

Evaluation of ProTaper Ultimate, ProTaper Next, and ProTaper Gold system instruments for debris and irrigant extrusion

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Abstract

Aim: The aim of this investigation was to compare recently released ProTaper Ultimate system (PTU) instruments, ProTaper Next (PTN), and ProTaper Gold (PTG) in terms of apically extruded debris and irrigant.

Methodology: Forty-five human extracted mandibular molar teeth had their mesial roots decoronated. The roots were then split into three groups (n = 15) for the root canal preparation system: PTU, PTG, and PTN. Using the Myers and Montgomery technique, the roots were embedded in the experimental apparatus to collect and analyze the extruded material. The root canals were prepared according to the manufacturer's instructions. The weights of the extruded debris and irrigant were analyzed using ANOVA with post hoc Tukey tests to evaluate the level of significance ($p < 0.05$).

Results: The PTU group produced the least amount of irrigant and debris. The amount of extruded irrigant produced by each group was statistically significantly comparable ($p > 0.05$). PTU produced lower debris weight than PTG in terms of debris extrusion ($p < 0.05$). For apically extruded debris, no statistically significant differences were observed among the other comparison pairs ($p > 0.05$).

Conclusion: For apically extruded irrigant extrusion, the investigated instrument systems produced comparable results. Similar to PTG, the recently introduced PTU method showed promising findings.

Keywords: Irrigant extrusion, debris, rotary instruments, nickel-titanium, ProTaper Ultimate, ProTaper Next, ProTaper Gold

Introduction

An essential component in the effectiveness of an endodontic treatment is chemomechanical preparation. It includes using instruments to shape the canal system and irrigants to rinse it (1). Irrigants and debris, including pulp tissue, dentin particles, organic and inorganic tissue remains, bacteria, and their byproducts, can be forced out of the apical foramen during chemomechanical preparation (2). An inflammatory process, flare-ups, and post-operative pain are all possible outcomes of apically extruded material, which might compromise the outcome of root canal therapy (3, 4). The file kinematics, number of instruments used, metallurgical properties, taper, cross-section, and cutting efficacy of the instrument are significant factors influencing the apical extrusion phenomenon (5).

Rotary NiTi files from the ProTaper system are claimed to be the most commonly used and long-lasting systems available on the market (6). ProTaper Universal NiTi rotary system comprises 1 pre-flaring (SX) and 2 shaping (S1 and S2) files, 3 finisher (F1, F2, and F3) files, and 2 larger finisher (F4 and F5) files. The ProTaper Gold (PTG) system was created in 2014 and shares the same geometry as the ProTaper Universal system. However, the alloy is thermomechanically treated (Gold Wire), which improves its flexibility and cycle fatigue strength (7). ProTaper Next, released in 2013 and using M-wire technology, exhibits better mechanical properties than traditional NiTi-alloyed instruments (8). By using fewer files for preparation, the system, which has five finishing instruments (X1, X2, X3, X4, and X5), reduces the working time. The off-centered rectangular cross-sectional design of the files provides a snake-like movement that prevents screwing (9). This results in irregular and reduced contact of the file with the root canal, which is associated with less debris extrusion (10).

ProTaper Ultimate is a newly introduced file system among the ProTaper system files (11). The sizes of the instruments were similar to those of the PTG and ProTaper Universal systems but were manufactured with three different types of heat-treated alloys: Slider (M-Wire), Shaper, F1, F2, F3 (Gold Wire), and FX and FXL (Blue heat-treated wire). As an advancement over ProTaper Universal and ProTaper Gold, ProTaper Ultimate offers significant advantages over earlier ProTaper generations, including increased flexibility, increased resistance to cyclic fatigue, and enhanced simplicity (12). It maintains the same philosophy and uses a technique similar to that of its predecessors (12).

PTG and PTN systems had been previously compared for apically extruded debris (9, 13). However, to the best of our knowledge, no study has compared PTU with other file systems produced by ProTaper technology or any other file systems for apically extruded debris and irrigant.

The aim of this in vitro study was to evaluate and compare the PTU system files, which contain M-Wire and Gold Wire technology, with the M-Wire system (PTN) and Gold Wire system (PTG) for debris and irrigant extrusion.

The null hypotheses were as follows: there would be no differences among the file systems for debris (H_{01}) and irrigant extrusion (H_{02}).

Materials and Methods

This study was approved by the Health Sciences Ethics Committee of Ankara Yıldırım Beyazıt University, with approval number 2023-180.

Sample size calculation

As a result of the power analysis performed with G*Power software (Version 3.1.9.7; Heinrich-Heine-Universität, Düsseldorf, Germany), the required sample size per group was calculated (effect size = 0.50, α = 0.05, power = 0.80). Considering a dropout rate of 10%, 45 human mature mandibular molar teeth with straight roots and root canals were included in the study.

Sample selection and grouping

The mesial roots of teeth without caries, resorption, calcification, or cracks were decoronated from the cemento-enamel junction to obtain 16-mm roots under water coolant. A #15 K file was inserted into the mesiobuccal canal of the roots until it could be seen from the apical foramen to provide an apical patency procedure. The working lengths of the mesiobuccal root canals were determined as 15 mm. The roots were randomly allocated into three groups: ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland), ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland), and ProTaper Ultimate (PTU; Dentsply Maillefer, Ballaigues, Switzerland).

Test apparatus

The previously used method was imitated in this study for the collection and evaluation of apically extruded material (14). The caps of 2-ml Eppendorf tubes were cut off and weighed three times on a digital precision balance at 10^{-4} g precision. The mean of these values was recorded as the pre-weight. Pre-weighed Eppendorf tubes were inserted into glass vials. The rubber plugs of the vials were drilled, and the roots were bonded to these holes with cyanoacrylate from the cemento-enamel junctions. The openings of the glass vials were closed with rubber plugs, and the apical foramen of the roots was placed inside the Eppendorf tubes. The inner and outer pressures were balanced by inserting a 23-G needle into the rubber plugs. Apically extruded material was collected in Eppendorf tubes during the preparation procedure.

Experimental groups

- **ProTaper Next group (n=15):** These files were used in the following sequence: X1 (#17/.04) followed by X2 (#25/.06) at 300 rpm speed and 2 N/cm torque. The files were used with a brushing motion until the apical foramen was reached. The root canals were irrigated with 1 mL of distilled water at each instrument change.
- **ProTaper Gold group (n=15):** ProTaper Gold instruments were used by the following sequence: S1 (#18/.02) with a torque of 5.2 N/cm, S2 (#20/.04v) and F1 (#20/.07v) at 1.5 N/cm, and F2 file (#25/.08v) at 3.12 N/cm. All files were used at 300 rpm. S1 and S2 files were used at the coronal aspects of the roots, and F1 and F2 were used at the working length with slight in-and-out movement. The root canals were irrigated with 0.5 mL of distilled water at each instrument change.
- **ProTaper Ultimate group (n=15):** The Slider (#16/.02v), Shaper (#20/.04v), F1 (#20/.07v), and F2 (#25/.08v) instruments were used consecutively with a torque of 400 rpm / 4 N/cm. The files were used at 400 rpm speed, with an outward brushing motion and a light inward pecking motion to progressively advance toward the working length. The root canals were irrigated with 0.5 mL of distilled water at each instrument change.

All procedures were performed by a single operator. All systems were used with the same endodontic motor under minimal apical pressure, according to the manufacturer's instructions. A total of 2 mL of distilled water was used for each specimen. After the apical foramen was reached, a size 15 K-file was inserted 1 mm beyond the apical foramen for the apical patency procedure before distilled water irrigation.

A 27-G open-ended dental injector needle was inserted to a maximum depth of 1 mm shorter than the working length and used with an in-and-out motion for the irrigation procedure.

Debris and irrigant extrusion evaluation

After root canal preparation, the Eppendorf tubes were carefully and quickly removed from the test apparatus to evaluate irrigant extrusion. The tubes were weighed three times, and the mean of the three measurements was recorded as weight-1. The irrigation solutions in the tubes were evaporated at 68°C for 5 days in an incubator. The tubes were weighed three times again, and the means were recorded as weight-2. The extruded debris weight was calculated by subtracting the pre-weight from weight-2, and the extruded irrigant weight was calculated by subtracting weight-2 from weight-1.

The schematic representation of the study is graphically illustrated in Figure 1.

Statistical analysis

The statistical analysis was performed using the IBM SPSS Statistics for Windows software (Version 21.0; IBM Corp., Armonk, NY, USA).

Statistical significance was defined at $p < 0.05$. The data was examined for the normality of distribution using the Kolmogorov-Smirnov test. The data revealed a normal distribution for the groups. Analysis of variance (ANOVA) and post hoc Tukey tests were used to compare the amounts of extruded debris and irrigant.

Results

Table-1 shows the results obtained from the groups. The lowest amounts of debris and irrigant were observed in the PTU group. All groups showed statistically similar extruded irrigant weights ($p > 0.05$). In terms of debris extrusion, PTU provided decreased debris weight than PTG ($p < 0.05$). There was no statistically significant difference between the other comparison pairs for apically extruded debris ($p > 0.05$).

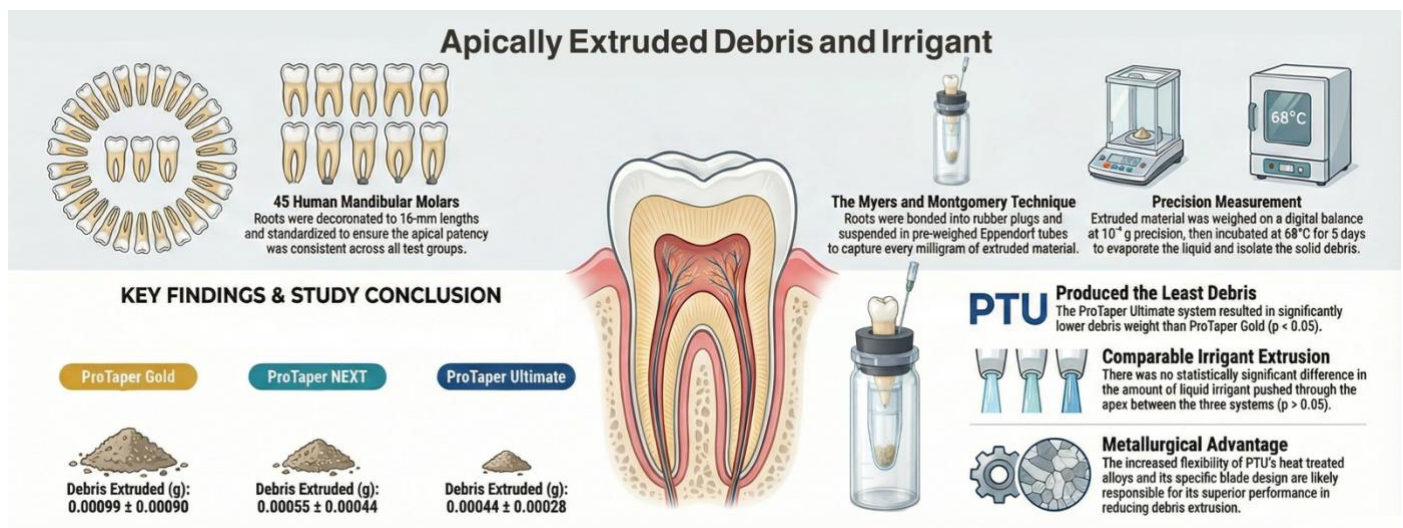


Figure 1. Schematic representation of the study.

Table 1. The mean and standard deviation values for apically extruded debris and irrigant.

Groups	Debris (g)	Irrigant (g)
ProTaper Next	0.00055 ± 0.00044 ^{A, B}	0.9436 ± 0.4057 ^A
ProTaper Gold	0.00099 ± 0.00090 ^B	0.9388 ± 0.3694 ^A
ProTaper Ultimate	0.00044 ± 0.00028 ^A	0.7009 ± 0.3251 ^A

Different uppercase letters mean significant difference among the groups within the same column (ANOVA)

Discussion

In this study, various heat-treated alloyed ProTaper system instruments for irrigant and debris extrusion were compared. The PTG system consists of different alloyed instruments. Gold Wire technology is used in the manufacturing of the PTG system, whereas M-wire technology is used in the PTN system. The PTU system produced less debris extrusion than the PTG system; however, both systems produced comparable irrigant extrusion. As a result, H₀₂ was accepted, and H₀₁ was rejected.

The PTU system, the latest version of ProTaper NiTi files, was created to introduce a novel idea known as "Deep Shape" by combining the best features of its previously produced predecessor (6). Only the PTU system's Slider file is composed of M-Wire among the PTG and PTU system files used in this study; all other PTG and PTU files are created using the Gold Wire technology. Although the apical diameter, tapers, and helical angles of the PTG and PTU instruments were comparable, the PTU system was reported to have greater flexibility and a greater angle of rotation than the PTG system (6). The ProTaper Universal NiTi system files and PTG system files have the same apical diameters and tapers. In contrast to the ProTaper Universal system, the PTG system produced less debris extrusion (9, 15). Because PTG is more flexible than ProTaper Universal, it has been argued that it produces less debris extrusion (15). Compared to PTG, the greater flexibility of the PTU system may permit less debris development. PTG F1 and F2 files have lower blade numbers and higher helical angles than PTU F1 and F2 files, respectively (6). The differences in the design of the instruments could lead to differences in the amount of extruded debris. A previous study comparing PTU and PTN for apically extruded debris claimed that these two systems provided similar debris extrusion, supporting the results of this study (16).

It has previously been demonstrated that the PTG system greatly increased the amount of debris extruded compared to the PTN system (9). In this study, teeth with curved root canals were used for the experiments. PTG and PTN were found to be comparable for apically extruded debris in another investigation, which supports the findings of the current study (13). In that study, teeth with straight root canals were used, similar to the present study. Variations in the tooth types used across

studies may have led to inconsistent results. Compared with other tooth types, post-endodontic pain was more common after treatment of mandibular molars (17). Therefore, mandibular molars were selected for this study.

The kinematics of the instruments affect the amount of apical debris extrusion. More debris is extruded during reciprocal motion than during rotational motion (18-20). Every system used in this investigation was performed with a continuous rotating motion but with varying torque and speed settings. The variations between the groups could be caused by the torque and speed settings. The effects of torque and speed on debris extrusion should be assessed in future studies.

The total volume of the irrigation solution used for one sample was equal in all groups in the study. The amount of solution used between each file was determined by dividing the total volume by the number of files in each group (0.5 mL for the PTG and PTU groups and 1 mL for the PTN group). No difference was found among the tested groups for the extruded solution. The X1 (17/.04), S2 (#20/.04v), and Shaper (#20/.04v) files had the same tapers and relatively similar apical diameter values. Similarly, the apical diameter values of X2 (25/.06) and F2 (#25/.08v for PTG and PTN) were the same, and their tapers were closer. Comparable levels of irrigation extrusion may be due to files having similar apical diameter and taper values.

Various methods have been used to evaluate irrigant extrusion. Previously, extruded irrigant measurements were evaluated by placing the calibrated tube next to the Eppendorf tube in which the extruded solution was collected (21, 22). The calibrated tubes consisted of clean tubes filled with 0.05 mL increments of irrigant using a micropipette, with calibrations marked at different levels. This method is considered subjective because it depends on visual comparison. Several studies evaluating irrigant extrusion tested the amount of extruded irrigant by measuring the volume in 0.1- or 0.01-mL increments using an insulin syringe (23, 24). However, during the collection procedure, small amounts of debris may be collected together with the irrigant, or small amounts of solution may remain at the bottom of the bottle, which could change the weight of the extruded debris.

Several previous studies measured irrigant weights similar to the method used in this study with the formula used in the study. The extruded irrigant weight was calculated as the difference between the weight

measured immediately after the final irrigation procedure (weight-2) and the sum of the empty Eppendorf tube and debris (weight-1) (25-29).

In this study, distilled water was used for irrigation instead of sodium hypochlorite, as it has been reported to promote crystal formation, which may increase debris weight (5). The use of distilled water can be a drawback, as it does not mimic clinical conditions. Previously, the amounts of extruded debris and irrigant were evaluated using various alternative methods, such as floral foam (30), 1.5% agar gel (31), and coating the roots with a thin silicon layer (32) to imitate the periapical tissues. The lack of periapical tissue imitation could be a limitation of the previous study.

Within the limitations of this study, the PTU system exhibited lower debris extrusion than the PTG system, despite the files of the systems having similar geometries, tapers, and apical diameters. However, the PTU system files have different types of heat-treated alloys, which can be a reason for the difference in debris extrusion. Further studies comparing these systems are recommended.

Conclusion

The ProTaper Ultimate system produced less debris extrusion weight than the ProTaper Gold instrument system. All of the instrument systems caused similar extrusion of irrigant.

Disclosures

Ethical Approval: Ethics committee approval for this study was received from the Health Sciences Ethics Committee of Ankara Yıldırım Beyazıt University, in accordance with the World Medical Association Declaration of Helsinki, with approval number 2023-180.

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