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Apical extrusion of debris during root canal preparation using a novel nickel-titanium file system: WaveOne gold

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Abstract

Aim: This study was intended to evaluate the amount of apically extruded debris following root canal preparation with three different instrumentation systems.
Materials and Methods: Sixty mandibular incisor teeth were selected and randomly divided into three groups (n = 20/group) according to the instrumentation system used: the ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland), the Twisted File Adaptive (TFA; SybronEndo, Orange, CA, USA), and the WaveOne Gold (WOG; Dentsply Maillefer, Ballaigues, Switzerland). All apically extruded debris was collected and dried in preweighed glass vials. The mean weight of the apically extruded debris was obtained using a microbalance. The time for root canal preparation was also recorded. The data were analyzed using a one-way analysis of variance.
Results: The mean weights of apically extruded debris were 0.00035 ± 0.00014 g (PTN); 0.00023 ± 0.0001 g (TFA); and 0.00019 ± 0.0001 g (WOG) ($P < 0.01$). The mean preparation time value was 301,13 ± 62.14 s (PTN); 234.27 ± 34.88 s (TFA); and 239.8 ± 58.6 s (WOG) ($P < 0.05$).
Conclusions: The PTN system extruded more debris than the TFA and WOG systems. The TFA and WOG systems were faster than the PTN system.

Keywords: Apical extrusion; ProTaper Next; Twisted File Adaptive; WaveOne Gold

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Introduction

One of the main reasons for the failure of root canal treatment is the apical extrusion of pulp tissue, microorganisms, and irrigants beyond the apical foramen.[1] The extrusion of debris may be affected by natural physical factors associated with the anatomy of the tooth as well as mechanical factors such as the specific design of the instrument used and the use of rotary instruments.[2] None of the current instruments and preparation techniques can prepare root canals without debris extrusion, although the amount of debris extruded may vary according to the preparation technique and file system used.[3],[4]

The ProTaper Next system (PTN; Dentsply Maillefer, Ballaigues, Switzerland) is used with continuous rotation, and it has five shaping instruments: X1 (17/0.04), X2 (25/0.06), X3 (30/0.07), X4 (40/0.06), and X5 (50/0.06). PTN files are manufactured using an M-wire alloy, and they have a snake-like swaggering movement due to the off-centered rectangular cross-section. The X1 and X2 files both have an increasing and decreasing percentage tapered design on a single file.[5]

The Twisted File Adaptive (TFA; SybronEndo, Orange, CA, USA) system's unique motion features a combination of continuous and reciprocating movement. The system first rotates the file clockwise (CW), and when the TFA instrument is subjected to no or very light stress, system works with intermittent rotation with 600ª CW and stops. On the other hand, with increased instrumentation stress, the TFA instrument adapts to a reciprocating motion. SM1 (20/0.05), SM2 (25/0.06), and SM3 (35/0.04) files are available for narrow canals.[6],[7]

The WaveOne Gold (WOG; Dentsply Maillefer, Ballaigues, Switzerland) is a novel file system manufactured using a thermal process that enhances the cyclic fatigue resistance and flexibility of the instruments. This single-file reciprocating system has four tip sizes: Small (20/0.07), Primary (25/0.07), Medium (35/0.06), and Large (45/0.05). The files have a parallelogram-shaped off-centered cross-section with 85° cutting edges in contact with the canal with a variable and reducing taper.[8]

There are studies that comparing PTN and TFA systems,[9],[10] but there is only one study that evaluates WOG system regarding apical debris extrusion.[11] Therefore, the aim of this study was to evaluate the amount of apically extruded debris and the preparation time involved in using a novel reciprocating single file system WOG and to compare the results against a combination continuous and reciprocating file system TFA, and a multiple-file continuous rotation system PTN.

Materials and Methods

Human mandibular single-rooted incisors were selected from a collection of teeth that had been freshly extracted for periodontal and prosthodontic reasons. Any soft-tissue remnants and calculi on the external root surface were removed using hand and ultrasonic devices. Each tooth was radiographed in the buccolingual and mesiodistal directions to evaluate the root canal morphology. Teeth with more than one canal and apical foramen, an immature root apex, root canal treatment, and a root canal curvature of more than 10° were excluded from the study.[12] The incisal edge of each tooth was flattened to 18 mm to create a reference point, and a coronal access cavity was prepared using a high-speed bur. In addition, only teeth with an initial apical diameter corresponding to the size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) were selected. Sixty mandibular incisor teeth met all of the inclusion criteria and so were included in the study. The working length (WL) was determined to be 1-mm short of the length of a size 15 K-file that was visible at the major diameter of the apical foramen.

Preweighed glass vials (10 ml) were used for debris collection. Three consecutive measurements were taken using an analytical balance with an accuracy of 10^{-5} (AUW-220D; Shimadzu, Tokyo, Japan) and the mean values were recorded. Holes were created in the rubber stoppers of the vials using a hot instrument. The tooth was inserted under pressure through the rubber stopper up to the cementoenamel junction and then fixed using cyanoacrylate. To equalize the air pressure, a 27-gauge needle was inserted alongside the rubber stopper during instrumentation. Forty-five teeth were randomly divided into three groups according to the instrumentation system used ($n = 20$).

The PTN group: the files were used at the WL according to the manufacturer's instructions. A brushing outstroke motion with an endodontic motor (X-Smart Plus, Dentsply, Ballaigues, Switzerland) at 300 rpm and 2 N/cm was used. The instrumentation sequence was X1 (17/0.04) and X2 (25/0.06). Once the instrument had negotiated the full WL and rotated freely, it was removed.

The TFA group: TFA files were used at the WL with a TF Adaptive setting on Elements motor (Axis/SybronEndo, Coppell, Texas, USA). The instrumentation sequence was SM1 (20/0.05) and SM2 (25/0.06). Once the instrument had negotiated the full WL and rotated freely, it was removed.

WOG group: In this group, a WOG Primary file (25/0.07) was used at the WL with an endodontic motor (X-Smart Plus, Dentsply Maillefer, Ballaigues, and Switzerland). WOG files are used with a gentle inward stroking motion with short 2–3 mm amplitude as per the manufacturer's instructions. Once the instrument had negotiated the full WL and rotated freely, it was removed.

In the PTN and TFA groups, the instruments were withdrawn when resistance was felt, and before being reused, 2 ml irrigation was performed. In the WOG group, after proceeding 2–3 mm into the root canal, 2 ml irrigation was performed. To standardize the irrigation protocol, in each sample a 27-gauge double-sided vented irrigation needle (Calasept, Nordiska Dental, Sweden) was inserted into the root canal until resistance was felt and a total of 10 ml of distilled water was used.

After instrumentation of the root canals, the stopper, needle, and tooth were separated from the vial, and the apical part of the tooth was washed with 1 ml of distilled water to collect debris that had adhered to the root surface. The vials were then stored in an incubator at 68°C for 5 days to evaporate the distilled water. After the incubation period, the vials were weighed again. This second measurement was made in a similar manner to the first measurement. The weight of the extruded debris was determined by subtracting the weight of the preweighed empty vials from the weight of the vials containing debris. The time for canal preparation was also recorded, including the total active instrumentation, instrument changes within the sequence, cleaning the flutes of the instruments, and irrigation.

When assessing the results obtained in this study, the IBM SPSS Statistics 22 (IBM SPSS, Turkey) program was used for all statistical analyses. The normality of the data was tested using the Shapiro-Wilk test. All data were statistically analyzed using a one-way analysis of variance. Tukey's HSD test and Tamhane's T2 test were used for multiple comparisons. The level of significance was set at $P < 0.05$.

Results

The mean values of the apically extruded debris and the standard deviations are shown in [Table 1]. Significant differences were observed between the groups in terms of the quantities of apically extruded debris ($P < 0.01$). The PTN group extruded significantly more debris than the TFA and the WOG groups ($P < 0.01$). The WOG group extruded less debris than the TFA group, but the difference was not statistically significant ($P > 0.05$).

	Mean±SD	
	Apically extruded debris (g)	Preparation time (s)
PTN	0.00035±0.00014[a]	301.13±62.14[A]
TFA	0.00023±0.0001[b]	234.27±34.88[B]
WOG	0.00019±0.0001[b]	239.8±58.6[B]
P (ANOVA)	0.001	0.002

Different letters indicate statistically difference ($P<0.01$). PTN: ProTaper Next, TFA: Twisted File Adaptive, WOG: WaveOne Gold, SD: Standard deviation, ANOVA: Analysis of variance

Table 1: Mean weight of apically extruded debris (g) and mean preparation time values (s) in groups

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The preparation time for the PTN group was significantly longer than that for the TFA and the WOG groups ($P < 0.05$). There was no significant difference between the TFA and the WOG groups with respect to preparation time ($P > 0.05$) [Table 1].

Discussion

Since Vande Visse and Brilliant [13] conducted the first study concerning the apical extrusion of debris in 1975, up-to-date variable factors that may affect apical debris extrusion such as irrigation, preparation technique, and nickel-titanium (NiTi) file systems used for preparation have been studied.[14],[15],[16]

In this study, generally accepted experimental model was used to collect apically extruded debris.[17] It is important to emphasize that the current results cannot be directly extrapolated to the clinical situation because of the absence of any periapical tissue simulation that may inhibit debris extrusion. Although the periapical tissues are not mimicked, this technique allows a comparison of the file systems.[16]

The literature presents controversial results, especially when comparing reciprocating single file and continuous rotation multi-file systems in terms of apical extrusion. With regard to movement kinematics, some authors have stated that reciprocal motion may act as a mechanical piston that appears to increase the transportation of debris toward the apex, while continuous rotation provides the coronal transportation of dentin.[18],[19] However, other authors have suggested that reciprocating motion actually imitates the balanced-force technique that causes less debris extrusion.[20],[21]

We investigated three NiTi file systems due to their different movement kinematics as well as the fact that the WOG is a novel file system. There is only one reported study evaluating the WOG system in terms of apical debris extrusion. With consistent our study, Karataş *et al*. reported that WOG system caused less debris extrusion.[11]

The results of this study indicated that there was no significant difference between the WOG and TFA systems in terms of apical debris extrusion. WOG files engage and cut dentin in a 150° CCW direction and then disengage 30° in a CW direction. Consequently, the instrument makes a reverse rotation of 360° after three cycles.[8] TFA motion depends on the stress loaded on file, so reciprocating angles may vary along a wide range, while there might only be reciprocating or continuous rotation during the entire root canal preparation.[7] Karataş *et al.*[22] evaluated the effect of different kinematics (TFA motion, 90 CW-30 CCW, 150 CW-30 CCW, and continuous rotation) on apical debris extrusion using TFA instruments. According to their results, when the reciprocation range increases, apical debris extrusion decreases. There was no significant difference between the 150 CW–30 CCW and the TF Adaptive motion groups. Further, the 150 CW–30 CCW motion was similar to the WOG system's motion, albeit in a reverse action.

In a previous study, Kirchhoff *et al.*[10] compared the PTN and TFA systems. No significant difference was reported, and the average debris extrusions were similar. Several possible reasons may account for the differences from our findings. First, they used a 10^{-4} analytical balance to measure the apically extruded debris. Second, after reaching the WL, sonic activation of the irrigant was applied. Moreover, the authors noted that a reciprocating movement was often required during preparation in the TFA group. Working using a continuous rotation of TFA instruments in a manner similar to the PTN group may have caused there to be no difference between the groups.

Another factor that may affect debris extrusion is the design of the file, for example, the cross-section, rake and helicoidal angles, distance between flutes, taper, tip design, flexibility, alloy, and number of files.[23] The cross-section of the WOG file is a parallelogram, and there is only one cutting edge in contact with the canal wall. Along the active part of the file, there is a constant helical angle of 24°. The additional space around the instrument also provides space for debris removal. The tip of the WOG file is roundly tapered and semi-active.[8] The WOG group produced less quantity of debris than other groups in the present study. This result may be explained by the constant helical angle and the additional space around the WOG instrument that might provide space for debris accumulation and the coronal removal of debris. In this study, the PTN group extruded significantly more debris than the WOG group. The PTN system has a bilateral symmetrical rectangular off-centered cross-section and a variable taper design as similar to the WOG system. Based on this result, the improved design of the WOG instrument appears to have a positive effect on apical debris extrusion. Yet, as both the PTN and WOG file systems have a similar instrument design, it may be speculated that the movement kinematics of the WOG instrument is the principal reason behind the positive effect on debris extrusion.

When evaluating preparation time, the TFA and WOG systems are faster than the PTN system. Numerous studies have shown that single file systems reduce working time.[20],[24],[25] The reduction in the number of instruments used may be a time-saving advantage.[9] Although two files were used for preparation in both the PTN and TFA groups, the TFA system was found faster than the PTN system. PTN files have an increasing and decreasing taper design on a single file. In the X1 file, at the level of 3, 9, and 16 mm, the diameter of the file is 0.31, 0.70, and 1.16 mm, respectively, while the Twisted SM1 file has a 0.44, 0.56, and 0.84 mm diameter at the same level. The larger diameter of the X1 shaping files may have caused the longer preparation time.

Conclusions

Within the limitation of this study, all instrumentation system produced debris extrusion. The WOG and TFA systems are associated less debris extrusion and needed less time than PTN system.

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Conflicts of interest

There are no conflicts of interest.

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Tables

[Table 1]