

Effect of Instrumentation Techniques and Kinematics on Apical Extrusion of Debris: An *In Vitro* Study

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ABSTRACT

Aim: To evaluate the effect of instrumentation kinematics on debris extrusion by comparing the amount of apically extruded debris after canal preparation using ProTaper next in continuous rotation as well as forward reciprocating motion and WaveOne gold in reverse reciprocating motion.

Materials and methods: We randomly divided ninety buccal roots of maxillary bicuspid with fully formed apices into three groups. After achieving the coronal access, the patency of the root canals was established with a size 10 K file. The canals were then instrumented using ProTaper next in continuous rotation or in a forward reciprocating motion and WaveOne gold in reverse reciprocating motion. Eppendorf tubes were used to collect the debris extruded through the apical foramen. The tubes were placed in a -80° freezer for 8 hours and then in a lyophilizer for 24 hours. The quantity of the apically extruded debris was assessed by subtracting the weights of Eppendorf tubes before and after instrumentation. The analysis was done using a one-way ANOVA test and the Bonferroni test to compare the groups.

Results: The mean weight of extruded debris with WaveOne gold in reverse reciprocation was significantly lower than ProTaper next in forward reciprocation and ProTaper next in continuous rotation (p value = <0.001).

Conclusion: WaveOne gold in reverse reciprocation was associated with a significantly lower amount of apical extrusion of debris than ProTaper next rotary files in forward reciprocation and continuous rotation.

Clinical significance: According to the results of this study, reciprocating instrumentation technique was associated with a less amount of debris extrusion compared to continuous rotation.

Keywords: Debris extrusion, Forward reciprocation, Kinematics, ProTaper next files system, WaveOne gold.

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INTRODUCTION

The primary success of endodontic therapy depends on the success of chemomechanical preparation of the root canal system. During the preparation, dentinal debris, irrigants, microorganisms, necrotic pulp tissue, and their by-products may extrude apically and may result in postoperative complications such as flare-up.¹ Studies have proved that debris extrusion is inevitable with the present instrumentation kinematics. Apical extrusion of debris varies according to the instrument type, kinematics, design, and the number of files used regardless of whether a sequential or a single file system is used. A common finding of the studies examining the amount of apically extruded debris was that the techniques that incorporate rotational motion generate less debris than push-pull instrumentation, and the crown-down technique has been associated with the least amount of debris extrusion compared with techniques involving a linear filing motion. Thus, engine-driven rotary systems have tended to extrude less debris than hand techniques.^{1,2} In 2008 Yared proposed a canal preparation technique using F2 ProTaper in reciprocation and this was shown to maintain the original root canal anatomy with least possible distortion.³

Therefore, the aim of the study was to assess the amount of apically extruded debris after canal preparation using WaveOne gold (WOG) in a reverse reciprocating motion and ProTaper next (PTN) file system in a sequential manner in rotation or forward reciprocating motion.

The null hypothesis was that there would be no significant difference in the mean weight of debris extruded apically between PTN in rotation or forward reciprocating motion and WOG in a reverse reciprocating motion.

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MATERIALS AND METHODS

Ninety freshly extracted human maxillary premolars with moderately curved buccal roots (curvature $<10^{\circ}$) with mature apices according to the Schneider method were selected for the study.⁴ The curvatures of the roots were determined using CBCT (CS 9300) 3D imaging software. The buccal cusps were flattened using carbide discs to maintain the tooth length to 20 mm. After achieving coronal access, the apical patency of the canals was confirmed using a K file of size 10 (Dentsply Maillefer, Switzerland). The apical width was approximated to a snug fit with a K file of size 15. The working length (WL) was achieved by deducting 1 mm from the apical foramen. Two mL of distilled water was used as an irrigant during instrumentation. Irrigation was done using a 27-gauge side vented needle, which was introduced into the canal without resistance.⁸

Myers and Montgomery's experimental model (1991) was used to assess the extruded debris.⁵ The Eppendorf tubes were

pre-weighed using the analytical balance (Sartorius-Germany) having an accuracy of 10^{-4} g. Before weighing, the teeth were inserted through the orifice made on the stopper of Eppendorf tubes, until the cemento-enamel junction (CEJ) was 1–2 mm above the stopper. This assembly was fitted onto a glass vial and a rubber-dam sheet was used to check seepage of over-flowing irrigant during irrigation. The samples were randomly divided into three groups as follows:

Group I PTN-R—ProTaper Next in Continuous Rotation ($n = 30$)

ProTaper next files (Dentsply Maillefer, Switzerland) were introduced into the canal in the following order using a torque-controlled endodontic motor (X-Smart plus, Dentsply Maillefer, Switzerland) at a speed of 300 rpm and a torque of 2.5 N cm. X1 file (17/0.04) followed by X2 file (25/0.06) was used in a brushing outstroke motion till the working length. During instrumentation the canals were irrigated with distilled water and K-file of size 10 was used to confirm patency.

Group II PTN-FR—ProTaper Next in Forward Reciprocation ($n = 30$)

The instrumentation sequence was similar to that of group I. The files were used in a forward reciprocating motion (150° clockwise and 30° counter-clockwise) using a torque-controlled cordless endodontic motor (Endomax, Dentamerica) at a speed of 300 rpm and a torque of 2.5 N cm.

Group III WOG—WaveOne Gold in Reverse Reciprocation ($n = 30$)

A reciprocating WaveOne gold file having a size 25 and a taper of 0.07 was used in an endodontic motor (X smart plus, Dentsply Tulsa Dental) with a pecking motion up to the the middle third and last 3 mm was by an in-and-out motion until the WL was reached. The canal was rinsed with distilled water, and #10 K-file (Dentsply Tulsa Dental) was used to confirm patency before the file was reused. This procedure was repeated until the file reached the WL. The canal was then rinsed with distilled water.

After instrumentation, the stopper, the needle, and the teeth were detached from the Eppendorf tubes. The adhered debris present at the external root tip was collected by rinsing with 1 mL distilled water. Tubes were placed in a -80° freezer for 8 hours followed by placing in a freeze drier (lyophilizer) for one day for evaporation of distilled water before weighing the dry debris.

The Eppendorf tubes were weighed to obtain the final weight of the tubes, including the extruded debris. Pre and post-instrumentation weight of the Eppendorf tubes for each group was subtracted and the weight of the extruded debris was determined. Three consecutive weights were recorded and mean value was calculated.

Statistical Analysis

Statistical analysis SPSS version 20 software (Chicago, IL, USA) was used and all the experimental groups were compared statistically

Table 1: A comparison of apical extrusion debris between groups

Groups	N	Mean \pm SD	p value
Group I	30	0.038 \pm 0.0412	<0.001
Group II	30	0.0076 \pm 0.017	
Group III	30	0.006 \pm 0.014	

Table 2: Pair wise comparison

Parameter	Groups	p value
Apical extrusion debris	PTN R-PTN FR	<0.001
	PTN R-WOG	<0.001
	PTN FR-WOG	1.000

using a one-way ANOVA test (Table 1). Bonferroni test (Table 2) was done to find the statistical significance between individual groups. According to the results of the present study, all the file systems tested produced a measurable amount of debris extrusion. The mean and standard deviation of apical extrusion of debris values for individual groups are given below.

Bonferroni test was conducted to verify whether the difference is statistically significant between the individual groups.

RESULTS

The results of Bonferroni test showed that a statistically significant difference ($p < 0.05$) was present between group I and group II ($p < 0.001$) and group I and group III ($p < 0.01$) file systems. No significant difference was observed between group II and group III ($p = 1.00$)

DISCUSSION

According to the results of the present study, apical debris extrusion occurred independent of the type of instrument used. The full-sequence rotary NiTi instruments (group I) extruded significantly more debris compared with reciprocating sequential file system (group II) and reciprocating single file system (group III). ProTaper next file system in rotation motion (group I) extruded significantly more debris than the other groups (group II and group III). The results were consistent with previous studies, which demonstrated that no method could completely prevent debris extrusion.⁶⁻⁸ The obtained differences may be caused by the preparation technique, the cross-sectional design, and the taper of the instruments.^{9,10}

Among the recent generation of shaping files, ProTaper next presents uniqueness with the center of mass and the center of rotation with an offset design. This design provides a more cross-sectional space for enhanced cutting, loading, and successfully allowing the debris to travel out of the canal coronally, compared to a file with a centered mass and axis of rotation.² It may also decrease the chances for the file packing the debris laterally, aiding in reducing the chances of blockage of the root canal system. These files produce a mechanical wave of motion that travels along the active length of the file. This unique design is advantageous in minimizing the engagement between the file and dentin, which may also enhance the removal of debris out of a canal and improve flexibility of the files. This could be the main advantage of the PTN file system that might have led to the less amount of debris extrusion apically.^{9,11} Reddy and Hicks has shown that the instrument design also plays a major role in the variations recorded in the apical extrusion of the debris.²

Even though WaveOne gold file has a higher taper (0.07) than the ProTaper next (0.06) file system, in this study, PTN in rotation (group I) resulted in a greater amount of debris extrusion. This might be due to the difference in kinematics used in these files systems.

In this study, a standardized protocol was followed to decrease the number of variables in root canal instrumentation. A single operator performed the entire study to minimize the operator-influenced bias. The apical diameter of master apical instruments in all the groups was standardized at ISO size 15 to avoid any variations in the amount of extruded debris due to the size of apical enlargement. The working length for all of the specimens was 1 mm

shorter than the root length. A fixed amount of distilled water (2 mL) was chosen as an irrigant for this study to reduce the chances that particulate matter indwelling in other irrigants might possibly hinder the final values. Apical patency was maintained during all experimental procedures, and thus, the amount of apical extrusion was not limited.

In the present study, the methodology proposed by Myers and Montgomery in 1991 was used because it has been applied previously in other studies to collect and quantify apically extruded debris.⁵ The present method uses Eppendorf tubes to collect the extruded debris, and it is reliable, simple, and reproducible. In this study it was revealed that all of the instrumentation systems tested caused apical extrusion of debris.^{7,9,12}

The present study showed a significant difference in the amounts of debris extruded between groups.

There are studies both in favor of and against the use of reciprocating motion. According to De-Deus et al., the movement kinematics itself may play a role in packing the debris into the irregularities of the root canal space and pushing them beyond the apex.¹³ However, Arslan et al. and Caviades-Bucheli et al. reported that reciprocation resulted in lesser debris extrusion, which is in support for PTN used in a forward reciprocating motion and WOG in reverse reciprocation.^{14,15}

On the contrary, studies supporting continuous rotational motion extruding less debris are also reported.^{14,16} Capar et al., Koçak et al., and Cakici et al. compared apical extrusion associated with various systems, including PTG, Reciproc, PTN, and PTU files and have reported significantly less extrusion with PTN files. ProTaper next rotary system consists of a unique set of instruments with variable percentage of tapers.^{6,7,17}

De Dues et al. reported that single-file reciprocating systems achieve faster mechanical preparations, with a reduced number of instruments. This enables preparing significant amounts of dentin in short periods of time and hence, prone to force more debris and irrigants through the apex.¹³ Therefore, multi-file systems that involve more technical steps tend to extrude less debris. According to Tanalp and Güngör, the number of instruments and the kinematics may contribute to debris extrusion during the application of the instrumentation technique.⁹ Bürklein and Schäfer had reported that the full-sequence rotary instrumentation was associated with less debris extrusion when compared with the use of reciprocating single file systems.¹⁸ Nayak et al. reported that among the reciprocating single-file systems, Reciproc produced significantly more debris compared to the WaveOne.¹⁹

The WaveOne gold in reverse reciprocation showed significantly lower debris extrusion when compared to PTN in forward reciprocation and continuous rotation motion. Studies conducted by various authors have shown similar results favoring the reciprocating motion.^{17,20} But on the contrary, there are studies that favor rotational motion.¹⁸ According to McKendey, reciprocating motion mimics the balanced force technique, which is known as a pressure less movement that extrude less debris apically.²¹ Reciprocating motion has clockwise (CW) and counter-clockwise (CCW) movement, which may have various angles in both directions. It can be either reverse reciprocation with a reciprocating angle of x° CCW to y° CW or forward reciprocation with x° CW to y° CCW. Reciprocating motion that has the same reciprocating angle in both directions was stated as complete oscillating reciprocation.²¹

Because of the absence of a physical back pressure provided by periapical tissues, apical extrusion was not limited. Because of

the zero back pressure used in this study design, gravity may have carried the irrigant out of the canal. This is an imminent shortcoming of *in vitro* designs with no periapical resistance, as already discussed by Myers and Montgomery.⁵

CONCLUSION

In conclusion, full-sequence rotary instrumentation (group I) was associated with more debris extrusion when compared to the reciprocating sequential file system (group II) and reciprocating single-file system (group III). The clinical relevance of this phenomenon and whether it outweighs the reported good shaping ability and cleaning efficiency of the reciprocation single-file systems need to be evaluated in further studies.

CLINICAL SIGNIFICANCE

According to the results of this study, the reverse reciprocating technique was associated with a less amount of debris extrusion than forward reciprocation and continuous rotation. Thus, the reverse reciprocation technique is a more prudent option for root canal instrumentation.

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