



Evaluation of the amount of apically extruded debris using different root canal instrumentation systems

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Abstract

The purpose of this study was to evaluate the amount of apically extruded debris using 5 types of nickel–titanium endodontic instruments (Hand ProTaper, Rotary ProTaper, Rotary Mtwo, RECIPROC and WaveOne). Seventy-five freshly extracted mandibular premolar teeth were used in this study. All teeth were shortened to a length of 14mm. The specimens were randomly divided into five groups (each group containing 15 samples) according to the type of instrumentation systems used. Group I: instrumented by hand ProTaper system (Hand technique). Group II: instrumented by rotary ProTaper system. Group III: instrumented by rotary Mtwo system. Group IV: instrumented by single file RECIPROC system. Group V: instrumented by single file WaveOne system. Debris extruded from the apical foramen was collected into pre-weighed glass vials. The difference between the weights of vial (pre-weight and post-weight) represented the weight of debris extruded from apical foramen during canal preparation. The results showed that all groups induced extrusion of debris, Mtwo group (III) has statistically the lowest mean value of apically extruded debris in comparing with all other groups, followed by rotary ProTaper (II), hand ProTaper (I), and WaveOne (V) groups respectively. While the RECIPROC group (IV) has statistically highest mean value.

Keywords: Apical extrusion, Rotary systems, Single-file systems, NiTi instruments.

Introduction

Root canal preparation is one of the most important stages in endodontic treatment. It includes mechanical cleansing by instruments and the use of irrigants. During the procedure, there is always the possibility of pulp tissue fragments, dentine chips, necrotic tissue, microorganisms, and intracanal irrigants being extruded beyond the apical foramen even when the WL is controlled. The extruded material referred to as ‘worm of necrotic debris’ has been related to periapical

inflammation and postoperative flare-ups. A thorough control of the WL may decrease this risk, but nevertheless any extrusion of debris may potentially cause postoperative complications such as flare-ups^(1,2). Flare-up is described as the occurrence of pain, swelling, or the combination of both during or after completion of root canal therapy. This phenomenon is also called inter appointment emergency. Occurrence of inter-appointment flare-up is extremely undesirable for patients; proper

measures should be employed for reducing apical extrusion of infected debris⁽³⁾.

During the last decade, root canal preparations with rotary nickel–titanium instruments have become popular. Because canal preparation with rotary nickel–titanium systems remains significantly more centered in the root canal, this results in less transport of materials than hand instruments filing with stainless steel files⁽⁴⁾. In the progressive ProTaper system, the shaping files have an increasing taper from tip to coronal, whereas the finishing files have a decreasing taper. It has been claimed that the increasing taper instruments have enhanced flexibility in the middle region and at the tip, and that the decreasing taper instruments provide larger taper in the important apical region but make them stiff⁽⁵⁾. Mtwo system is another full rotary nickel–titanium system. It has basic sequence and shaping sequence. Mtwo is unlike other modern nickel–titanium systems, Mtwo is used with “single-length technique”, and all the instruments are taken to the full WL⁽⁶⁾. As entire canal length is approached at the same time, this technique has also been called “simultaneous technique”⁽⁷⁾.

Recently, reciprocating system was introduced. RECIPROC and WaveOne files are able to completely prepare root canals with only one instrument. These files are made of a special nickel–titanium alloy called M-wire that is created by an innovative thermal treatment process. The benefits of this M-wire alloy are increased flexibility and improved resistance to cyclic fatigue of the instruments⁽⁸⁾. The RECIPROC and WaveOne files are used in a reciprocal motion that requires special automated devices⁽⁹⁾. Many researchers found that instrumentation techniques produce some debris extrusion^(10,11,12,13). This

can induce inflammation within the periapical area; therefore, instrumentation technique that causes less extrusion of debris is more desirable⁽¹⁴⁾. The aim of this study was to evaluate the apically extruded debris by using different instrumentation techniques.

Materials and Methods

Seventy-five freshly extracted sound mandibular premolar teeth with straight root were selected for this study. Teeth, which had immature apices, calcified canals, root fracture, or crack were excluded from the study. The roots would be 14mm in length. The roots with mature centrally located and patent apical foramen (# 15 K-file could pass through the apex with resistance) were selected for this study. For all roots # 20 K-file was inserted passively to full WL, and couldn't pass beyond the WL through the apical foramen.

Sample preparation:

After extraction, all selected teeth were cleaned from soft periodontal tissue by periodontal curette, and immersed in 2.5% NaOCl for one hour. Then, the root surfaces were verified with a magnifying eye lens and light cure device for any visible cracks or fractures. Teeth were then stored in normal saline with daily change till the time of use⁽¹⁵⁾. To facilitate instrumentation, and eliminate any variables in access preparation, all teeth were decoronated by using a diamond disc under copious water to establish a uniform length of 14mm^(16,17). Then, all roots were measured using digital caliper.

The specimens were randomly divided into five groups (each group containing 15 samples) according to the type of instrumentation systems used:

1. Group I: 15 samples were instrumented by hand ProTaper system (Hand technique).
2. Group II: 15 samples were instrumented by rotary ProTaper system (full rotary NiTi technique).
3. Group III: 15 samples were instrumented by rotary Mtwo system (full rotary NiTi technique).
4. Group IV: 15 samples were instrumented by single file RECIPROC system (reciprocating technique).
5. Group V: 15 samples were instrumented by single file WaveOne system (reciprocating technique).

Method of sample fixation and debris collection:

All collecting vials were coded numerically and weighed with electronic balance. This is called the pre-instrumentation weight. The vials were stored in the desiccator that contained CaCl₂ until used⁽¹⁸⁾. The method used for debris collection was carried out as described by Myers and Montgomery⁽¹⁹⁾. A flask was inserted in the hole of a specially designed rectangular wood base that give fixation to the flask during instrumentation. Each vial was inserted inside the flask to avoid any contamination during instrumentation. Each root was inserted inside rubber stopper of each vial (in the center) (Fig. 1). Then, the flask was coated from the external surface with rubber dam material and ligature with floss. Finally, a vented needle (25-gauge) was inserted through the rubber stopper to equalize the pressure inside and outside of vials.

Preparation of canals:

The sequences used in this study were done according to the manufacturer's instructions for each system. All canals prepared to MAF # 40. Disposable plastic syringe 3ml with

27-gauge needle was used for irrigation in this study. The needle tip was inserted passively and never allowed to bind as the irrigant was being slowly deposited into the canal and never allowed to reach more than 2mm from the WL (needle tip wasn't passed more than 11mm inside canal)^(18,20,21). After each file # of the (hand and rotary files) or after three pecking motion of the (reciprocating files), the file was removed from the canal to clean the flutes from debris to prevent clogging of files during instrumentation and the canal was irrigated with 1ml of DW. The canal remain patent by insertion # 15 K-file⁽¹⁵⁾. When the instrumentation was completed, 1ml of DW was used as final flushing to clean the remnant debris inside the canal^(16,22,23).

Group I: Hand ProTaper instruments were used according to the manufacturer's instructions using rotational movement in our sense exerting sufficient pressure at apical level. HPT file was engaged dentin lightly by rotating the handle CW until the file just snug, then disengaged the file by rotating the handle CCW, after that the dentin was cutted by rotating the handle CW while simultaneously withdrawal of the file. Handle motion was repeated until desired length was achieved. The canals were instrumented to MAF # F4/.06. The instrumentation sequence was (SX.S1,S2,F1,F2,F3, and F4).

Group II: Rotary ProTaper instruments were used according to the manufacturer's instructions using (Endo-Mate motor) at constant speed 300 rpm. The instrumentation was completed in crown down manner using gentle in and out motion. The canals were instrumented to MAF # F4/.06. The instrumentation sequence of RPT

NiTi files was used as the same as the sequence of HPT NiTi files.

Group III: Rotary Mtwo instruments were used according to the manufacturer's instructions using (Endo-Mate motor) at constant speed 280 rpm. The instrumentation was completed in full-length technique using gentle in and out motion. The canals were instrumented to MAF # 40/.06. When full WL was reached, the next instrument in the sequence was used. The instrumentation sequence was started with # 10/0.04 file, # 15/0.05 file, # 20/0.06 file, # 25/0.06 file, # 30/0.06 file, # 35/0.06 file, and end with # 40/0.06 file sequentially. Each instrument was used to full WL.

Group IV: A R40/.06 RECIPROC file was used in a reciprocating motion according to the manufacturer's instructions using (SILVER[®] RECIPROC[®] endo motor). The silicon stopper was set on the RECIPROC file at 2/3 of WL. Then, the file was introduced in the canal with a slow in-and-out pecking motion without pulling the instrument completely out of canal. After three in-and-out movements, the RECIPROC file was pulled out of the canal to clean the flutes, and the canal was irrigated with 1ml of DW. The RECIPROC file was used until it had reached 2/3 of the WL as indicated by stopper on the file. Then the file was reused in the same manner until the WL had been reached.

Group V: A large WaveOne file (# 40/.08) was used in a reciprocating motion according to the manufacturer's instructions using (WaveOne[™] endo motor). The silicon stopper was set on the WaveOne file at 2/3 of WL. Then, the file was introduced in the canal

with a slow in-and-out pecking motion without pulling the instrument completely out of canal. After three in-and-out movements, the WaveOne file was pulled out of the canal to clean the flutes, and the canal was irrigated with 1ml of DW. The WaveOne file was used until it had reached 2/3 of the WL as indicated by stopper on the file. Then the file was reused in the same manner until the WL had been reached.

Collection of debris and storage of vials:

On completion of the root canal preparation, the root was separated from collecting vial where the root apex was washed with 1ml of DW in the collection vial ^(22,24). Then the vials were placed in dry-heat oven at 110°C and were checked every half hour until the vials appeared dry ⁽¹⁸⁾, after that the vials were removed from the oven and placed in a dry sealed desiccator which contains CaCl₂ crystals for at least 24 hours before beginning weighing the vials to absorb the moisture ^(16,18,25) (Fig. 2). The vials were removed from desiccators and weighed daily with an electronic balance with an accuracy of (0.00001g), until three consecutive weights with a difference of < 0.00002g were obtained for each vial, and the mean value was calculated, this is called the mean post-instrumentation weight ^(21,23). The pre-instrumentation weight was subtracted from the post-instrumentation weight of each vial and the difference was recorded as the weight of the extruded debris ^(19,23,26).

Results

According to the results of this study, all groups induced extrusion of debris with different values, Table (1) and (Fig:3). Mtwo group (III) showed the lowest mean value of apically

extruded debris (AED) in comparison with other groups followed by RPT (II), HPT (I), and WaveOne (V) groups respectively. While the RECIPROC group (IV) has a highest mean value. Analysis of variance (ANOVA) test showed a very highly significant difference among groups, Table (2).

The least significance difference test (LSD) showed that there were no significant differences between group I (HPT) and group II (RPT) ($P \geq 0.05$). Group I (HPT) showed a significant difference ($P < 0.05$) with group III (Mtwo) and group V (WaveOne), and showed a very highly significant difference ($P \leq 0.001$) with group IV (RECIPROC). Group II (RPT) showed a significant difference ($P < 0.05$) with group III (Mtwo) and group V (WaveOne), and showed a very highly significant difference ($P \leq 0.001$) with group IV (RECIPROC). Group III (Mtwo) showed a very highly significant difference ($P \leq 0.001$) with group IV (RECIPROC) and group V (WaveOne). Group IV (RECIPROC) showed a significant difference ($P \geq 0.05$) with group V (WaveOne), Table (3).

Discussion

During root canal treatment, debris and irrigant may extrude from the apical foramen and cause post-instrumentation pain or flare-up⁽²⁷⁾. When debris is pushed out of apical foramina, it will result in an Ag-Ab reaction. This reaction will generate an acute inflammatory reaction in the periapical tissues, and cause damage to the cell membrane resulting in prostaglandins release, and ultimately pain for patient^(11,28).

All roots were instrumented to the same # of MAF (40) to minimize group disparity^(24,35,36). Dryness of the NaOCl irrigant resulted in salt crystals which cannot be separated from the

cutting debris, so that NaOCl was replaced by DW to avoid such discrepancy in data collection^(15,29).

Instrumentation was confined to 1mm short of the apical foramen^(15,23) because WL 1mm short of canal length contributed to significantly less debris extrusion^(19,29,30). In order to minimize the variables through the study, all the canals were instrumented by one operator (the researcher)⁽²³⁾. The operator was shielded from seeing the root apex during the instrumentation procedure by a rubber dam that obscured the glass flask^(17,19). The vials were placed in the hot air oven at 110°C and were checked every half hour until the vials appeared dry then placed the vials in dry sealed desiccators contained on CaCl₂ to ensure that all moisture was eliminated from debris and prevent moisture absorption from the surrounding environment that may increase weight of vials in order to obtain the net weight of the vial.

The results of this study showed that all instrumentation systems produced AED with different values, that was in agreement with other studies^(17,20,23,31,32), whose found that all the instrumentation techniques extruded debris apically.

According to the results of this study, Mtwo system was significantly extruded the lowest mean of AED in comparing to other groups, and this result is in agreement with⁽²³⁾ who showed that Mtwo file produced the lowest mean of AED. According to the design features of Mtwo, the space for dentin removal is deeper at the back of the blade, and this may reduce the risk of apical extrusion⁽³³⁾. Moreover, the No. and depth of the flutes in the Mtwo instruments differ from tip to handle with shallower flutes near the tip (the instruments have a progressively widening space between blades from the tip toward the handle), which may

increase the capacity to remove debris coronally^(7,34,35).

When comparing the cross section of Mtwo with PT system, Mtwo instruments possess double-cutting edge and S-shaped geometry with minimum radial contacts and have a smaller cross-sectional area, which increases their flexibility and providing maximum space for dentin removal, as well as Mtwo has large and deep flutes for continuous upwards evacuation of dentine chips^(33,36), while PT instruments possess three sharp cutting edges and convex triangular cross section. So that, the debris space of PT was smaller than that of Mtwo and this may be lead to more AED from PT file than Mtwo file⁽³⁷⁾.

The shorter pitch design extruded less debris apically than longer ones, because the short pitch files have more threads along the same length than long pitch files. They have more grooves between the cutting edges, to entrap more debris during preparation, which in turn might reduce the quantity of debris extruded apically⁽³⁸⁾.

Mtwo system has gradual increasing of tapering while PT system has aggressive increasing of tapering, that result to a faster cutting and more debris in PT system. This agrees with the findings of^(17,23,29) whose results showed that PT extruded more debris than Mtwo.

The results of this study showed that HPT extruded non-significantly more debris than RPT and significantly more debris than Mtwo. This result agrees with the result of⁽³³⁾, but disagrees with^(31,39) whose results showed that RPT extruded more debris than HPT. The time of contact between the file and the root canal wall and rotational speed and torque may a factor that affect the amount of AED. The engine-driven rotary file (RPT and Mtwo) contacted the apical area for a lesser period of time and the rotational

speed and torque is fixed, whereas, the HPT file prepared the apical area for an extended period of time and the rotational movement of the file was an "operator controlled variable factor"^(39,40).

According to the results of this study, both reciprocating single-file systems (RECIPROC and WaveOne) extruded significantly more debris in comparing to all other groups. These results are in agreement with. **Adl et al.** and **Jindal et al.**^(14,29) suggested that reduction of debris extrusion in rotary preparation techniques is not due to the crown down technique but rather related to rotational motion of files. A probable explanation for this finding is that rotary motion tends to pull dentinal debris into the flutes of the file and directs it toward the coronal aspect of the canal^(30,40,41).

Ruddle⁽⁴²⁾, concluded from another study of **Blum et al.**⁽⁴³⁾ that continuous rotation compared to reciprocation, requires less inward pressure and improves capacity to auger the debris out of a canal. Since reciprocating movement is formed by a wider cutting angle and a smaller releasing angle, while rotating in the releasing angle, the flutes in reciprocating files will not remove debris but push them apically. Moreover, both WaveOne and RECIPROC techniques use a single file of greater taper (.06, .08) respectively, which directly reach the apex. In order to reach the apical WL, reciprocating instruments are used with force directed apically, which makes an effective piston to propel debris from a patent apical foramen. Since reciprocating instruments are used without any preliminary coronal enlargement. This results in a greater engagement of flutes and, consequently, more torque or applied pressure are needed. Also, the use of NiTi instruments sequence can be an

important factor in reducing the amount of apical transportation and avoiding to push debris by forcing instruments apically⁽⁴⁴⁾.

When comparing the two reciprocating single files, the RECIPROC file was extruded significantly higher amount of AED in comparison to WaveOne. This result is in agreement with⁽²³⁾. Cross section of WaveOne was changeable from tip (modified triangular convex with radial land) to (triangular convex with neutral rake angle) near shift, While the cross section of RECIPROC was one (S-shaped) with sharp cutting edges. So the instrument with radial land tends to burnish the cut dentine into the root canal wall, while the instrument with positive cutting edges seem to cut and remove dentine chips. So this may lead to increase of AED by RECIPROC more than WaveOne⁽⁴⁵⁾.

It must be emphasized that the result of this study should not be directly extrapolated to the clinical situation. In keeping with other authors, it may be considered that the persistence of residual pulp tissue in vital cases or the presence of periodontal tissue or even granulation tissue in chronic periodontitis could act as natural barriers and limit apical extrusion of debris and irrigant in vivo^(31,29).

Conclusions

1. All instrument types that were used in this study produced a measurable amount of apically extruded debris with different values.
2. Full rotary and hand instrumentation were associated with less debris extrusion compared with the use of reciprocating single-file system.
3. Rotary Mtwo nickel-titanium files caused the least extrusion of debris.

4. Reciprocating RECIPROC files caused the greater extrusion of debris than the other instruments.

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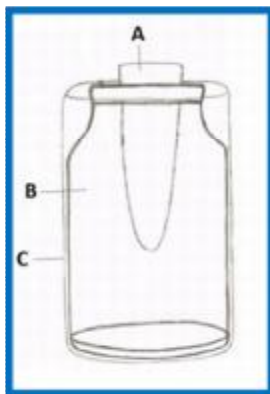


Fig. 1: Glass flask held vial and root.
A, root. B, glass vial. C, glass flask.

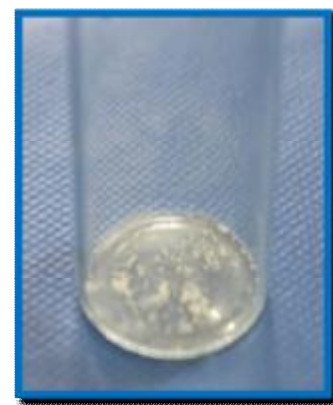


Fig. 2: Dry debris collected in a glass vial.

Table (1): The mean values of apically extruded debris (in mg) and SD for all groups.

Groups	N	Mean	SD	Min.	Max.
I	15	0.737	0.152	0.580	1.080
II	15	0.729	0.154	0.570	1.000
III	15	0.600	0.145	0.410	0.890
IV	15	0.999	0.212	0.790	1.380
V	15	0.869	0.210	0.610	1.160

Table (2): ANOVA test for mean of apically extruded debris among groups.

	Sum of Squares (SS)	df	Mean Square (MS)	F-test	P-value	Sig.
Between Groups	1.389	4	0.347	11.067	0.000	***
Within Groups	2.197	70	0.031			
Total	3.586	74				

Table (3): LSD test for multiple comparison between groups.

Groups	Mean Difference (I-J)	SE	P-value	Sig.	
Group I	Group II	0.00800	0.06469	0.902	NS
	Group III	0.13733	0.06469	0.037	*
	Group IV	-0.26200	0.06469	0.000	***
	Group V	-0.13200	0.06469	0.045	*
Group II	Group III	0.12933	0.06469	0.049	*
	Group IV	-0.27000	0.06469	0.000	***
	Group V	-0.14000	0.06469	0.034	*
Group III	Group IV	-0.39933	0.06469	0.000	***
	Group V	-0.26933	0.06469	0.000	***
Group IV	Group V	0.13000	0.06469	0.048	*

$P \geq 0.05$ Non-Significant (NS)

$P < 0.05$ Significant (S) *

$P \leq 0.01$ High Significant (HS) ** * $P \leq 0.001$ Very High Significant (VHS) ***

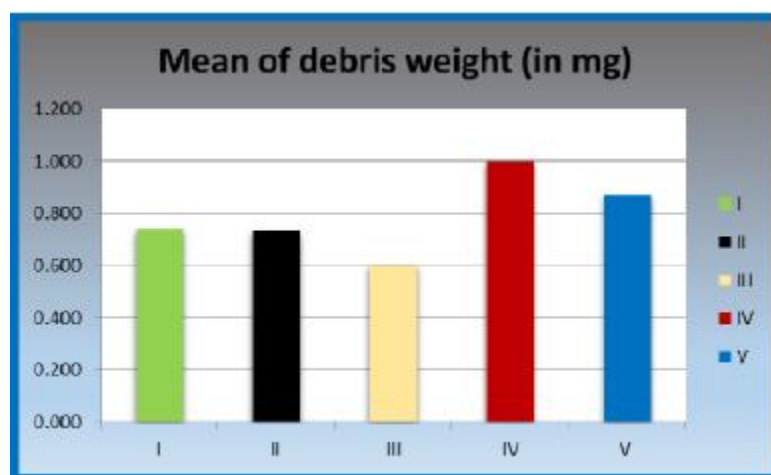


Fig.3: Bar chart graph for mean of apically extruded debris among five groups.