one-shaped endodontic files have been introduced as a single file shaping system used in continuous clockwise rotation motion for quick and safe root canal preparation.[9]

The XP-endo Shaper is an extremely novel shaping equipment that may be used to greatly facilitate endodontic procedures. This file's distinguishing characteristic is its ability to shape 3D canals and perform less invasive cleaning and shaping. It aids in the entire chemical and mechanical preparation of complex canals. It is composed of NiTi MaxWire (martensite-austenite). This exceptional property of this alloy is its outstanding flexibility.[10]

Considering the expanding use of nickel-titanium (NiTi) rotary tools in endodontic treatments and the appearance of new files, examination of the cleaning ability of these instruments appears to be essential. Scanning electron microscopy (SEM) is considered a useful tool for comparing and examining the effects of various endodontic instruments on the cleanliness of dentin surfaces. Higher magnification levels are necessary for the evaluation of fine debris and smear layers, and this can only be accomplished with the use of SEM.[11] Therefore, the present study was performed to assess the smear layer and debris removal following canal preparation with ProTaper Next, One Shape, and XP Shaper files. Scanning electron microscopy was used in this study.

Within the various file systems, there would be no discernible variation in the debris and smear layer scores, according to the null hypothesis.

MATERIAL AND METHODS

The study was conducted in the Endodontic Department at Pharos University in Alexandria.

Sample size calculation

The minimal sample size is calculated based on a previous study aimed to compare the cleaning ability of rotary NiTi systems with different kinematics: Protaper next (PTN); One shape (OS) and XP Shaper file. The sample size was calculated to detect the difference in debris and smear layer scores. Based on Ismail et al. (2019) [12] results, adopting a power of 80% (β=0.20) to detect a standardized effect size in debris score (primary outcome) of 0.528, and level of significance 5% (α error accepted =0.05), the minimum required sample size was found to 10 specimens per group (number of subgroups=3) (Total sample size= 30 specimens). [13] Any specimen loss from the study sample due to processing error will be replaced to maintain the sample size. [14]

Software: The sample size was calculated using GPower version 3.1.9.2 [15]

The sample size was determined using the information from earlier research. Based on the computation, a minimum of 10 teeth should be included in the sample size for each group. The study included thirty permanent human single-rooted teeth that were extracted for periodontal reasons and had straight, patent root canals with mature, full root apices that showed no anatomic variation. Teeth with fractures, immature apexes, root resorption, caries or root fillings, and calcification were excluded from this study. Also, teeth with apical diameters larger than size 15 or with an altered apex were not included in the study.

Tooth preparation:

The samples were stored in distilled water after being cleaned to get rid of organic material and calculus, and then rinsed with sodium hypochlorite. To create segments that were all the same length, each sample was decoronated with a root length of 14 mm. In teeth with intact root apices, patency of apical foramina was standardized using size 10 stainless steel K-Files (Dentsply Maillefer). The parallel radiograph technique was utilized to assess all teeth from the buccolingual and mesiodistal angles (10 mA, 70 kvp, and 0.4 s) (Alexandria, Egypt). [8]

Randomization technique

Teeth were given numbers from 1 to 30, and then a computer-generated list of random numbers was used to allocate each tooth to one of the four groups (I, II, and III) .

I	12	6	2	18	25	14	28	30	8	24
II	20	3	21	9	15	5	10	17	23	19
III	7	26	1	11	29	16	4	27	13	22

Root canal instrumentation

Teeth were randomly assigned into three groups. Groups I, II, and III were instrumented with ProTaper Next files (PTN), one shape (OS) file, and an XP shaper file, respectively. ProTaper Next files with the sequence X1, X2, and X3, which correspond to the sizes of 17/04, 25/06, and 30/07, respectively, were utilized in the PTN group. The files were rotated at a speed of 300 rpm and with torque values of 200 gcm. The OS file was used in the One Shape group with 400 rpm rotational speed and 400 gcm torque values with in and out movements without applying pressure. The instrument was taken out, cleaned, and the root canal was irrigated when there was apical resistance. The XP-endo Shaper file was rotated at 800 rpm with 1.0 Ncm torque after inserting the instrument's tip into the canal. Up and down gentle strokes were applied until the WL was reached. A 30-G needle was used to irrigate with

5 mL of 5.25% sodium hypochlorite during the preparation stage. After irrigating the canals for a minute with 17% EDTA, saline irrigation was used. The samples were stored at 37 °C and 100% relative humidity until they were needed.[10, 11]

Scanning electron microscopy preparation and examination

On the buccal and lingual surfaces of the root, two longitudinal grooves were made using a disc. Using a stainless-steel chisel, the roots were divided lengthwise into two parts. The sections were ready for investigation using scanning electron microscopy (SEM) at Alexandria University's Faculty of Science. The samples were dehydrated in solutions of ethanol with varying concentrations after being fixed for the first time in 4% formaldehyde and 1% glutaraldehyde. For analysis, the samples were sputter-coated with gold after being mounted on aluminum stubs using conductive paint.[16]

A thorough examination of the canal wall from the apex to the most coronal part was performed, and then, six SEM photomicrographs were obtained at a standard magnification of ×1,000 for debris evaluation and ×5,000 for smear layer evaluation at each third (coronal, middle, and apical).

The images were scored by three trained operators who were blinded to the preparation procedures.

Debris scoring was as follows: [1]

- Score 1: Clean root canal wall.
- Score 2: a few small agglomerations of debris.
- Score 3: many debris agglomerations covering less than 50% of the canal wall
- Score 4: more than 50% of the canal wall is covered by debris
- Score of 5: nearly complete root canal wall covered by debris

Smear layer scoring was as follows:[1]

- Score 1: All the dentinal tubules are open.
- Score 2: 25%–75% of the dentinal tubules are open.
- Score 3: A total of 25% of the dentinal tubules are open, with a homogeneous smear layer covering the canal wall.
- Score 4: No dentinal tubules are open; a homogeneous smear layer completely covers the canal wall.
- Score 5: A heavy, inhomogeneous smear layer covering the canal wall.

Statistical analysis

Scores for the smear layer and debris were recorded independently. For normally distributed quantitative variables, the F test (ANOVA) was used to evaluate the data, and for pairwise comparisons, the post hoc test (Tukey) was employed. A significance threshold of $P < 0.05$ was applied.

RESULTS

Scanning electron microscopy results:

Scanning electron micrographs of the three studied groups (Groups I, II, and III) show representative samples of the root canal dentinal surface at three different levels (coronal, middle, and apical). Compared with the other two groups, group I presented a rough dentinal surface with more debris; on the other hand, group III presented a smoother surface with almost no debris on the dentinal surface. (**Fig. 1**)

Higher magnification of the scanning electron micrographs (magnification ×5,000) revealed that group III had a smoother surface than did the other two groups, with patent dentinal tubules and no smear layer. (**Fig. 2**)

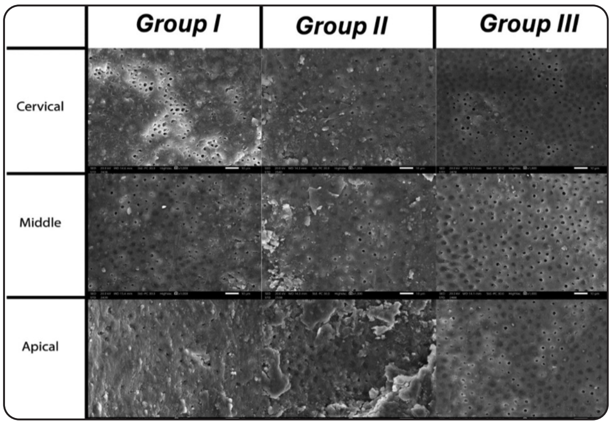

Fig. (1) Representative scanning electron microscopy (SEM) images of debris in the cervical, middle, and apical thirds of the three different groups. Group I (ProTaper Next files)- Group II (One shape (OS))-Group III (XP shaper file) (× 1000)

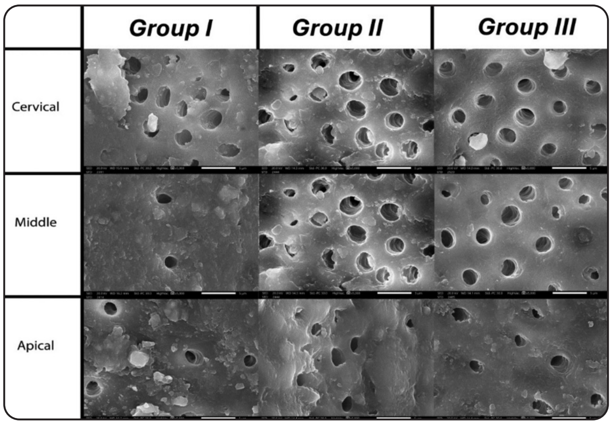

Fig. (2) Representative scanning electron microscopy (SEM) image of the smear layer in the cervical, middle, and apical thirds of the three different groups. Group I (ProTaper Next files)- Group II (One shape (OS))-Group III (XP shaper file) (× 5000)

Debris and smear layer scoring results

These results confirmed the scanning electron microscopic findings.

Table (1) compares the three studied groups according to debris scoring. There was a statistically significant difference in the debris score among the three systems (<0.001). The PTN group recorded 3.78 ± 0.55, one shape recorded 3.10 ± 0.77, and the XP-endo Shaper group recorded 1.36 ± 0.50. The XP-endo Shaper group presented the greatest degree of debris removal among the studied groups. Group I had higher debris scores than groups II and III. The bar graphs (Fig. 3) show the results of debris scoring among the three groups.

Table (2) shows a comparison between the three studied groups according to smear layer scoring. There was a statistically significant difference among the three groups in terms of smear layer score (<0.001). The PTN group recorded 2.61±0.78, one shape recorded 3.33±0.73, and the XP-endo Shaper group recorded 1.57±0.51. The XP-endo Shaper group presented the best smear layer removal among the studied groups. Group II had higher smear layer scores than groups I and III . The bar graph (Fig. 4) shows the results of smear layer scoring among the three groups.

TABLE (1) Debris scores for the three groups

	Group I (n = 18)	Group II (n = 21)	Group III (n = 14)	F	p
Debris					
Min. – Max.	3.0 – 5.0	2.0 – 5.0	1.0 – 2.0		
Mean ± SD.	3.78 ± 0.55	3.10 ± 0.77	1.36 ± 0.50	59.524*	<0.001*
Median	4.0	3.0	1.0		
Significance between groups	p_1=0.004*,p_2<0.001*,p_3<0.001*				

TABLE (2) Smear layer scores for the three groups

	Group I (n = 18)	Group II (n = 21)	Group III (n = 14)	F	p
Smear layer					
Min. – Max.	2.0 – 5.0	2.0 – 4.0	1.0 – 2.0		
Mean ± SD.	2.61 ± 0.78	3.33 ± 0.73	1.57 ± 0.51	26.751*	<0.001*
Median	2.50	3.0	2.0		
Significance between groups	p_1=0.006*,p_2<0.001*,p_3<0.001*				

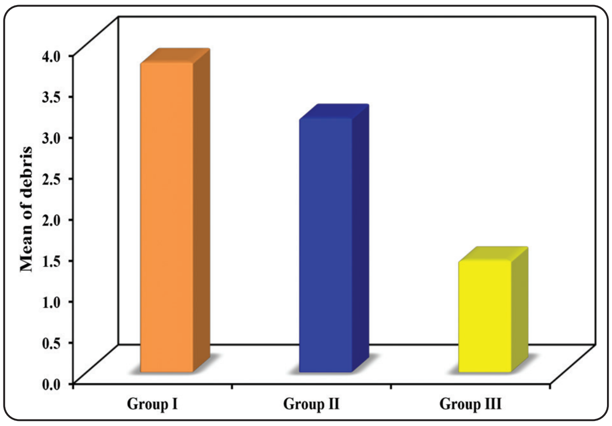

Fig. (3): Debris scores of the three different study groups

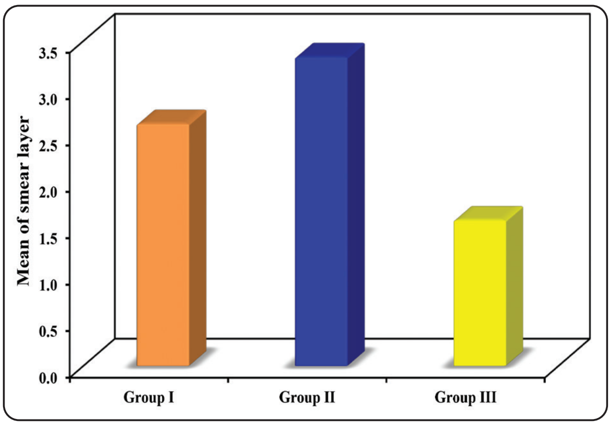

Fig. (4): Smear layer scores of the three different study groups

DISCUSSION

To the best of our knowledge, no information has been released comparing the ProTaper Next file system's cleaning and shaping capabilities to that of One Shape and XP shaper files. In this investigation, XP Shaper file and one-shape single file were compared to full-sequence ProTaper Next rotary file.

Instrumentation aims to provide a constant tapering preparation that preserves the anatomy of the canal, appropriate irrigation, full debridement, local medication application, and permanent root filling. Mechanical instrumentation is essential for the various treatments used to remove bacteria from the root canal.[17] The residual tissue and debris in the canal may have an impact on the filling quality of the root canal. They can serve as nutrients for bacteria, causing treatment failure. As a result, a method that can eliminate the remaining debris as much as possible should be identified.[18]

The ability of scanning electron microscopy (SEM) to differentiate between debris areas and the smear layer was taken into consideration when evaluating the cleaning efficacy of the three file systems. SEM also generates high resolution and magnified three-dimensional images. Large amounts of debris were visible at low magnification (1000x), minute details like the smear layer and dentinal tubules needed a higher magnification. [1]

In the current study, the XP-endo Shaper files performed better than other files in terms of debris and smear layer removal. This outcome can be explained by the fact that, when the file tip reaches the working length, the ProTaper full sequence file contacts and cuts the coronal and middle thirds of the canal, producing more debris and smear layers than those in the XP single file system.

Furthermore, smear layer removal in one-shape single file group was lower than that of protaper Next multiple file systems. This might be as a result of the shorter preparation times associated with using single file systems, like one shape file, which lowers the amount of irrigant that penetrates the canal and results in ineffective cleaning. [19] Moreover, the XP Shaper file's motion encourages the upward removal of debris along its flutes. The XP Shaper's exceptional cleaning capacity can be attributed to its flexible design, adaptable core, and snake-like shape, which allow it to expand and contract as it rotates inside the canal, resulting in a cleaner canal surface.[20]

The null hypothesis was rejected since there was a discernible difference between the experimental groups in terms of debris and smear layers on canal walls, and there was a statistically significant difference between the three groups regarding debris and smear layer scores.

CONCLUSIONS

The results of this study showed that the XP shaper files outperformed the other two file systems in the coronal, middle, and apical regions of the root canal when it came to removing smear layers. The ranks of smear layer removal by the various files showed that Group III surpassed Group II and Group I.

Declaration

Author declaration: There are no conflicts of interest for the writers.

Funding: The research described in this publication was not supported financially.

Ethics approval: The study was carried out in accordance with the Alexandria University Faculty of Dentistry's ethical principles for conducting human research, with approval number (Ethics Committee No 0883-02/2024) (IORG 0008839). .

Informed consent: Not applicable.

Availability of data and materials: The corresponding author can be contacted for access to all study data upon request.

Authors' contributions:

The current paper was conceived by ES, and it was validated through data curation, investigation, and resource management in addition to writing, revising, and editing the original draft and creating the visuals.

Data curation, research, resources, writing, preparation of the initial manuscript, visualization, and writing, reviewing, and editing of the work were all aided by OA.

Using statistical data, RA assessed the scoring results of the endodontic root canal therapy. Additionally, **RA** assisted with resource management, data curation, investigation, writing, original draft preparation, visualization, and writing, reviewing, and editing the paper.

HS contributed to the methodology of the SEM and interpreted the SEM photomicrographs, validation, data curation, investigation, resources, writing-original draft preparation, visualization, and writing-reviewing and editing of the paper**.**

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