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Comparison of ProTaper Ultimate, TruNatomy, and Rotate rotary files in apical debris extrusion

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Abstract

Aim: The aim of this study is to evaluate the amount of debris extruded apically by the primary shaping files of three rotary file systems manufactured with different alloy technologies [TruNatomy (TRN), ProTaper Ultimate (PTUltimate), and VDW.Rotate (VDW.R) files].

Methodology: Thirty lower premolar teeth with moderate curvature (10-20˚) were randomly divided into three equal groups (n=10) according to three rotary file systems [TRN (26.04v), PTUltimate (25.08v), and VDW.R (25.06v)]. The debris extruded apically was collected in Eppendorf tubes of known weights. After preparation, the tubes were placed in an incubator at 70˚C for five days to evaporate the distilled water. The tubes filled with debris were then weighed again, and the net weight of the extruded debris was calculated in grams (g) by subtracting the initial weight from the final weight. The data were analyzed using one-way ANOVA test.

Results: There was no significant difference in the amount of debris extruded apically by the three shaping files ($p > 0.05$). The highest amount of debris extruded apically was 0.9534 g for PTUltimate. VDW.R extruded the minimum amount of debris apically, with 0.1833 g.

Conclusion: All rotary files have caused apical debris extrusion. Even though there was no significant difference among the files, the VDW.R file extruded less debris compared to other file systems.

Keywords: Apically extruded debris, nickel-titanium file, root canal preparation, ProTaper Ultimate, TruNatomy, VDW.Rotate

Introduction

The transport of dentin chips, remnants of pulpal tissue, necrotic residues, irrigation solutions, and microorganisms and their by-products to the periapical region is one of the complications that may occur during root canal preparation. In this situation, the debris transported to the periapical area initiates an acute inflammatory response, infection, postoperative pain, and interappointment flare-ups and long-term failure (1, 2). This process may delay the healing of periapical tissue (1). Uncontrollable factors by the doctor in apical debris extrusion are apical foramen width, amount of microorganism, and virulence of the microorganism (3); whereas the characteristics of the file, chosen preparation and irrigation activation technique, the used irrigation needle, and how far behind the needle is positioned apically are completely controllable by the operator (4-6). All root canal preparation instruments and techniques may cause varying quantities of root canal contents to be extruded outside the apical foramen. (4, 7, 8). This situation has encouraged manufacturing companies to diversify file designs, and there are many files with different characteristics on the dental market today.

The blade and section design, tip type, taper, shape, alloy, heat treatment type, and working kinematics constitute the characteristics of the file. All these variables are effective on the amount of debris extruded apically (9). Today, with the endodontic preparation concept becoming more minimally invasive, file systems that respect tooth anatomy have been developed. One of them is the TruNatomy (TRN; Dentsply Sirona, Maillefer, Ballaigues, Switzerland) rotary file system made from heat-treated Superflex alloy, which gives high flexibility to the files (9). The TRN file system has been produced using a thinner NiTi wire (0.8 mm) instead of the traditional NiTi wire used in the production of most standard files (1.2 mm) (10). According to the information provided by the manufacturer, this NiTi alloy has been subjected to a special heat treatment (11). This file system includes an orifice modifier, a glider, and three shaping files with different apical diameters that can be pre-bent if necessary. While the Glider file has a centered parallelogram cross-section, the shaping files consist of three uncentered parallelogram files: small (20.04v), prime (26.04v), and medium (36.03v). This thin file design, special thermal treatment to the alloy, and regressive taper ensure the maximum preservation of pericervical dentin and effectively cleaning the apical portion of the root (10, 11).

The newest member of the ProTaper series is the ProTaper Ultimate (Dentsply Sirona) file system introduced in 2021. In its design, the Deep Shape preparation principle is adopted in the apical third of the file, allowing sufficient conicity in the canal behind the physiological narrowing of the root and permitting the deepest placement of the irrigation needle and/or activator (12). The concept of minimal invasive endodontics is adopted in the coronal two-thirds (13). This system, consisting of an Orifice opener [SX (20.03v)], a Slider (16.02v), a Shaper (20.04v), and five finishing files [F1(20.07v), F2(25.08v), F3 (30.09v), FX (35.12v) and FXL(50.10v)], has increased the revolutions per minute (rpm) compared to the previous versions: ProTaper Universal, ProTaper Next, ProTaper Gold series. Additionally, this file system includes three different heat treatment technologies. While the Slider file is produced with m-wire alloy technology, SX, Shaper F1, F2, and F3 files are made from gold-wire alloy, and FX and FXL files are made from blue-wire alloy (13).

VDW.Rotate file (VDW GmbH, Munich, Germany) is introduced as a new version of the Mtwo file. The manufacturer offers file options with three different tapers, identified by the rings placed on the handle of the files. The basic file series includes files of dimensions 15.04v (glide path), 20.05v, and 25.04v/.06v. Additionally, the system holds different file options for larger canal anatomies (14). The manufacturer states that thanks to the blue-wire technology, the files are more flexible, allowing preparations that seamlessly follow the natural canal anatomy (14).

Despite the numerous studies on apical debris extrusion caused by different endodontic systems (15-18), there is no study comparing the TRN, PTUltimate, and VDW.R file systems on the amount of debris extruded apically. This study is designed to compare the amount of debris extruded apically from teeth with moderate curvature by these three file systems. The null hypothesis was that there would be no difference in the amount of debris extruded apically between the three file systems.

Materials and Methods

Sample size calculation

The necessary minimum sample size was found to be at least 8 per group, based on the data of a previous study (19), with an effect size f=0.722, 1-α=80%, and 1-ß=0.84.6 (G*Power 3.1, Heinrich Heine Universität, Düsseldorf, Germany). However, considering a possible dropout risk of 20%, a total of 10 teeth were used in each group.

Sample selection and preparation

This study was approved by the Fırat University Research Ethics Committee, with the approval number 2023/09-35. Single-rooted mandibular premolar teeth extracted for orthodontic or periodontal reasons were selected for the study. Teeth with a single canal, single apical foramen, without restorations, fractures, calcifications, and resorptions were chosen. The soft tissue and deposits on the external surface of the teeth were cleaned. Then, the access cavities of the teeth were prepared. Periapical radiographs were taken in buccolingual and mesiodistal directions to determine the

root canal curvature. Teeth with a moderate (10-20°) curvature angle according to the Schneider classification were selected. The samples were separated from the crown portion of the teeth with a diamond blade, with a standard working length of 15 mm. Under a dental operation microscope (Zumax 2360, Suzhou, China), a #15 K-file (Mani Inc., Tochigi-Ken, Japan) was advanced along the canal until it was visible from the apical foramen, and then the stopper of the file was fixed at the reference point. At this point, the length of the file was measured, and the working length was determined to be 1 mm shorter. Teeth with an apical size larger than #15 were not included in the study. A total of 30 teeth that met the inclusion criteria were selected.

Evaluation of debris extrusion and first weighing

In this study, the Myers and Montgomery experimental model, with minor adaptations, was used to evaluate apical debris extrusion by rotary instruments (20). 30 Eppendorf tubes to be used in the study were numbered. Empty tubes were weighed three times with an electronic scale with a precision of 10^{-5} (Denver Instrument, New York, USA), and the average of these weights was recorded separately for each tube (first weighing). Then, the caps of other Eppendorf tubes not included in the study were removed. Following that, each tooth was placed inside a preweighed Eppendorf tube at the cementoenamel junction level and fixed using a rubber stopper. A 27-G needle (Ayset, Adana, Turkey) was placed through the rubber stopper to balance internal and external air pressures (Fig. 1). Eppendorf tubes were placed in glass vials covered with aluminum foil to prevent the operator from seeing the debris generated during the preparation process. Then, the entire apparatus was immersed in a 35°C water bath to better simulate the clinical conditions.

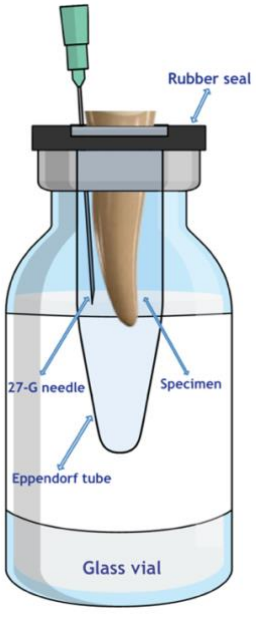

Figure 1. A schematic illustration of the apical debris collection model.

Preparation of Tooth Specimens

All samples were randomly divided into three groups (https://www.random.org). When using rotary file systems, TruNatomy 500 rpm, 1.5 torque; PTUltimate 400 rpm, 4.5 torque, and VDWR 400 rpm, 2.3 torque were used in accordance with the manufacturer's instructions (Table 1). The files were used on with 2–3 gentle apical movements with small amplitudes in-and-out motion, until they reached the working length of the canal. After each inward-outward movement, the canals were flushed with 2 ml of distilled water using a flexible irrigation needle (30-G; TruNatomy Irrigation Needle, Dentsply, Johnson City, TN, USA) placed up to 2 mm short to the working length. Apical patency was also checked using a size #10 K-file after each instrument and final irrigation. All teeth were rinsed with a total of 20 ml distilled water. All preparation procedures were performed by a single endodontist and the same endomotor (XSmart Plus, Dentsply Maillefer, Ballaigues, Switzerland) was used for all rotary file systems.

Second weighing and calculating the extruded debris

After the root canal preparation process, Eppendorf tubes were removed from the glass vials. The teeth were separated from the Eppendorf tubes, and the root surface was rinsed with 1 ml of distilled water to collect debris accumulated on the root surface. The tubes with an irrigation solution were stored in an incubator for five days at 70°C to evaporate the irrigating solution. When no moisture remained, three consecutive weight measurements for each tube were performed to measure the weight of the tubes containing debris, and the mean value was recorded (second weighing). The weight of the dry debris extruded apically was calculated by subtracting the first weight from the second in grams (g). The root canal preparations for all groups were performed by a single endodontist, while the extruded debris was assessed by a second endodontist who was blinded to the experimental groups.

Statistical analysis

The analysis was conducted using SPSS 21.0 software (IBM Corp., Armonk, NY, USA). Alpha type error was set to 5%.

In Table 2, descriptive statistics related to the amount of extruded debris are given. According to the Shapiro-Wilk test, the amount of extruded debris for the groups showed a normal distribution ($p > 0.05$). The amount of extruded debris between the groups was compared with a one-way ANOVA analysis.

Results

There were no instrument fractures or procedural errors during canal preparation. All three shaping files did not show a significant difference in terms of the amount of debris extruded apically ($p > 0.05$). The maximum amount of debris extruded apically was 0.9534 g, belonging to PTUltimate. VDW.R carried a minimum amount of debris apically, with 0.1833 g (Table 2).

Table 1. Characteristics of the file groups used in the study and tested for apical debris extrusion.

File System	Manufacturer	Size / Taper	Alloy	Cross-section	Settings [rpm / torque (Ncm)]	Kinematic
TruNatomy	Dentsply Maillefer, Ballaigues, Switzerland	26 / .04v (regressive)	Special NiTi heat-treated wire	Parallelogram, off-centered	500 / 1.5	Rotation
ProTaper Ultimate	Dentsply Maillefer, Ballaigues, Switzerland	25 / .08v (regressive)	Gold-wire	Convex triangular (variable parallelogram of 85-78°, rhomboid shape)	400 / 4.2 - 5	Rotation
VDW.Rotate	VDW GmbH, Munich, Germany	25 / .06v (constant)	Blue-wire	S-shaped, off-centered	400 / 2.3	Rotation

Table 2. Presentation of the average, standard deviation, minimum, and maximum amount of extruded debris in grams by groups.

Group (n=10)	Mean ± SD	Minimum	Maximum	p*
TRN	0.5517 ± 0.2134	0.2437	0.9264	0.566
PTUltimate	0.5905 ± 0.2619	0.2107	0.9534	
VDW.R	0.4832 ± 0.1952	0.1833	0.7267	

Abbreviations: * One-way ANOVA

Discussion

Although several factors influence postoperative pain, including preoperative pain level, number of appointments, irrigation method, method of determining working length, tooth type, instrument type, kinematics of the instrument, and extrusion of root canal filling material (21), one of the primary causes is apically extruded debris. The prevention of debris extrusion is crucial to reducing the incidence of this complication (22).

The amount of debris extruded apically is influenced by many factors, such as the size, taper, design, cross-sectional shape, and kinematics of the instrument used in chemomechanical preparation (23). Numerous studies exist regarding the apical extrusion of debris by rotary files used in chemomechanical preparation (16, 18, 23). However, upon examining the literature, no study was found that compared the rotary file systems (TRN, PTUltimate, and VDW.R) used in this study together. In addition, studies involving root canal preparation with rotary files have reported that apical extrusion of debris cannot be prevented (16,18,23). The occurrence of debris extrusion in all samples of the three file systems tested in our study is in line with other studies. Additionally, as no statistical difference was found between the groups regarding debris extrusion, the null hypothesis was accepted.

In root canal preparation, many factors, such as the apical anatomy of the tooth, instrumentation technique, length of the irrigation needle, apical penetration of the needle tip, and speed of irrigant application can cause the extrusion of debris and irrigation solution (5, 24). Therefore, a single-rooted, single-canalled mandibular premolar tooth was used in the study. Additionally, to reduce irrigant extrusion obtained with traditional metal needles (25), side-vented flexible needles were used, and the preparation and irrigation protocol were standardized by performing the procedures by a single operator. Moreover, various concentrations of sodium hypochlorite are used as irrigation solutions in routine endodontic treatments (26). However, since the crystallization of sodium hypochlorite could change debris weight and affect the results as stated in various studies (4, 27), distilled water was preferred as the irrigation solution in our study.

Different methods are available for evaluating debris extrusion. In this study, the experimental setup developed by Myers and Montgomery was preferred for its practicality, repeatability, and comparability with other studies (20, 28). In natural teeth, periapical

pressure and periodontal tissues form a natural barrier to prevent debris extrusion. Floral foam can be used to simulate clinical conditions in laboratory settings (6), but it was not used in our study due to its disadvantages, such as absorbing debris and irrigation solutions, altering the results (4). Additionally, in this experimental setup, the apparatus was placed in a 35°C hot water bath to mimic in vivo conditions (29).

The quantity of apically extruded debris is affected by instrument system properties such as crosssection design, shaping ability, kinematic, tip size, and taper (30, 31). In this study, file systems with similar kinematics were compared. All of these file systems have an off-center cross-sectional design. Additionally, both the NiTi wires and heat treatments used in the production of the files are different from each other (11, 13, 14). Various studies have reported that the apical diameters of rotary files are related to debris extrusion (15). Therefore, file systems with similar apical diameters were used in our study. Statistically, even though no difference was found, the least extrusion was caused by VDW.R, and the most by PTUltimate. No study regarding debris extrusion with PTUltimate has been found in the current literature. However, in a study evaluating the shaping ability and effects on smear layer removal of TRN, PTUltimate, and WOG files, although not statistically significant, TRN showed less canal volume change compared to PTUltimate files. These results were reported to be potentially due to TRN's thinner wire structure, more centered preparation, and the design of the instrument (32). In our study, the greater debris extrusion from PTUltimate files compared to the thinner TRN might have resulted from similar reasons. Moreover, in a study evaluating VDW.R and TRN regarding debris extrusion, VDW.R showed better results than TRN. Additionally, it was stated in the study that increasing the taper angle would not cause more apical debris extrusion (18). In our study, file systems with different taper angles were used, and although not statistically significant, the best results belonged to the 0.06 tapered VDW.R files. The findings obtained in our study are in line with the studies mentioned regarding taper angle (16-18). The results obtained in our study might be caused by differences in instrument design, quality of the manufactured wire, thickness of the manufactured wire, and differences in torque and rpm values between the files, and more in-vitro studies should be conducted.

In the debris collection setup established in our study, only the amount of extruded debris can be measured, and one of the limitations of this study is the inability to determine the amount of extruded irrigation solution. Additionally, not using solutions that dissolve organic or inorganic tissue as the irrigation solution may affect the amount of debris extruded from the apical. Nevertheless, the results of this in vitro investigation should be regarded with care, and a clinical study should be conducted to confirm them. Periapical tissues surrounding the root apices were not simulated.

Conclusion

Within the limitations of this study, all rotary file systems caused apical debris extrusion. Additionally, no significant difference was observed between TRN, PTUltimate, and VDW.R files, though VDW.R extruded less apical debris. Based on the findings of this study, further research is needed to evaluate the effects of newly developed rotary file systems on apical debris extrusion in different root canal morphologies.

Disclosures

Ethical Approval: Ethics committee approval was received for this study from Fırat University, Research Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2023/09-35.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – M.E.; Design – M.E., M.Y.Ö.; Supervision – M.Y.Ö., L.l.T.; Materials – M.E., M.Y.Ö.; Data Collection and/or Processing – M.E., M.Y.Ö.; Analysis and/or Interpretation – M.Y.Ö.; Literature Review – M.E., L.l.T.; Writer – M.E., M.Y.Ö.; Critical Review – M.E., L.l.T.

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