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APICAL DEBRIS EXTRUSION AND ROOT CANAL CLEANLINESS USING SEVERAL ROTARY NICKEL TITANIUM FILES WITH DIFFERENT KINEMATICA IN ROUND AND OVAL CANALS

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KEYWORDS

Apically extruded debris, Canal wall cleanliness, NiTi instruments, Oval canals, Reciprocation, Rotation and round canals.

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ABSTRACT

Aim: This study was conducted to evaluate and compare the amount of apically extruded debris and canal wall cleanliness using different Ni-Ti instruments (ProTaper file F2, Twisted File 25 and Reciproc R 25) used in continuous rotation and reciprocating motion, in round and oval root canals. **Materials and Methods:** One hundred twenty extracted single rooted teeth were divided into two groups according to the cross section; 60 round and 60 oval cross section. Each group was subdivided into three subgroups according to the file system (20 ProTaper, 20 Twisted File and 20 Reciproc). Each subgroup was further divided into two divisions according to the motion used (10 rotation and 10 reciprocation). Teeth were mounted in glass vials through holes in the rubber stoppers. The glass vials were weighed before instrumentation. Root canal preparation was performed according to its assigned system according to the manufacturer's instructions, and sterile water was used as root canal irrigant. After instrumentation, the amount of apically extruded debris was evaluated by weighing the samples on the microbalance. Thereafter, roots were longitudinally divided for evaluation of smear layer by Scanning Electron Microscope (SEM). The data were tabulated and subjected to statistical analysis. **Results:** Reciprocating motion extruded more debris than continuous rotation motion. SEM examination revealed greater amount of smear layer in the oval cross section canal than round cross section canal. **Conclusion:** All instrumentation techniques and motions were associated with extruded debris. All instrumentation techniques and motions were not capable of completely preparing oval canals.

INTRODUCTION

The ultimate objective of root canal preparation is elimination of irritant and maintenance of healthy periapical tissues. One of the principal causes of postoperative pain (flare-ups) is the apical extrusion of irritants such as necrotic debris, dentinal particles and irrigating solutions during root canal preparation. Therefore, cleaning and shaping techniques and instruments that would minimize the extrusion of debris would help to reduce the incidence of such flare-ups [(1)].

Root canal preparation using either manual or rotary instruments always causes the formation of pulpal debris, smear layer and smear plugs which cover the whole root canal surface. One of the challenges facing clinicians is cleaning and shaping of root canals which may have complex morphology. Endodontic files regardless of their type and form produce a preparation with round outline which in most of the cases not coincide with the outline of the root canal. So incomplete cleaning is usually observed when the canal outline deviates from a round form as in roots with oval cross section [2].

By far the greatest number of commercially available files utilized to shape root canals are manufactured from nickel-titanium and mechanically driven in continuous rotation. Recently, reciprocating movement relieves stress on the instrument by special counterclockwise (cutting action) and clockwise (release of the instrument) movements. It should be appreciated that there are both advantages and disadvantages associated with utilizing continuous rotation versus reciprocation [3].

Therefore, this study was conducted to compare different rotary NiTi systems used in continuous rotation and reciprocating movements as regard the amount of apically extruded debris and canal wall cleanliness in round and oval canal.

MATERIALS AND METHODS

One hundred twenty extracted human teeth with single canal and of similar lengths were collected. All teeth were analyzed by digital radiography (Schick Tech Inc, Long Island City, NY) in the buccal and proximal directions to confirm non complicated root canal anatomy, single straight root canals, mature root formation, no signs of cracks, no internal and/or external resorption, no caries, no root calcification and no pulp stones. The soft tissue remnants and calculi on the external root surface were removed mechanically.

Standard access cavities were prepared by a high-speed hand piece and Endo access bur (Dentsply, Maillefer, Ballaigus, Sweitzerland). To achieve uniformity, the canal patency was controlled with a size 10 K-file (Dentsply, Maillefer, Ballaigus, Sweitzerland). The working length of each canal was determined as 1 mm short of the length of a size 15 K-file (Dentsply, Maillefer, Ballaigus, Sweitzerland) that was visible at the major diameter of the apical foramen.

By means of bidirectional radiographs [4] (radiographs were taken in buccolingual and mesiodistal directions), root canals were categorized as oval or circular-shaped canals. The space corresponding to the root canal lumen was measured 5 mm from the apex; when the buccolingual diameter was 2-2.5 times larger than the mesiodistal diameter, the canals were classified as oval-shaped. For round-shaped canals; the mesiodistal diameter had to be similar to the buccolingual diameter. Teeth were divided into 60 with round cross section (Group A) and 60 with oval cross section (Group B).

Empty glass vials were weighed using Analytic Balance (Radwag, Rondon, Poland) taking three consecutive readings and the average value was recorded. The teeth were mounted through a hole in the rubber stopper of glass vials before canal instrumentation. The rubber stopper with the tooth was then fitted into the mouth of a glass vial. The apical part of the root was suspended within the vial, which was used as a collecting container for apical debris and irrigant extruded through the foramen of the root. The glass vial was vented with a 25-gauge needle alongside the rubber stopper during instrumentation to equalize the air pressure inside and outside the apparatus [1].

Each group was sub divided into three subgroups according to the file system used during root canal instrumentation (n=20), as follow:

Subgroup 1: Root canals were instrumented with Pro-Taper system (file F2) (Dentsply, Maillefer, Ballaigus, Switzerland).

Subgroup 2: Root canals were instrumented with twisted file system (file 25) (SybronEndo, Orange, CA, USA).

Subgroup 3: Root canals were instrumented with Reciproc system (R25) (VDW, Munich, Germany).

Each sub group was further divided into two divisions according to motion used during root canal instrumentation (n=10), **Division T**: Rotation and **Division R**: Reciprocation.

To avoid variation and eliminate baises, the cleaning, shaping and irrigation of all samples were completed by the same trained operator. In all experimental groups, an electric and torque controlled endodontic motor (Sirona Dental Systems GmbH, Bensheim, Germany) was used according to the manufacturer's instruction. Once the instrument had negotiated to the working length and had rotated freely, it was removed. Each instrument was used to prepare one canal only. After 3 pecks, all instruments were removed from the canal and the debris was cleaned from the flutes and root canals were irrigated with 5 mL of sterile water using a 27 gauge needle in disposable plastic syringe. The needle tip was inserted passively 1mm shorter than the working length and never allowed to bind as the irrigant was being deposited into the canal. As soon as full working length has been reached, the instrument was withdrawn from the root canal.

The apically extruded debris evaluation:

Debris adhering to the outer surface of the root apex was collected by washing of the apex with an additional 2 milliliter of sterile water into the vial. The vials were stored in an incubator at 68°C for 5 days to evaporate the irrigant from the vials [1]. Thereafter, vials with dry debris were weighed on an Analytic Balance (Radwag, Radom, Poland). Three consecutive readings were noted for each sample and the average value was recorded. The amount of apically extruded debris was calculated by subtracting the weight of the preweighed empty vials from the weight of vials after instrumentation and collection of debris [1].

Smear layer evaluation:

Root canals of each instrumented tooth were dried with paper points. The crown of each tooth was removed at the level of the cement-enamel junction in order to obtain root segments of approximately 12 mm in length. Roots were split longitudinally in a bucco-lingual direction by making two grooves on the buccal and lingual aspects of each root with a low speed diamond disk. The grooves were not deep enough to enter the canals and a plastic instrument was then used to section the root into two halves. For each root, the half containing the most visible part of apex was conserved and coded [5].

The cleanliness (smear layer) of each canal was evaluated in the middle third (The long diameter of oval shaped canals is more frequently seen at 5 and 10 mm distance from the apex, which logically would indicate that these areas are more prone to be out of reaching the files) under Scanning Electron Microscope (SEM) (Quanta 250 FEG, FEI Company, Netherlands) at 1000 X. The evaluation was performed in a blind manner by one observer who was not informed of the nature or purpose of the investigation. Evaluation was repeated twice for the first 20 specimens to insure intra examiner consistency.

Samples were evaluated according to the following scoring system [6]**:**

- Score 1: no smear layer, orifice of dentinal tubules patent.
- Score 2: 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.

Data about the amount of apically extruded debris measurements, evaluation and scores of canal wall cleanliness were collected, tabulated and statistically analyzed.

Statistical Analysis

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Apical extrusion data showed parametric (normal) distribution while smear layer data showed non-parametric (not-normal) distribution.

For parametric data; One-way ANOVA followed by Turkey's post hoc test was used to compare between more than two non-related samples. Independent sample t-test was used to compare between two non-related samples.

For non-parametric data; Kruskal Wallis test was used to compare between more than two non-related samples. While Mann Whitney test was used to compare between two non-related samples.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows (SPSS Inc, Chicago, IL).

RESULTS

1. Apical debris extrusion :

i. **Comparison between groups (Round and Oval cross section):**
Regardless of system or motion used for instrumentation, preparation of oval root canals resulted in more debris extrusion than round root canals (table 1).

ii. **Comparision between divisions (Reciprocation versus rotation):**
Regardless of root canal cross section and system used for instrumentation, reciprocation motion produced a statistically significant more debris extrusion than rotation motion (table 1).

iii. **Comparison between subgroups (Different systems used for instrumentation):**

In round cross section canals, regarding rotation motion, Twisted File showed the least debris extrusion followed by ProTaper file with no statistically significant difference between them. While Reciproc file showed the highest debris extrusion. However, there was no statistically significant difference between systems when used in reciprocation motion.

In oval cross section canals, prepared by either rotation or reciprocation motion showed a statistically significant difference between systems used, as Reciproc file showed the least debris extrusion followed by Twisted File while ProTaper showed the highest debris extrusion (table 2).

Collectively Reciproc file showed the least debris extrusion followed by Twisted File while ProTaper showed the highest debris extrusion.

Table (1): *The mean, standard deviation (SD) values of apically extruded debris of different cross sections and different instrumentation motions.*

variables	Subgroup 1 (ProTaper)					Subgroup 2 (TF)					Subgroup 3 (Reciproc)				
	T(rotation)		R(reciprocation)		P – value	T		R		P- value	T		R		p- value
	Mean	SD	M	SD		M	SD	M	SD		M	SD	M	SD	
Group A (round)	0.0299	0.0018	0.0328	0.0021	0.004*	0.0288	0.0018	0.0342	0.0019	≤0.001*	0.0314	0.0012	0.0347	0.0018	≤0.001*
Group B (oval)	0.0522	0.0014	0.0589	0.0031	≤0.001*	0.0500	0.0011	0.0530	0.0019	≤0.001*	0.0415	0.0022	0.0481	0.0020	≤0.001*
P- value	≤0.001*		≤0.001*			≤0.001*		≤0.001*			≤0.001*		≤0.001*		

Table (2): *The mean and standard deviation (SD) values of apically extruded debris with different file systems.*

Variables	Debris apical extrusion							
	Group A (round)				Group B (oval)			
	Division T (rotation)		Division R (reciprocation)		Division T		Division R	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Subgroup 1 ProTaper	0.0298^{b}	0.0018	0.0328^{a}	0.0021	0.0522^{a}	0.0014	0.0589^{a}	0.0031
Subgroup 2 Twisted File	0.0288^{bc}	0.0018	0.0342^{a}	0.0019	0.0500^{b}	0.0011	0.0530^{b}	0.0019
Subgroup 3 Reciproc	0.0314^{a}	0.0012	0.0347^{a}	0.0018	0.0415^{c}	0.0022	0.0481^{c}	0.0020
P-value	0.005*		0.102ns		≤0.001*		≤0.001*	

2. Root canal wall cleanliness :

i. ***Comparison between groups (Round and oval cross section):***

Regardless of system or motion used for instrumentation, root canals with oval cross section showed a statistically significant more smear layer than root canals with round cross section (table 3).

ii. ***Comparison between divisions (Reciprocation versus rotation motion):***

With all systems used for root canal preparation there was no statistically significant difference between rotation and reciprocation in smear layer values in both round and oval cross section of root canals (table 3).

Table (3): *The mean, standard deviation (SD) values of smear layer of different cross sections and different motions after instrumentation.*

variables	Subgroup 1 (ProTaper)					Subgroup 2 (TF)					Subgroup 3 (Reciproc)				
	T		R		P- value	T		R		P- value	T		R		P- value
	Mean	SD	M	SD		M	SD	M	SD		M	SD	M	SD	
Group A (round)	2.70	0.48	2.70	0.48	1ns1	2.50	0.71	2.60	0.52	0.912ns	2.40	0.52	2.40	0.52	1ns
Group B (oval)	3.80	0.42	4.10	0.32	0.315ns	3.70	0.48	3.90	0.32	0.481ns	3.60	0.52	3.70	0.48	0.739ns
P- value	≤0.001*		≤0.001*			≤0.001*		≤0.001*			≤0.001*		≤0.001*		

iii. Comparison between subgroups (Different systems used for instrumentation):

Regardless of root canal cross section and motion used during instrumentation, there was no statistically significant difference between root canals prepared by ProTaper, Twisted File and Reciproc. Root canals prepared by Reciproc showed the least smear layer score followed by Twisted File and ProtTaper file (table 4).

Table (4): *The mean and standard deviation (SD) values of smear layer amount of different file systems.*

Variables	**Smear layer amount**							
	Group A (Round)				**Group B (Oval)**			
	Division T		**Division R**		**Division T**		**Division R**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Subgroup1 (ProTaper)	2.70	0.48	2.70	0.48	3.80	0.42	4.10	0.32
Subgroup 2 (Twisted File)	2.50	0.71	2.60	0.52	3.70	0.48	3.90	0.32
Subgroup 3 (Reciproc)	2.40	0.52	2.40	0.52	3.60	0.52	3.70	0.48
P-value	0.445ns		0.399ns		0.631ns		0.086ns	

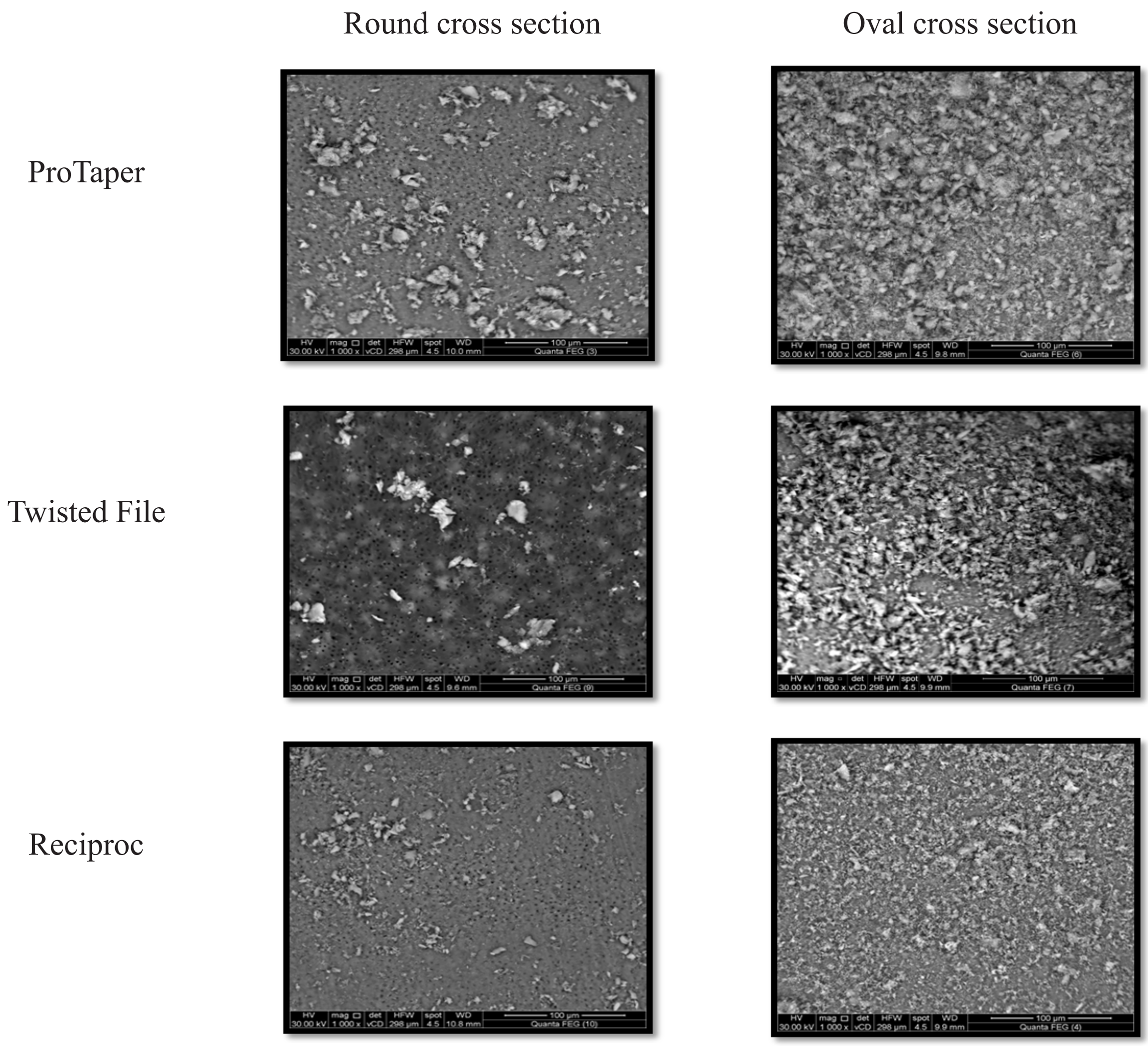

Fig. (1) Showing SEM of root canal samples prepared with the tested files in rotation motion (1000 X).

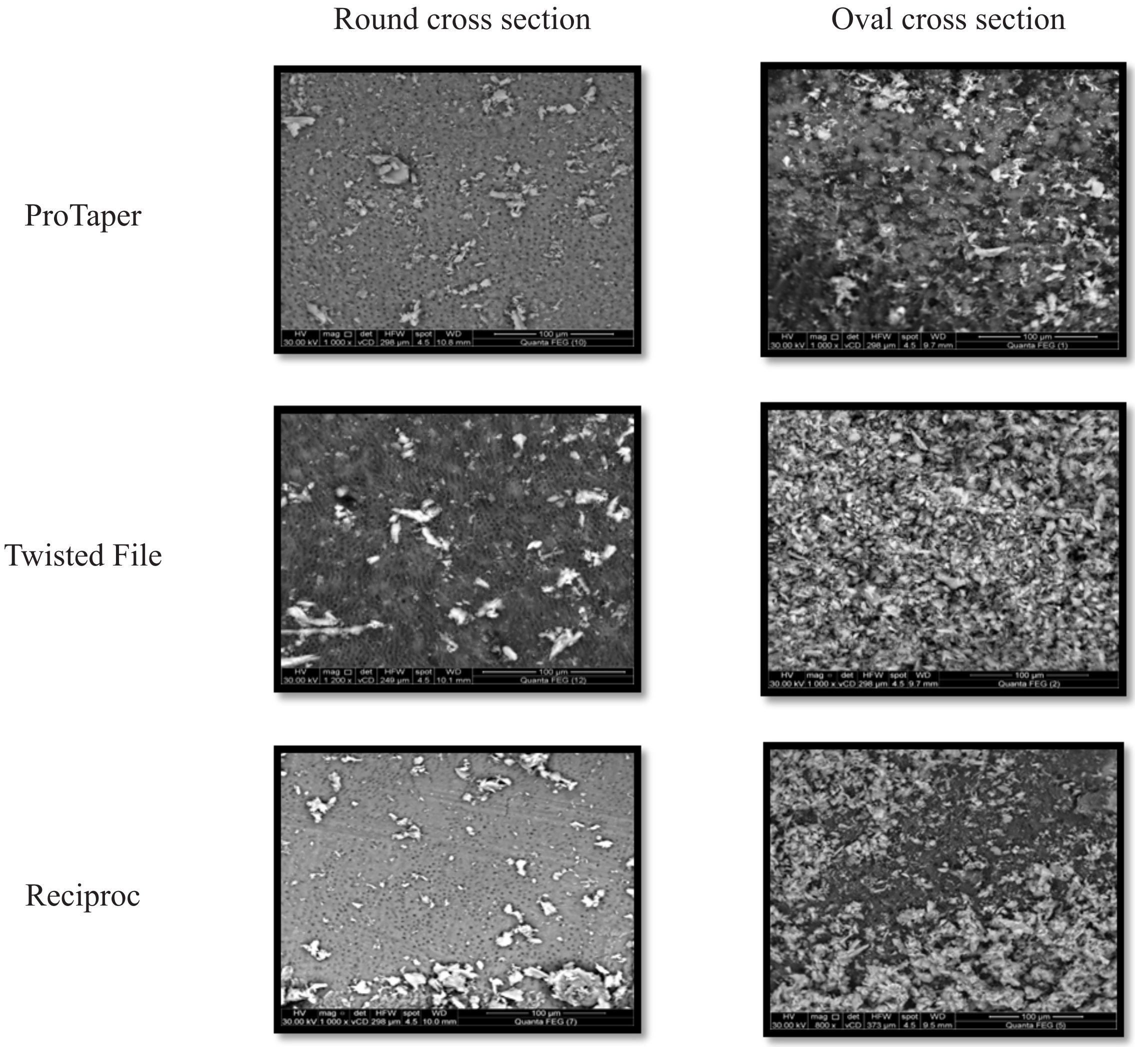

Fig.(2): Showing SEM of root canal samples prepared with the tested files in reciprocating motion (1000 X).

DISCUSSION

The extrusion of debris, bacteria and irrigant beyond the apex may have undesired consequences such as induction of inflammation, postoperative pain and delay of periapical healing (7).

The use of irrigants selected during routine endodontic procedures, such as Sodium Hypochlorite (NaOCl), seems more logical and reflects clinical conditions more precisely. However sodium crystals cannot be separated from debris and might adversely affect the reliability of the experimental methodology. Therefore, distilled water was used as an irrigant to prevent misleading weight measurements as a result of possible crystallization of sodium hypochlorite solution (8).

Thorough debridement of the root canal system is considered the most important step in endodontic therapy to reduce bacterial numbers and to prepare canals to a uniform shape for obturation. With techniques currently available, complete debridement is generally not possible because of the intricate anatomy of the root canal system [2].

The long diameter of oval shaped canals is more frequently seen at 5 and 10 mm distance from the apex, which logically would indicate that these areas are more prone to be out of reaching the files. So this area at the middle part of the root was tested under SEM in this study.

In general, the design of rotary files along with the motion used tends to direct debris toward the canal orifice, packing the dentinal debris into the flutes of the instruments and forcing them outside toward the orifice, thus avoiding their compaction in the root canal. Variability has been observed between different rotary systems in term of debris extrusion. This thought to be caused by differences in cross section and cutting blade design of a particular system as well as taper, tip, configuration, concept of use, flexibility, alloy, and number of files, kinematics and cutting efficacy [9].

The three tested systems were chosen due to their difference in metallurgical structure. ProTaper F2 file manufactured from conventional Ni-Ti alloy. Twisted File 25, manufactured by plastic deformation, a process similar to the twisting process that is used to produce stainless steel K-files. According to the manufacturer, a thermal process allows twisting during a phase transformation into the so-called R-phase of nickel-titanium. Reciproc, M-wire alloy is the main characteristic of this instrument. The M-wire alloy increases flexibility and improves its resistance to cyclic fatigue [10].

According to the results of this study, regardless of system or motion used for instrumentation, preparation of oval canals showed a statistically significant more debris extrusion than round root canals. The shape and size of root canal significantly influences the amount of apically extruded debris [11]. As rotary instruments tend to create round preparation in oval canals which may result in more cutting of dentin and more extrusion of debris than round canals[8].

The present study showed no statistically significant difference in debris extrusion between ProTaper F2, Twisted File 25, and Reciproc R 25. The highest mean value was found in ProTaper file followed by Twisted File. While the least mean value was found in Reciproc file. These results may be due to the design features of each file, as ProTaper file has a convex triangular cross section and small ship space which might have enhanced transportation of debris apically [12], while Twisted File has a triangular cross section with larger chip space and Reciproc file has identical s-shaped cross section with sharp cutting edge with large chip space [13]. A smaller cross section creates more space between the instrument and the canal walls, because of their small core diameter. Reciproc instruments are characterized by an extra space between the canal walls and the instrument, which allows more debris collection and facilitates easier removal capability [14]. In accordance with our results Cicek et al [15] found no significant difference between Twisted File and ProTaper. In contrary Burkelin et al [16] reported that Reciproc extruded more debris than ProTaper, the difference may be related to the type of motion used during instrumentation.

According to the results of this study, regardless of root canal cross section and system used for instrumentation, reciprocating motion produced a statistically significant more debris extrusion than rotation motion. Continuous rotation may improve coronal transportation of dentin chips and debris by acting like a screw conveyer [3].

Based on the results of this study, root canals with oval cross section showed a statistically significant more smear layer than root canals with round cross section. Rotary Ni-Ti systems are unable to produce optimal preparation of oval shaped canals as a result of the large difference between instrument designs and root canal geometry [17]. Rotary instruments were reported to prepare a circular bulge, leaving unprepared lingual and buccal extensions [2]. Such unprepared areas might also be packed with dentin chips generated and pushed therein by rotary instruments. Packed debris can interfere with the quality of the obturation and infected root canals can harbor bacteria to serve as a potential source of persistent infection [18].

According to the results of our study, there was no statistically significant difference in smear layer between canals prepared by ProTaper file, Twisted File and Reciproc file. The highest mean value was found in ProTaper followed by Twisted File while the least mean value was found in Reciproc file. This result may be due to the design features of the file, as Reciproc file has a deep groove that allows more debris transportation during action. Sharma et al [19] reported that the cleaning efficacy of Twisted File is better than ProTaper file because Twisted File has a triangular cross-section that enhances flexibility and generates less friction inside the canal walls due to a lack of peripheral lands. It has a variable pitch that minimizes the “screw-in” effect, allows debris to be effectively channeled out of the canal due to flute widths and flute depths that become accentuated toward the handle. In addition, Fayyad et al [20] stated that ProTaper removes more tooth structure than Twisted File as ProTaper has sharp cutting edges and multiple tapers within the shaft.

In the present study, there was no statistically significant difference between rotation and reciprocation in smear layer value. The reciprocating motion has an advantage in fracture resistance but in cleaning and cutting efficiency has no advantage when compared with rotation motion [14]. In agreement with our results, Stern et al [13] evaluated the effect of instrumentation kinematics on cutting efficacy and reported that the use of single ProTaper F2 Universal instruments with the reciprocating motion removed a similar dentine volume to that produced when using a full sequence of the same instrument with rotational motions.

CONCLUSION

Under the circumstances of this study, the following conclusions could be drawn: All endodontic rotary instruments tested extruded apical debris.

Rotation motion was associated with less debris extrusion compared to reciprocating motion.

Complete cleanliness was not achieved by any of the techniques and instruments investigated.

All endodontic rotary instruments tested were unable to produce optimal cleaning of oval shaped root canals as a result of the large difference between instrument design and root canal geometry.

The reciprocating motion has no advantage in cleaning efficiency when compared with rotation motion.

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