Apical extrusion of debris using reciprocating files and rotary instrumentation systems

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Abstract

Background: To compare the preparation time and amount of apically extruded debris after the preparation of root canals in extracted human teeth using the reciprocating files and rotary nickel-titanium systems.

Procedure: Sixty extracted human mandibular premolars were used. The root canals were instrumented using reciprocating (WaveOne, Reciproc, SafeSider) or rotary motion (Typhoon, ProTaper Universal, Mtwo), and the debris produced was collected in glass vials. The remaining debris was assessed using a microbalance and statistically analyzed using the one-way ANOVA and Duncan multiple range tests at a significance level of $P < 0.05$. The time required to prepare the canals with different instruments was also recorded.

Results: The Reciproc group produced significantly less debris when compared to the Typhoon group ($P < 0.05$), and instrumentation with the single-file systems was significantly faster than in the multi-file systems ($P < 0.05$). The WaveOne group extruded significantly more debris per unit of time than the other groups, with the exception of the Typhoon group ($P < 0.05$).

Conclusion: According to our study, all systems caused apical debris extrusion. However, the Reciproc group was associated with less debris extrusion when compared to the other groups.

Key words: Apical extrusion, endodontics, single file systems

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Introduction

One of the goals of endodontic treatment is to complete debridement of root canals using files and irrigation solutions. However, during root canal treatment, dentine chips, pulp tissue, which contain microorganisms, may be extruded into the periapical tissues. As a result of this extrusion, postoperative complications and pain or flare-ups may occur, and this situation may delay periapical healing.[1-4]

It is well-documented that all preparation techniques are associated with the extrusion of infected debris into the periapical tissues in spite of preparations maintained short of the apical foramen,[5-8] but the amount of debris extrusion into the periapical tissues may differ according to the preparation techniques and the design of the file systems.[5,9-13] Al-Omari and Dummer[9] reported that the least amount of debris extrusion was associated with the balanced-force and crown-down techniques, whereas the most extrusion occurred with techniques involving a linear filling motion.

Vande Visse and Brilliant[8] first evaluated the amount of debris apically extruded during instrumentation. They found that instrumentation with an irrigant produced extrusion, whereas instrumentation without an irrigant did not produce collectible debris, however, it is impossible to clean root canal systems without irrigants.

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Other studies also found less dentinal debris extrusion when using engine-driven rotary systems despite hand instrumentation.[5,14] File systems can differ greatly in their design, such as in radial lands, flute depth, different tapers, and cross-sections, and kinematics, and this situation may influence the amount of apically extruded debris through the apical foramen.[15]

The aim of this *in vitro* study was to compare the preparation time and amount of apically extruded debris after the preparation of root canals in extracted human teeth, using the ProTaper Universal rotary system (Dentsply Maillefer, Ballaigues, Switzerland), Mtwo rotary system (VDW, Munich, Germany), Typhoon rotary files with Controlled Memory Wire (DS Dental, Johnson City, TN), WaveOne NiTi system (Dentsply Maillefer, Ballaigues, Switzerland), Reciproc NiTi system (VDW, Munich, Germany), and EZ-Fill SafeSider (Essential Dental Systems, South Hackensack, NJ).

Procedure

Sample selection

Eighty-five extracted human mandibular premolars with mature apices, single canals, and of similar lengths were selected for this study. The teeth were kept in 5.25% sodium hypochlorite (NaOCl) (Cağlayan Kimya, Konya, Turkey) for 2 h to clean the periodontal tissue remnants on the root surface. The root surfaces were further scaled with a periodontal curette, and the teeth were stored in a 10% buffered formalin phosphate solution. All teeth were analyzed using the VistaScan digital radiographic system (Dürr Dental, Beitigheim-Bissingen, Germany) in the buccal and proximal directions to confirm single, straight canals. Only the teeth with straight (<10°) and single canals were included. The degree of curvature was calculated using the methodology described by Schneider,[16] and 22 teeth were excluded because they had curved canals. The apical regions of the roots were observed with a stereomicroscope (Expert DN; Müller Optronic, Erfurt, Germany) under × 20 magnifications to confirm a single apical foramen. Only the teeth with a single apical foramen were included, and three teeth were excluded because of multiple apical foramina. Furthermore, the canals were controlled for apical patency with a size 15 K-file (Dentsply, Maillefer). Teeth, in which a 10 K-file could barely be seen through the apex, and a 15 K-file fit tightly at the apical foreman, were included. Finally, 60 teeth were left to study. In order to create an easy reference point for the working length (WL), the crowns were ground with a high-speed bur under copious water spray until equal tooth lengths were created (16 mm). WL was established by subtracting 1 mm from the canal length (15 mm). Then 60 teeth were randomly assigned to 6 groups, with 10 teeth in each.

Irrigation procedure

After each file or after three pecking motions, 31-gauge NaviTip needles (Ultradent, South Jordan, UT) were inserted as far as possible without resistance, until 2 mm short of the predetermined WL and the root canal was irrigated with 1 ml distilled water. The apical patency was checked using a 10 K-file and the canal was re-irrigated with 1 ml distilled water. After the last file, the needle was placed 2 mm from the WL, and 3 mL of distilled water was applied.

Root canal preparation

ProTaper preparation

The ProTaper instruments were used according to the manufacturer's instructions using a gentle in-and-out motion with an electric and torque-controlled endodontic motor (VDW Silver; VDW GmbH, Munich, Germany). For each file, the individual torque limit and rotational speed programmed in the file library of the motor were used. The following sequence was used: SX file (1/2 of the WL); S1 and S2 file (2/3 of the WL); F1 (20.07), F2 (25.08), F3 (30.09), F4 (40.06) (full WL). Shaping SX, S1, and S2 files were used in the canals with a buccal and lingual brushing motion. Once the instrument had negotiated the full WL and rotated freely, it was removed. As a result of the ProTaper sequence, all of the canals in this group were instrumented with 7 NiTi instruments.

Mtwo preparation

The Mtwo instruments were used according to the manufacturer's instructions, using a gentle in-and-out motion with an electric and torque-controlled endodontic motor. For each file, the individual torque limit and rotational speed programmed in the file library of the motor were used. All Mtwo instruments (size 10.04, 15.05, 20.06, 25.06, 30.05, and 40.04) were used to the full WL of the canals. Once the instrument had negotiated the full WL and rotated freely, it was removed. As a result of the Mtwo sequence, all of the canals in this group were instrumented with 6 NiTi instruments.

Typhoon preparation

The Typhoon instruments were used at 400 rpm with 2.5 Ncm of torque via a gentle in-and-out motion with an electric and torque-controlled endodontic motor. The following sequence was used: Size 35.06 (1/2 WL); size 30.04, 30.06, 35.06, and 40.06 (full WL). Size 35.06 was used in the canals with a buccal and lingual brushing motion. Once the instrument had negotiated the full WL and rotated freely, it was removed. As a result of the Typhoon sequence, all of the canals in this group were instrumented with 5 NiTi instruments.

SafeSider preparation

The SafeSider instruments were used with the Endo-Express (Essential Dental Systems, South Hackensack, NJ) reciprocating handpiece at 2500 rpm in a slow, in-and-out pecking motion. The following sequence was used: Size 15.02, 20.02 (full WL); Pleezer reamer (1/2 WL); size 25.02, 30.02, 35.02, and 40.02 (full WL). The Pleezer reamer was used in the canals with a buccal and lingual brushing motion. Once the instrument had negotiated the full WL and rotated freely, it was removed. As a result of the SafeSider sequence, all of the canals in this group were instrumented with 7 NiTi instruments.

Reciproc preparation

An R40 Reciproc file with a size of 40.06 was used in a reciprocating, slow, in-and-out pecking motion according to the manufacturer's instructions. After 3 pecking motions, the flutes of the instrument were cleaned. Once the instrument had negotiated the full WL and reciprocated freely, it was removed.

WaveOne preparation

A Large WaveOne file with a size of 40.08 was used in a reciprocating, slow, in-and-out pecking motion according to the manufacturer's instructions. After 3 pecking motions, the flutes of the instrument were cleaned. Once the instrument had negotiated the full WL and reciprocated freely, it was removed.

Preparation time

The time for canal preparation was recorded and included the total active instrumentation: Instrument changes within the sequence, cleaning of the flutes of the instrument, and irrigation.

Debris collection

In this study, the experimental model described by Myers and Montgomery[17] was used. Stoppers were separated from the Eppendorf tubes and the receptor tubes were individually weighed 3 times by an electronic balance (Shimadzu SAUW-220D, Japan) with an accuracy of ±0.00001 g to obtain the mean weight of each one. A hole was then created in each stopper. Each tooth was inserted up to the cementoenamel junction, and a 27-G needle was placed alongside the stopper for use as a drainage cannula, and to balance the air pressure inside and outside the tubes. Then, each stopper with the tooth and the needle was attached to its Eppendorf tube, and the tubes were fitted into the vials.

To avoid variation and eliminate bias, the same trained operator completed the cleaning, shaping, and irrigation of all of the samples. The operator was shielded from seeing the root apex during instrumentation by an aluminum leaf that covered the Eppendorf tube.

After the instrumentation was complete, the stopper, needle, and tooth were separated from the Eppendorf tube, and the debris adhered to the root surface was collected by washing the root with 1 ml distilled water in the preweighed receptor tube. The receptor tubes were then stored in an incubator at 70°C for 5 days in order to evaporate the moisture before weighing the dry debris. An electronic balance with an accuracy of ±0.00001 g was used to weigh the tubes containing the debris. Three consecutive weights with a difference of <0.00002 g were obtained for each tube, and the mean value was calculated. The dry weight of the extruded debris was calculated by subtracting the weight of the empty tube from the weight of the tube containing the debris.

Statistical analysis

The amount of extruded debris, preparation times, and extruded debris per unit of time were analyzed statistically using the one-way ANOVA and Duncan multiple range tests at a significance level of $P < 0.05$.

Results

Preparation time (s), amount of apically extruded debris (g), and amount of apically extruded debris per unit of time (g/s) after the use of different instruments are shown in Table 1.

The instrumentation time with the Mtwo and ProTaper was significantly longer than with all other instruments ($P < 0.05$). However, the instrumentation time with the single-file systems, WaveOne and Reciproc, was significantly shorter than with all of the other instruments

Table 1: Preparation time (s), amount of apically extruded debris (g) and amount of apically extruded debris per unit of time (g/s) after the use of different instruments

Instrument	Preparation time (s)	Debris extrusion (g)			Amount of apically extruded debris per unit of time (g/s)
	Mean±SD*	Mean±SD*	Minimum	Maximum	Mean±SD*
WaveOne	53.1±27.28*	0.00211±0.00190*,#	0.00050	0.00550	0.05775±0.06972*
Reciproc	68.1±28.65*	0.00121±0.00054*	0.00042	0.00214	0.01883±0.00752#
SafeSider	89.2±24.38**	0.00157±0.00082*,#	0.00015	0.00268	0.01862±0.01109*,#
Typhoon	95.5±16.86**	0.00295±0.00191#	0.00019	0.00599	0.03031±0.01711#
ProTaper	137.7±5.93***	0.00226±0.00222*,#	0.00033	0.00666	0.01628±0.01581#
Mtwo	147.5±12.92***	0.00185±0.00174*,#	0.00004	0.00579	0.01221±0.01045#

*,#Symbols indicate significant differences between groups ($P<0.05$). SD=Standard deviation

($P < 0.05$). There was no statistically significant difference between the SafeSider and Typhoon instrumentation systems ($P > 0.05$).

The amount of extruded debris was recorded for all groups. The highest amount of debris was extruded by the Typhoon group, and the lowest was from the Reciproc group. This difference was statistically significant ($P < 0.05$). The Reciproc produced less debris when compared with the other instruments, but this was not statistically significant, with the exception of the Typhoon group ($P > 0.05$).

The WaveOne group extruded significantly more debris per unit of time than the other groups, with the exception of the Typhoon group ($P < 0.05$).

Discussion

One of the most significant complications that occurs as a consequence of apical extrusion during root canal procedures is interappointment flare-ups, as well as postoperative pain, which is an undesirable occurrence both for the patient and the practitioner.[3]

In this study, to eliminate possible complications, such as WL loss or nonstandard preparation and irrigation in curved root canals, straight and single-rooted teeth were used and these teeth were decoronated for easy reference points. The generally accepted method of Myers and Montgomery[17] was used to collect the apically extruded debris. Although the vital periapical tissues, such as the periodontal ligament, cannot be mimicked, the technique allows for the comparison of file systems. Furthermore, an absence of the physical backpressure provided by periapical tissues in apical extrusion was not limited.[18] To eliminate complications like the precipitation of sodium crystals, NaOCl was not used for irrigation. Distilled water was used to determine the real amount of apically extruded debris.

In this study, we compared various NiTi file systems and root canal preparation principles. To our knowledge, no previous study has compared the apical debris extrusion of the SafeSider, Reciproc, WaveOne, and rotary instruments. The Typhoon, Mtwo, and ProTaper are rotational systems with multifile sequences. Koçak *et al*.[19] reported an accumulation of 0.000471 g of apical debris using a ProTaper system with mandibular premolars. The lower amount of collected debris compared with our data may be caused by the final finishing file. Koçak *et al*.[19] used a ProTaper F3 as the master apical file. However, in the current study, a ProTaper F4 was used as the master apical file.

Bürklein *et al*.[20] reported an accumulation of 0.00023 g of apical debris using an Mtwo system with maxillary incisors. The lower amount of collected debris compared with our data may be caused by the final finishing file. Bürklein *et al*.[20] used an Mtwo 25.06 as the master apical file, but in the current study, an Mtwo 40.04 was used as the master apical file.

To our knowledge, no previous study has evaluated the apical debris extrusion of the Typhoon and SafeSider instruments. In this study, the Typhoon group produced the highest mean extrusion value, and this was a statistically significant difference according to Reciproc group. The SafeSider group produced the second lowest mean extrusion value.

Reciproc is a single-file root canal preparation system. Recently, Bürklein *et al*.[20] reported that the Reciproc system produced more debris than the ProTaper system, which they attributed to the cross-sectional design and cutting efficiency of the instruments. In contrast, we found no differences among the systems, likely because of the increased WL diameter.[10] The Reciproc instrument produced less debris compared with the other instruments. This result is in agreement with another study reporting that reciprocating instruments were associated with reduced debris extrusion.[19]

WaveOne is a single-file root canal preparation system that also produced more debris than the Reciproc. We suspect that the larger apical taper of the WaveOne instrument may cause more aggressive preparation of the canals, which could explain the larger quantity of debris apically extruded by the WaveOne.[11]

The single-file systems were significantly faster than the multi-file rotary systems ($P < 0.05$), and this result is in agreement with another study reporting that single-file systems were associated with a reduced preparation time.[21] To our knowledge, no previous study has mentioned the amount of extruded debris per unit of time. In our study, we found a lesser amount of debris extruded per unit of time for the Mtwo group and the highest value of extruded debris per unit of time in the WaveOne group. In spite of the amount of debris extruded by the WaveOne and Mtwo groups being similar, the time taken to prepare the canals was very different. The difference between the Mtwo and WaveOne groups, according to the amount of extruded debris per unit of time, may be due to this situation. Furthermore, this result shows that the aggressive cutting and high tapered NiTi instruments like WaveOne produces more debris per unit of time compared to low tapered NiTi instruments. This finding should be kept in mind while using these types of instruments.

Independently of the systems used, all instrumentation techniques produced debris extrusion. Further studies should evaluate the behavior of the newly introduced NiTi systems in complicated root canals.

Conclusion

Within the limitations of the present study, although there were no significant differences among the SafeSider, Reciproc, WaveOne, Mtwo, Typhoon, and ProTaper systems, the instrument design and working principles may affect the apical debris extrusion. Root canal preparation with single-file systems is significantly faster than the multi-file systems.

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