Cyclic Fatigue and Torsional Failure of EdgeTaper Platinum Endodontic Files at Simulated Body Temperature

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Ahmed Jamleh, BDS, MSc, PhD, Amjad Alghaihab, DMD,* Abdulmohsen Alfadley, BDS, MSc, FRCD(C),* Hussam Alfawaz, BDS, MS,† Abdullah Alqedairi, BDS, MS,† and Khalid Alfouzan, BDS, MSEd**

Abstract

Introduction: The aim of this *in vitro* study was to compare the cyclic fatigue resistance and torsional resistance of EdgeTaper Platinum (ETP) with those of ProTaper Gold (PTG) at simulated body temperature. **Methods:** ETP and PTG files with #25 tip size were selected. Cyclic fatigue tests were performed in a stainless steel artificial canal until file fracture occurred. The time to fracture was recorded. For the torsional resistance testing, the apical 5 mm of the file was firmly secured with acrylic resin, and the assembly was fixed over torque gauge device. A uniform torsional stress was applied with continuous rotation motion until fracture occurred. The torque at failure was recorded. Both experiments were conducted at $35 \pm 1°C$. Fractured surfaces were tested via scanning electron microscopy. Statistical analysis was performed using independent Student t test at 5% significance level. **Results:** The ETP had superior cyclic fatigue resistance than PTG ($P < .01$). However, it exhibited lower torsional resistance ($P < .05$). The ETP and PTG showed typical features of cyclic and torsional fatigue behavior under scanning electron microscopy. **Conclusions:** The ETP exhibited superior resistance to cyclic fatigue but failed to show any improvement in the torsional resistance compared with PTG. *(J Endod 2019;45:611–614)*

Key Words

Cyclic fatigue, EdgeTaper Platinum, ProTaper Gold, torsional resistance

Significance

The results indicated that the EdgeTaper Platinum was associated with superior cyclic fatigue resistance but failed to show any improvement in the torsional resistance compared with its counterpart, ProTaper Gold.

Nickel-titanium (NiTi) rotary files are increasingly used in root canal treatment since they shape the root canal easier, faster, and more predictably with lower canal transportation and apical extrusion when compared with hand stainless steel files (1–3). Nevertheless, they have a risk of unexpected fracture (4, 5). The negative impact of fractured files on the treatment prognosis (6) and difficulty in removing the fractured file from the canal make it imperative to understand the file's fracture mechanisms. Two mechanisms have been proposed for the file fracture: cyclic fatigue and torsional failure (7–9). The former occurs more frequently in curved canals due to repeated compressive and tensile stresses generated when the file rotates. The latter occurs when the file tip is locked but the shank of the file is still rotating (7, 8).

The stress generated on the file during canal preparation is greatly influenced by the operator's handling technique, method of use, and the complexity of the root canal system (8, 10). Furthermore, factors such as file geometry, alloy composition, and manufacturing methods can significantly influence the stress behavior of NiTi files and thus the propensity of the file to fracture (8, 11, 12).

NiTi rotary systems have advanced as various manufacturers aim to enhance the mechanical characteristics with different geometric design or thermomechanical processes as reflected in the different brands (13, 14). The ProTaper Gold (PTG; Dentsply Sirona, Ballaigues, Switzerland) has been introduced as a second version of ProTaper Universal (PTU) with the same sequence and design but with different proprietary advanced metallurgy. Previous studies (15, 16) found that PTG had improved resistance to cyclic fatigue but less resistance to torsional failure, compared with the PTU. EdgeEndo (Albuquerque, NM, US) has recently introduced several file systems that are similar in shape, manufacturing process, and preparation technique to other file systems on the market. A previous study showed that one of the EdgeFile systems had improved cyclic fatigue resistance (17). In addition, the EdgeTaper Platinum (ETP; EdgeEndo) was introduced on the market with the claim that it is manufactured using heat-treatment technology and has a design similar to that of PTG.

Because no data are available on the mechanical properties of this ETP system, the current study was conducted to investigate its cyclic fatigue and torsional resistance and

From the *Restorative and Prosthetic Dental Sciences, College of Dentistry, King Saud bin Abdulaziz University for Health Sciences, National Guard Health Affairs, Riyadh, Kingdom of Saudi Arabia, and King Abdullah International Medical Research Centre, National Guard Health Affairs, Riyadh, Kingdom of Saudi Arabia; and †Department of Restorative Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.

Address requests for reprints to Dr Ahmed Jamleh, Restorative and Prosthetic Dental Sciences, College of Dentistry, King Saud bin Abdulaziz University for Health Sciences, National Guard Health Affairs, P.O. Box 22490, Riyadh 11426, Saudi Arabia. E-mail address: aojamleh@gmail.com

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compare them with the PTG at simulated body temperature. The null hypothesis of the current study was that there would be no difference between the cyclic fatigue and torsional failure of the tested NiTi rotary systems.

Methodology

ETP and PTG were used in this study. Each group consisted of 30 brand new files. Files with a #25 tip size were used in this study, as this is the size commonly used size for preparation of root canals. All the files were inspected at 13.6× magnification (OPMI Zeiss Pico; Carl Zeiss MediTec, Dublin, CA) for any deformities or defects. No file was discarded.

Cyclic Fatigue Resistance Experiment

Fifteen files from each group were used. Cyclic fatigue resistance was tested by placing the file in an artificial canal that was milled in a stainless steel block using a laser micromachining technique. The canal had a curvature angle of 60° angle and 5 mm radius of file curvature with dimensions larger than the dimensions of the PTG F2 by 0.1 mm in width (18). The maximum curvature was set at 5 mm from the tip of the file. To determine the file fracture's time and prevent slippage of the file, the canal was covered with glass.

The artificial canal was stabilized inside a water bath with a preset temperature of 35°C with a tolerance limit of 1°C. An endodontic motor (X-Smart Plus; Dentsply Sirona) was mounted in a way that allowed downward movement of the file until a section of 19 mm from its tip was inserted inside the canal. Then, the motor rotated the file at 300 rotations per minute (rpm) until fracture occurred. The time to fracture was recorded in minutes. Once fracture was noticed audibly and/or visually, the time recording was stopped. The number of cycles to fracture was calculated by multiplying the time to fracture in (in minutes) by 300.

Torsional Resistance Experiment

Fifteen files from each group were used. The apical five millimeters of the file was firmly secured using a mixed autopolymerizing resin (DuraLay; Reliance Dental Mfg Co, Worth, IL) producing a resin base. The X-Smart Plus motor (Dentsply Sirona) was mounted using a vise such that it could secure the file in an upright position. The resin base was firmly fixed over a torque gauge device (TT01; Mark-10 Corporation, Long Island, NY), and the torque gauge was zeroed before each use. It was surrounded by a plastic chamber containing water at simulated body temperature (35 ± 1°C) throughout the experiment. A uniform torsional stress was applied by rotating the file clockwise at a speed of 40 rpm until fracture occurred. The values of torque at failure were recorded.

The torque gauge accuracy was ensured before use and the experimental procedures were performed by a single operator.

Scanning Electron Microscopy

From each group, 2 files fractured by cyclic fatigue and torsional resistance were selected for scanning electron microscopy (SEM) analysis to look for the topographic features of the fractured files. Before the microscopic evaluation, they were cleaned using absolute alcohol in an ultrasonic bath for 3 minutes to remove debris. Afterward, the files were dried at room temperature and then they were mounted vertically on 15-mm metal stubs using double-sided carbon tape. The mounted samples were placed inside the SEM (6360LV Scanning Electron Microscope; JEOL, Tokyo, Japan) with 20 kV and 32-mm working distance. The SEM photomicrographs were captured at 170× magnification.

TABLE 1. Cyclic Fatigue Resistance (n = 15) and Torsional Resistance (n = 15) of the Tested File Systems

	Cyclic Fatigue (rpm)	Torque at Failure (Ncm)
ProTaper Gold	1002.3 ± 304.8	3.81 ± 1.0
EdgeTaper Platinum	1506.0 ± 482.0	3.09 ± 0.8
P	.002	.03

Data are represented as mean ± SD.

Data Analysis

Because the data were normally distributed (Shapiro-Wilk test; $P > .05$), they were analyzed statistically using the Student t test at a 5% significance level.

Results

Table 1 shows results of the cyclic fatigue and torsional resistance data of the tested systems.

In the cyclic fatigue test, the ETP had superior resistance compared with PTG ($P < .01$). The fractured lengths were found to be comparable in PTG and ETP groups with 4.99 ± 0.94 and 4.51 ± 0.40 mm, respectively ($P > .05$).

In terms of torsional failure, the ETP demonstrated significantly lower resistance than the PTG ($P < .05$).

In the SEM images, the PTG and ETP exhibited typical features of cyclic and torsional fatigue behavior (Fig. 1). The cyclic fatigue caused crack initiation centers at the cutting edges of the fracture cross sections, with an area of microscopic dimples. The torsional failure generated a concentric abrasion pattern, with a dimpled surface with micro-voids at the center.

Discussion

The aim of this study was to investigate the cyclic fatigue and torsional resistance of the heat-treated ETP file and compare them with those of the PTG file. A major drawback of many laboratory tests that investigate the mechanical properties of NiTi rotary files is that confounding factors such as material properties, design, and dimensions of the file, are not eliminated. In addition, these factors are also brand-specific, making it difficult to investigate the effect that a single variable has on the mechanical properties of the file. However, PTG and ETP files are similar in design and undergo similar thermal treatment process. Therefore, any differences in the mechanical properties of these files can be explained by the superiority of one brand over the other. In fact, the current results found that, compared with PTG, ETP had improved resistance to cyclic fatigue but failed to show improvement in the torsional resistance. Thus, the null hypothesis was rejected.

PTG has been introduced as an updated version of the PTU. Previous studies (15, 16, 19) found that PTG is more resistant to cyclic fatigue than PTU. This can be explained by the thermal treatment process in PTG which produces files with 2-stage specific transformation behavior and high Af temperature (20). The high Af temperature means that the file will be in the martensitic phase at body temperature resulting in improved file's flexibility and resistance to cyclic fatigue (20). Furthermore, another previous study studied the cyclic fatigue of PTG at different temperatures and found its cyclic fatigue resistance consistent with our results at the simulated body temperature (21). Moreover, it is noteworthy that the current study found the ETP had significantly improved cyclic fatigue resistance by 50% more than the PTG.

Torsional resistance is a mechanical property that implies the potential ability of file to twist before fracture. This is necessary in

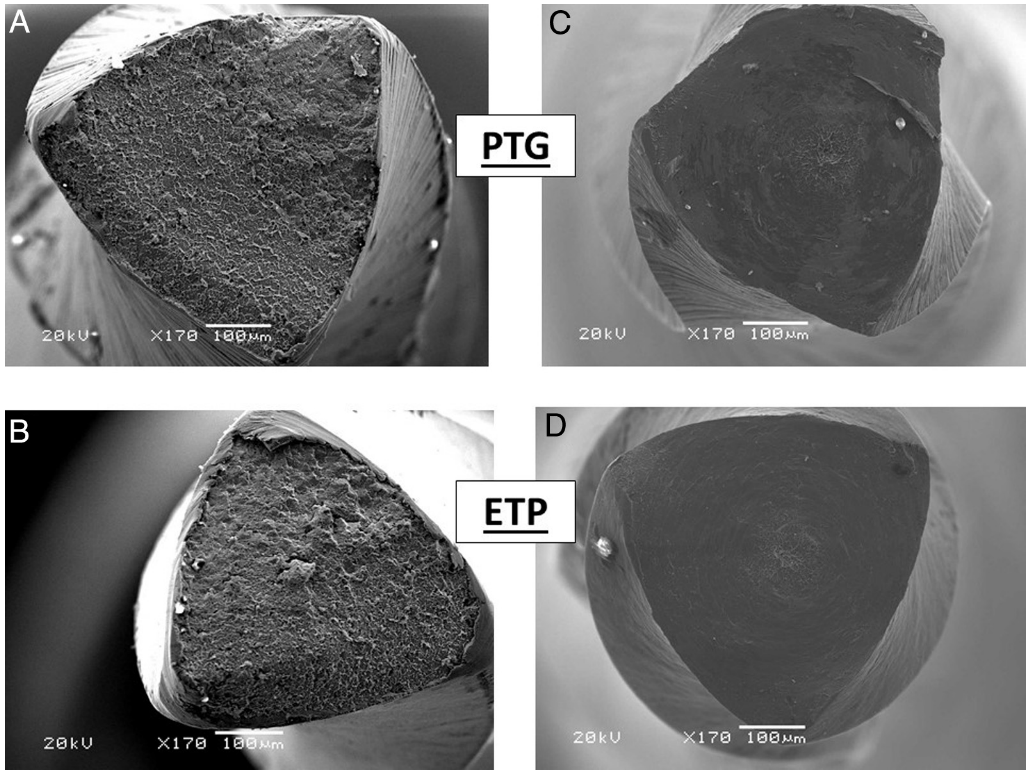

Figure 1. Scanning electron microscopic images showing the fractured surfaces of PTG and ETP after cyclic fatigue (*A* and *B*) and torsional failure (*C* and *D*).

constricted canals where the file is subjected to a high torsional load (22). This property is conventionally tested according to the American National Standard/American Dental Association specification no. 28 and ISO Specification 3630–1 (23), where 3 mm of the file tip is fixed, and the rotational speed is set at 2 rpm. However, in this study, the rotary NiTi file was secured at a level 5 mm from the tip as described in previous torsional resistance studies (14, 24, 25). Besides that, the rotational speed was set at 40 rpm because the rotary NiTi file is moving at higher speed than the manual file.

Past studies have shown that the PTG file is less resistant to torsional stress than the PTU file (15, 16). However, the PTG showed superior torsional resistance, compared with the ETP. Although the tested systems have identical design and features of fractured surfaces under SEM, difference in the torsional resistance were noted. This might be explained by other factors such as the phase transformation. It has been documented that performance of NiTi alloy is influenced by transformation from the austenitic phase to the martensitic phase. This transformation is induced by stress and/or temperature change (26–29). Further investigations should be performed to study the phase transformation behavior and their effect on the mechanical performance (26–29). Moreover, *in vitro* studies have tested the file systems under different temperatures and reported that changing the surrounding temperature affect the file performance (21, 24, 30–32). Therefore, the present study was conducted at a controlled temperature that is close to the intracanal temperature which was reported in a clinical study to be $35.1 \pm 1°C$ (33). This will make it more clinically relevant.

The artificial canals were made with dimensions similar to those of the tested files to eliminate the slight changes in file positioning which can affect the cyclic fatigue behavior. Consistent with previous studies, the fractured site was found to be close to the maximum curvature area; in the range of 4.51–4.99 mm from the file tip, showing that the point of maximum stress was similar in each condition. This confirmed the file positioning in a precise trajectory (16, 21, 31).

The goal of fractographic examination is to identify features on the fractured surface that may indicate the origin and the direction of the crack that has led to the material's failure (34). The fractured surface indicates the actual mechanism involved in the fracture process (2). Two mechanisms are involved in the fracture of NiTi rotary files: cyclic fatigue and torsional failure. The cyclic fatigue is characterized by the presence of fatigue striations. The torsional failure exhibits circular abrasion marks on the fractured surface. In the current study, the PTG and ETP showed similar fractographic features that were of typical cyclic and torsional fatigue behavior.

Conclusion

The ETP showed improved cyclic fatigue resistance but failed to show any improvement in the torsional resistance as compared with its PTG counterpart.

Acknowledgments

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The authors deny any conflicts of interest related to this study.

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