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Shaping Ability of Protaper Gold and Protaper Ultimate in Simulated Root Canals: A Comparative Study

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Abstract **Original Research Article**

This study aimed to compare the shaping ability of ProTaper Gold (PTG) and the newly developed ProTaper Ultimate (PTU) systems in artificial S-shaped canals. Both files are manufactured via gold thermal treatment methods and have variable taper along their working part. Thirty-Two S-shaped canals in clear resin blocks were prepared up to an apical size of 25 using PTU and PTG instruments (n = 16 canals/group). Resin blocks were filled with ink and photographed before & after instrumentation to develop composite images by superimposition. The amount of removed resin was measured perpendicularly to the canal surface in 18 points, in addition to the canal transportation and centering ratio. Statistical analysis was performed by using Manne-Whitney U-test ($\alpha = 0.05$). No broken files or aberrations were recorded during instrumentation. PTG significantly removed a higher amount of resin at 4, 6, 8, and 9 mm from the apex, but at 1 mm PTU significantly cut a higher amount ($p < 0.05$). Concerning transportation & centering ability, both files deviated from the center and at 3 mm PTU yielded significantly higher deviation, while at 4 mm PTG recorded a higher value ($p < 0.05$). In conclusion, PTU produced more conservative preparation than PTG especially in the coronal third, while for maintaining the original canal curve, PTG caused lesser deviation at the beginning of the apical curvature.

Keywords: Canal transportation, heat treatment, Propter Gold, shaping ability, S-shaped canals.

INTRODUCTION

Shaping the root canal space is a critical step to achieve the primary target of endodontic treatment, which is eliminating remaining pulp tissue, bacteria and providing space to ease irrigation and obturation. Meanwhile, keeping the original anatomy and preserving sound dentin to increase the longevity of the tooth [1, 2].

Challenging root canal anatomy is the norm rather than the exception and this adds more challenges to the instrumentation preventing proper disinfection and causing procedural errors such as instrument separation, transportation, ledges, or perforations [3].

Thermal treatment of NiTi by adjusting its transition temperature, while controlling the microstructure to produce an alloy mainly formed of R-phase or martensite contributed to a significant increase in flexibility and cyclic fatigue resistance [4-6].

It was recorded in many studies that the mechanical glide-path technique has been shown to remarkably reduce procedural time, decreasing postoperative pain and flare-ups, while preserving the morphology of the original root canal [7, 8]. The ProGlider (PG) (Dentsply Sirona, Ballaigues, Switzerland) is a single mechanical glide path file manufactured from M-wire and has increasing tapers from 2% to over 8% along its active portion. The file has a square cross-section with a diameter of 0.16 mm at D0 and 0.82 mm at D16. These design features will lead to safer preparation of the glide path with significant flexibility and 400% more resistance to cyclic fatigue [8, 9].

Employing the technological upgrade in metallurgy, PTG (Dentsply Sirona, Ballaigues, Switzerland) (Gold Wire) evolved from the Protaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland) with the same design and enhanced flexibility and resistance to cyclic fatigue [10]. This system encompasses 3 shaping [SX (19/.04v), S1

(18/.02v) and S2 (20/.04v)] and 5 finishing [F1 (20/.07v), F2 (25/.08v) F3 (30/.09v, F4 (40/.06v), F5 (50/.05v)]. These instruments with multiple changing tapers over the cutting part, convex triangular cross-section, center of mass of the instrument is aligned with the center of rotation, progressively changing helical angle and pitch and no radial lands.

The recently innovated PTU rotary system (Dentsply Sirona, Ballaigues, Switzerland) is the newest generation of the protaper group in which thermal treatment is used efficiently to produce a set of instruments with different mechanical behaviors with distinct crystallographic arrangements, to achieve a balance between flexibility and strength. According to the manufacturer, the instruments of this system [Slider (16/.02v), SX (20/.03v), Shaper (20/.04v), F1 (20/.07v), F2 (25/.08v), F3 (30/.09v), FX (35/.12v) and FXL (50/.10v)] are manufactured using 3 different heat-treated alloys: M-wire (Slider), Gold-wire (SX, Shaper, F1, F2, F3) and Blue heat-treated wire (FX and FXL). These instruments are manufactured from 1 mm wire instead of 1.2 mm for PTG except for FX = 1.2mm, multiple changing tapers over each file's cutting blades, the cross-sectional design is a parallelogram with variable acute angles at different lengths 85° at the tip then decreasing to around 75° - 80°, the files possess a geometry in which the center of mass of the instrument is not aligned with the center of rotation [11].

MATERIALS & METHODS

Specimen preparation

Thirty-two ISO #15, 0.02-tapered S-shaped endo resin blocks (Dentsply Maillefer, Ballaigues, Switzerland) were randomly divided into two groups (n = 16) according to the rotary instrument used for shaping PTG group and PTU group. Each simulated canal had a preoperative 30° coronal curvature with a 5 mm radius, 20° apical curvature with a 3.5 mm radius, and a length of 16 mm.

Photographic procedures

To insure uniformity of photographs of each specimen, a special mold was used to position the resin block meanwhile, the camera (HA2307 HDMI industrial camera, Shenzhen, China) was kept in the same position and settings for all samples. All photographs were captured by wireless remote control to avoid shaking the camera. The light source used during photography was (LED Light, Godox, Shenzhen, China).

Three holes were drilled with small-sized round bur (4 FG Round Carbide, BRASSELER, Savannah, USA) and marked with a pen (Lumocolor permanent marker; Staedtler, Nuremberg, Germany) to be a landmark on the surface to be photographed for easing superimposition (Fig 1).

A ruler fixed at the upper border of the resin block during photography to ease measurement scale and accuracy (Fig 2).

Enhancement of color contrast of the pictures by injecting all canals with black ink (Higgins, Leeds, MA, USA) before instrumentation and red ink (Higgins, Leeds, MA, USA) postoperatively. To, minimize the margin of error, all the photos were captured by the same person.

Root canal preparation

Canal patency is confirmed by an ISO standard size #10 K-file (Dentsply Maillefer, Ballagues, Switzerland). All the instruments were rotated using a motor (X-SMART DUAL, Dentsply Sirona, Ballaigues, Switzerland) with a 2:1 reduction ratio contra-angle handpiece according to the manufacturer's instructions. Irrigation with 3 mL of distilled water was done using a 30-gauge side-vented needle (Prorinse Maillefer, Ballaigues, Switzerland).

PTG group

Motor settings were rotational speed 300 rpm & torque 4 ncm. The preparation sequence was glide path preparation by PG to full working length (FWL). Then the following instruments were used in this sequence S1 and S2 in a brushing motion whereas, F1 and F2 in a pecking motion. Whenever there is apical resistance, the instrument was removed, cleaned, and the canal irrigated. Canal patency was maintained using a size 10 K-file.

PTU group

Motor settings were rotational speed 400 rpm & torque 4 ncm. The instrumentation sequence was glide path preparation using SLIDER passively to the FWL then SHAPER in a brushing action. After that, F1 and F2 are in a pecking motion to FWL.

All samples were prepared by the same operator. Each file was lightly coated with a lubricant paste (Glyde File Prep; Dentsply Sirona). Following the use of each file, the canal was irrigated with 3 mL of distilled water and recapitulated with a size 10 K-file then reirrigated. A total of 21 ml of distilled water was used per block.

Assessment of canal preparation

Superimposition of the pre- and post-preparation photographs done by Adobe Photoshop CC 2023 (Adobe Systems, San Jose, CA, USA) to produce composite images. Photographed surfaces were accurately superimposed by overlapping the drilled holes (Fig 1). A measurement scale was also prepared using the same software.

Concentric circles were arranged in 1 mm intervals while aligning the center of the smallest circle with the apical foramen. Perpendicular Lines were drawn to the prepared canal surface and intersected the concentric circles in the canal center [12] (Fig 2).

The width of the removed resin was measured perpendicularly to the canal surface by the ruler tool in Adobe Photoshop CC 2023 in 18 points (9 inner points and 9 outer points). The first measurement level was at 1 mm from the apex, and the last measurement level was 9 mm from the canal terminus. The apical third is represented by levels 1–3 while, levels 4–6 for the middle third, and levels 7–9 correspond to the straight portion of the canal (Fig 2) [13].

The shaping ability of the PTG and PTU systems was evaluated quantitatively by the following method (Fig 3):

1. The total amount of resin removal = X1 + X2 [14].
2. Amount and direction of transportation = X1-X2 [14].

X1 is the resin removed on the outer surface of the apical curve which is the distance between the margin of prepared canal and original canal on the inner surface while X2 is the same but on the outer surface.

- Positive results indicated transportation toward the outer side of the apical curve.
- Negative results indicated transportation toward the inner side of the apical curve.

3. Centering ratio (X1-X2)/Y [15].
   - Y is the final diameter of prepared canal. For an instrument to be centered, it should obtain a lower centering ratio.

Statistical analysis

Statistical analysis was performed by using the SPSS software (IBM SPSS Statistics 21, SPSS Inc. Chicago. IL. USA). The data were analyzed by the Mann-Whitney U-test, statistical significance level of 5% ($P < .05$).

RESULTS

No instrument separation or aberrations were recorded during the preparation of the S-shaped canals.

Amount of resin removed

In general, there is an increase in the amount of resin removed all over the canal length from the apex toward the orifice in both groups.

PTG removed a significantly higher total amount of resin by including all measurement levels (3.48 ± 0.2 mm) than PTU (3.2 ± 0.11 mm) ($P < 0.05$). Regarding coronal and middle thirds (4,6,8 and 9 mm from apex) PTG removed a significantly higher amount of resin, while at the apical third (1 mm from apex) PTU removed more resin ($P < 0.05$) (Fig 4).

Amount and direction of canal transportation

Overall, transportation was recorded in both groups. At the coronal third transportation was toward the outer surface of the coronal curve, in the middle third was toward the inner surface. The direction was toward the inner surface of the apical curve in the apical third. PTU at level 3 mm significantly caused higher transportation, but at level 4 mm PTG showed significantly higher transportation ($P < 0.05$) (Fig 5).

Centering ratio

The greatest deviation recorded for PTU & PTG was at the beginning of the apical curve (level 2 mm). In agreement with the results of transportation, PTU showed significantly more centered preparation than PTG at level 4 mm, on the contrary PTU recorded significantly more deviation than PTG at levels 2 and 3 mm (Fig 6).

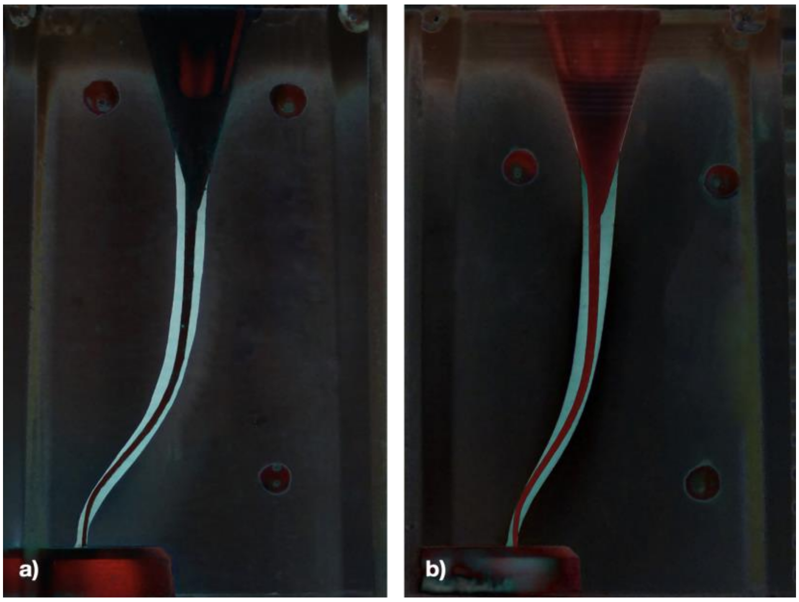

Figure 1: Representative superimposed images of samples prepared by a) PTU b) PTG.

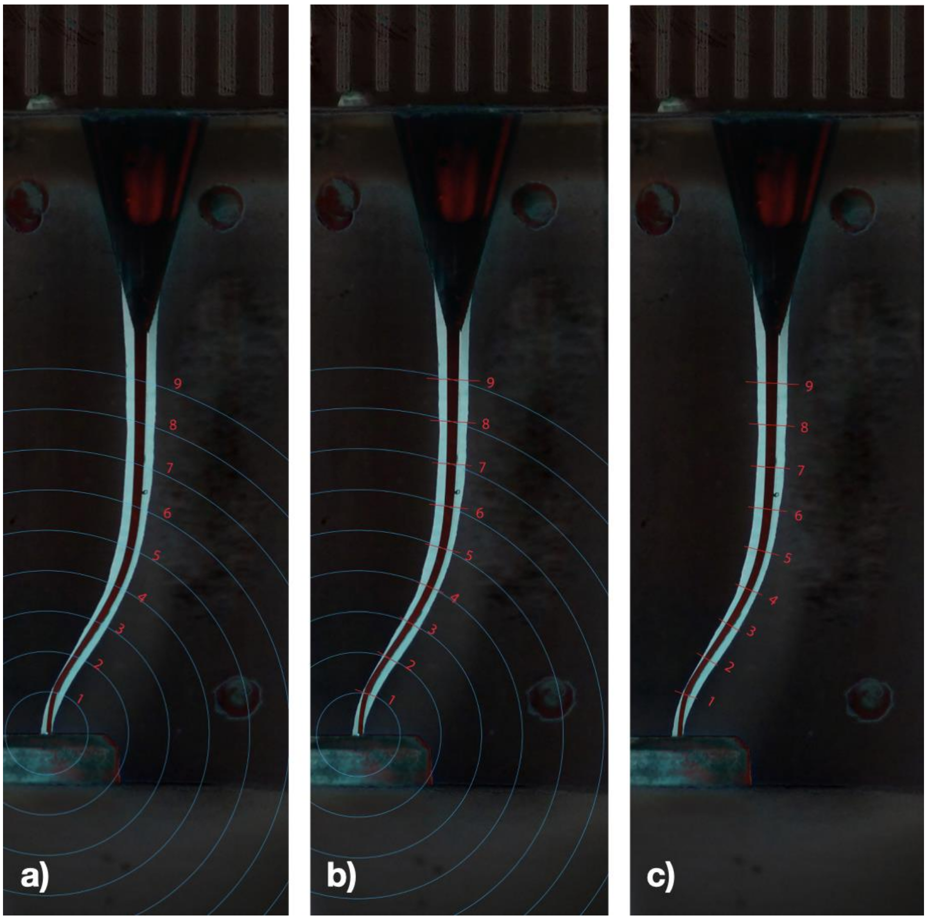

Figure 2: a) The concentric circles were arranged in 1 mm intervals. b) Lines were drawn perpendicularly to the prepared canal surface. c) 9 measurement levels

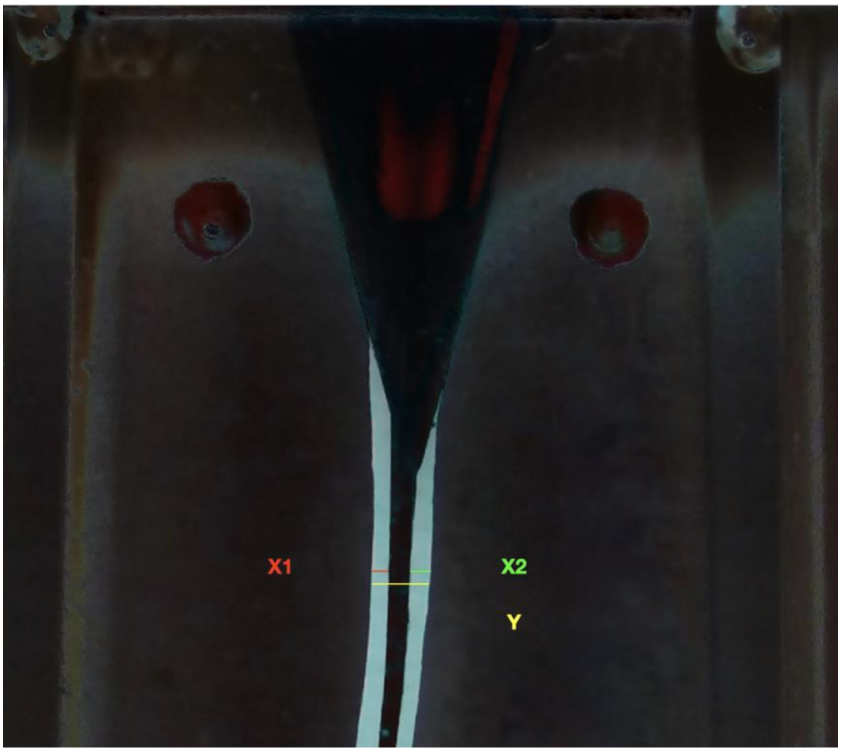

Figure 3: X1 is the amount of resin removed on the inner side, X2 is the amount of resin removed on the outer side, Y is the final canal diameter at the same level

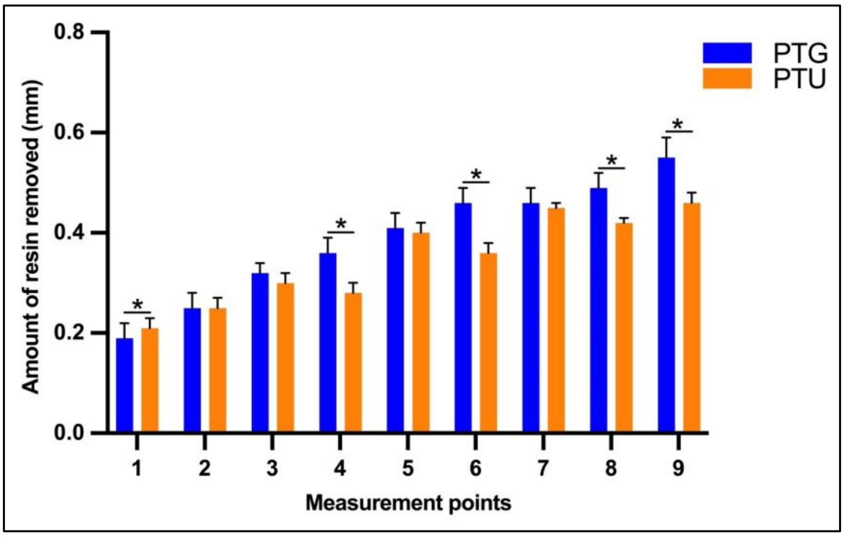

Figure 4: Mean and standard deviation of amount resin removed at different measurement levels. (*) means statistically significant between PTU and PTG different according to Manne-Whitney U-test (P < 0.05)

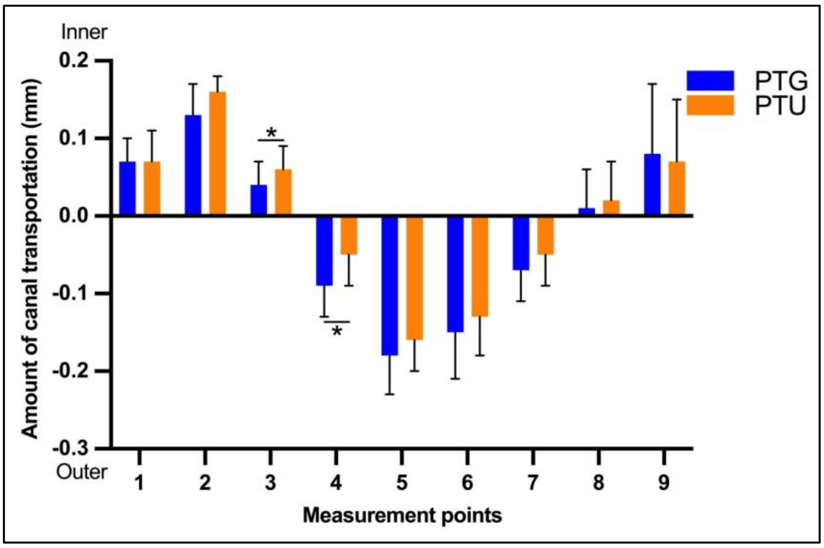

Figure 5: Mean and standard deviation of amount and direction of canal transportation at different measurement levels. (*) means statistically significant between PTU and PTG different according to Manne-Whitney U-test (P < 0.05)

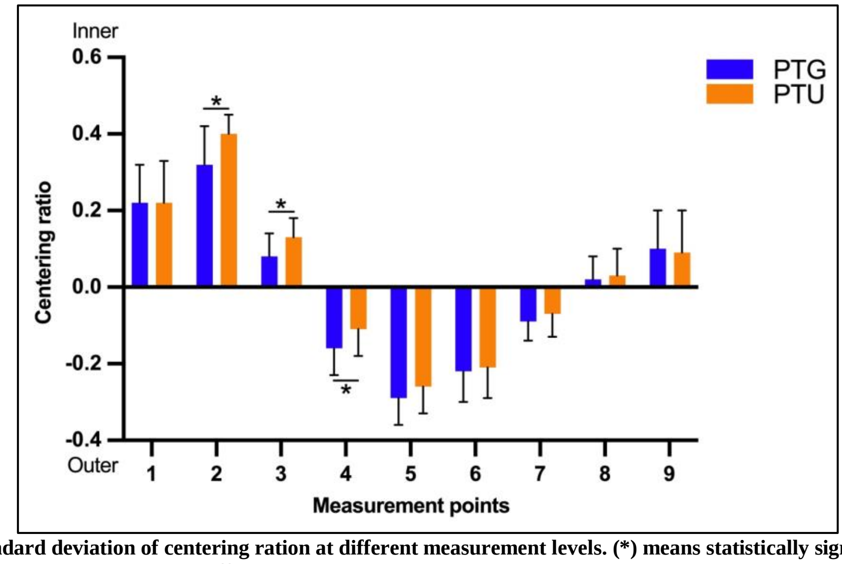

Figure 6: Mean and standard deviation of centering ration at different measurement levels. (*) means statistically significant between PTU and PTG different according to Manne-Whitney U-test (P < 0.05)

DISCUSSION

Centering ability is the capacity of an instrument to stay centered in root canal while performing its enlargement without causing iatrogenic errors [1]. Moreover, Preserving the native anatomical shape of the root that tapers from the apical foramen toward the canal orifice is one of the main pillars for successful canal shaping [1, 16].

To avoid the effect of the highly variable root canal anatomy that could influence the instrumentation results resin blocks were used in the current study as a replacement for natural teeth [17, 18]. This will aid in standardizing the anatomical parameters including diameter, length, and curvature for all the samples, and facilitates comparing various instruments [19]. However, the use of resin blocks is a limitation of this study as it has half the hardness of natural teeth, in addition to different thermal properties [20, 21].

In accordance with extensive literature data, image superposition is generally believed as a valid method to assess the shaping ability of root canal instruments on resin blocks with simulated root canals [22-24]. However, the two-dimensional evaluation of the samples is considered to be the main drawback of superimposition, as there is a lack of information about the material removed or the effect of the preparation in other planes [25].

Glide path files are used to preenlarge the canals to help the shaping files to follow the pathway and to decrease the torsional stress on NiTi rotary instruments [26]. Furthermore, shaping canals with 2 curvatures decreases the cyclic fatigue resistance [27].

Considering the lack of knowledge regarding the shaping ability of this new system (PTU), the current study was conducted to compare its performance with instruments of similar size and design from PG and PTG. The null hypothesis to be tested was that there would be no difference in the mechanical behavior among these different instruments [28].

In the current study, PTG removed a statistically significant higher amount of resin in the middle and coronal thirds as it has a larger diameter due to the greater taper as confirmed by other studies [29, 30]. At 1 mm from the apex, PTU removed a significantly higher amount, this result could be attributed to the design as the number of blades of the PTU shaper and finishers was higher than their PTG counterparts [28]. Also, a higher speed of rotation PTU (400 rpm) while for PTG (300 rpm) could be another reason, and this is in agreement with Peters et al. who found that increased rotational speed was associated with increased cutting efficiency [31].

Deviation of the prepared canal from its original axis after shaping means canal transportation [32]. High levels of transportation will subsequently increase the incidence of canal curvature straightening, ledge formation, and irregular apical enlargement [33-35]. García et al found that if the apical transportation value is more than 0.3 mm, this will decrease the sealing ability of filling material [36].

PTU significantly deviated from the center at the apical third, while PTG caused significant deviation at the middle third.

Many factors have been identified that can affect the incidence of canal transportation, such as geometry design features, kinematics, and metallurgical properties [37]. Differences in the file design were noticed between the PTU and PTG including cross-sectional design, the center of rotation, maximum flute diameter, number of blades along the working part, and rotational speed [28]. All these factors collectively will impact the file performance. Further studies are recommended to investigate the effect of each design parameter on the shaping ability of the newly introduced file PTU.

Under the conditions of the present study, it could be concluded that PTU file produced more conservative preparation in the coronal third. While PTG instruments showed more centered apical preparation.

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