ORIGINAL ARTICLE

Turk Endod J 2022;7(2):69–73
doi: 10.14744/TEJ.2022.63634

Comparison of the cyclic fatigue resistance of four different file systems at body temperature

Sıla Nur Usta, Ayhan Eymirli

Department of Endodontics, Hacettepe University Faculty of Dentistry, Ankara, Türkiye

Purpose: Maintaining the original root canal configuration and minimalizing iatrogenic errors are crucial to mechanical instrumentation. Thus, this study aims to compare the cyclic fatigue resistance of newly developed EndoArt Blue and EndoArt Gold rotary files with ProTaper Gold and ProTaper Universal rotary files at body temperature.

Methods: The study included EndoArt Blue, EndoArt Gold, ProTaper Gold, and ProTaper Universal rotary file systems (n = 12/each group). Files were rotated in the artificial canals at a 60° angle and a 5-mm radius of curvature until fracture occurred. The time to fracture (Ttf) was recorded when a fracture was visually and/or audibly detected. The lengths of the fractured fragments (FL) were also measured. The Ttf and FL data were statistically analyzed using Kruskal–Wallis, One-way analysis of variance and the Bonferroni test at the 5% significance level, respectively.

Results: EndoArt Blue files had the statistically highest fatigue resistance, and ProTaper Universal files had the lowest ($p< 0.001$). There was also a statistically significant difference between EndoArt Gold and ProTaper Gold file systems ($p = 0.001$). There was no statistically significant difference in FL among the groups ($p> 0.05$).

Conclusion: EndoArt Blue file system had a significantly higher cyclic fatigue resistance than EndoArt Gold, ProTaper Gold, and ProTaper Universal file systems.

Keywords: Cyclic fatigue resistance, endodontics, nickel-titanium alloys.

Introduction

Nickel-titanium (NiTi) instruments, produced in the late 1980s, are widely used in endodontic treatments (1). NiTi instruments have beneficial properties such as increased flexibility, shorter treatment time, and fewer procedural errors (2). However, these instruments might separate or fracture during treatment due to cyclic fatigue and torsional stress (3). Cyclic fatigue occurs by continuous tension and compression stresses on the maximum root canal curvature area, especially in curved root canals (4,5).

Various factors can affect the cyclic fatigue resistance of the NiTi instruments, including operational settings, alloy, and metallurgical properties of the instrument (6,7). The environmental temperature during testing influences the cyclic fatigue of these instruments (8). Therefore, methods such as heat treatment, electropolishing, alterations of cross-sections of instruments, and simulation of intracanal temperature were developed (9,10).

Cite this article as: Usta SN, Eymirli A. Comparison of the cyclic fatigue resistance of four different file systems at body temperature. Turk Endod J 2022;7:69-73.
Correspondence: Sıla Nur Usta. Department of Endodontics, Hacettepe University Faculty of Dentistry, Ankara, Türkiye.
Tel: +90 507 – 279 55 58 e-mail: silandeniz29@gmail.com
Submitted: December 29, 2021 Accepted: February 15, 2022

ProTaper Universal (PTU, Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) rotary system has a progressive taper and triangular cross-section design with a high cutting efficiency (11). According to the manufacturer, the progressive taper design of the ProTaper Universal files not only improves flexibility and cutting efficiency; but its shape is also carried through the system with precision-matched components. This system has three shaping (Sx, S1, S2) and five finishing (F1, F2, F3, F4, F5) files (12).

ProTaper Gold (PTG, Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) rotary system has a convex triangle cross-section and a variable taper (Sx, 18/.02, 20/.04, 20/.07, 25/.08, and 30/.09). Advanced metallurgy of a ProTaper Gold system increases flexibility and cyclic fatigue resistance (13).

EndoArt Blue (EAB, Inci Dental, Istanbul, Turkey) and EndoArt Gold (EAG, Inci Dental, Istanbul, Turkey) are recently-developed, heat-treated NiTi rotary file systems. These files have a convex triangle cross-section and control memory. It is commonly suggested that six files can be used during preparing root canals. These files can be categorized as a starter file (Sx), shaping files (S1, S2), and finishing files (F1, F2, F3) (14).

Due to the lack of knowledge and high demand for the use EAB and EAG file systems in Turkey, the investigation of these files' cyclic fatigue resistance is important. Although mechanical features of PTU and PTG files are well documented (15,16), no study compares the cyclic fatigue resistance of the EAG and EAB rotary file systems in the literature. Thus, this study aimed to compare the cyclic fatigue resistance of EAG, EAB, PTG, and PTU file systems at body temperature. The null hypothesis of this study is that there would be no difference between the cyclic fatigue resistance of these four file systems.

Materials and Methods

The total sample size for the study was based on the effect size calculation of the results of a previous study (17). An a priori ANOVA (fixed effects, omnibus, one-way) was selected from the F test family using an alpha-type error of 0.05 and power beta of 0.95 (G*Power 3.1 for Macintosh; Heinrich Heine, Universitat Dusseldorf, Dusseldorf, Germany). In total, 12 samples were indicated as the minimum ideal size required to observe the same effect.

Twelve EAG F2 (25/.06), 12 EAB F2 (25/.06), 12 PTG (25/.08), and 12 PTU F2 (25/.06) files were involved in the present study. All files were 25 mm long. Selected files were examined under a dental operating stereomicroscope at x20 magnification to determine deformations before the cyclic fatigue testing. Since no deformation was found, no files were excluded from the experiments.

Forty-eight files (n = 12 of each group) were placed into a stainless-steel artificial canal which has a 1.5 mm inner diameter, a 60° angle, and a 5-mm radius of curvature as demonstrated in previous literature (18). The distance between the root canal orifice and the first point of the curvature was 12.5 mm. In order to ensure better observation of fractured files, the top of the stainless-steel artificial canal was covered with a plastic sheet. The artificial canal was immersed in distilled water in a glass container and placed into a hot plate to keep the temperature at 35°C ± 1°C (19) (Fig. 1). The temperature of the block and solution was controlled via an infrared thermometer.

All files were used with an endodontic motor (X-Smart Plus, Dentsply, Maillefer, Ballaigues, Switzerland) connected to the cyclic fatigue testing device. All selected files were used according to the manufacturers' recommendations. The EAG and EAB files were operated at a speed of 300 rpm and torque of 3 N/cm^2. The PTU and PTG files were set at a speed of 300 rpm and torques of 2 and 3 N/cm^2, respectively.

Synthetic oil was used inside the artificial root canal model to reduce friction between the metallic files and the metallic walls of the root canal (2,20). Files were placed into the canal up to 17 mm and rotated in the artificial canals until fracture occurred. The time to fracture (Ttf) was measured in seconds by a chronometer in the control panel of the cyclic fatigue testing device. When a fracture was detected visually and/or audibly, time was recorded. The lengths of the fractured fragments (FL) were also measured with a digital microcaliper and recorded.

All statistical analyses were performed using SPSS 26.0 (SPSS, Inc., Chicago, IL, USA). The normality of the data was analyzed not only by the Shapiro–Wilk test but also normality was evaluated by using statistical parameters such as skewness and kurtosis (21). While the data of Ttf did not verify normal distribution, the data of FL verified normal distribution. Therefore, Ttf data were compared by the Kruskal–Wallis test. One-way analysis

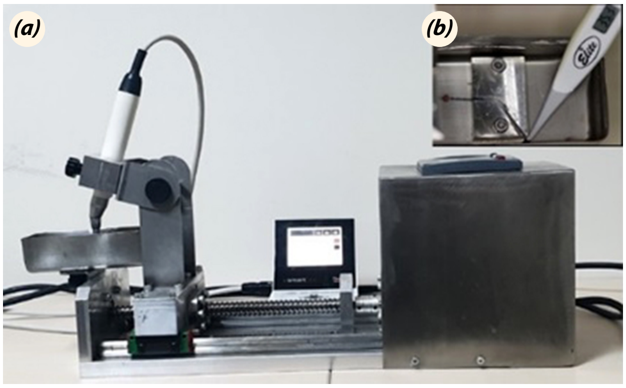

Fig. 1. Cyclic fatigue testing device **(a)**. Preheated distilled water **(b)**.

of variance and the Bonferroni test were performed to compare the data of FL. The statistical significance level was set at 5%.

Results

Table 1 presents the results of Ttf and FL. The mean values of Ttf were 579.9 ± 199.4, 285 ± 33.7, 237.5 ± 28.5, and 84.3 ± 11.9 sec for EAB, EAG, PTG, and PTU file systems, respectively. The EAB file system had the highest fatigue resistance, and the PTU file system had the lowest ($p < 0.001$). There was also a statistically significant difference between EAG and PTG file systems ($p = 0.001$).

The mean values of FL were found as 5.8 ± 0.5, 5.6 ± 0.7, 5.3 ± 0.6, and 5.2 ± 1.1 mm for PTG, EAG, PTU, and EAB file systems, respectively. There was no statistically significant difference in terms of FL ($p > 0.05$).

Discussion

Maintaining the original root canal configuration and minimizing iatrogenic errors is crucial for mechanical instrumentation (22). NiTi files mainly fracture due to cyclic fatigue during root canal preparation (23,24). The prognosis may be affected if file breakage impedes adequate shaping and cleaning of root canal system (25). Therefore, many innovations have been developed in metallurgy design, surface, and thermal treatments for NiTi alloys to improve cyclic fatigue resistance (22).

The present study compared the cyclic fatigue resistance of newly developed EAB, EAG rotary files with PTG, and PTU rotary files at body temperature. According to the results, the EAB file system had the statistically highest cyclic fatigue resistance than other file systems. Hence, the null hypothesis of this study was rejected. Additionally, FLs did not present any significant differences. This result indicates that the tested instruments were correctly positioned within the artificial canal, and similar stresses were induced (26).

Comparing the Ttf values of different NiTi endodontic rotary systems is highly challenged due to their differences in transversal designs, tapers, angular speeds, and NiTi alloy (27,28). The rotary instrument manufacturers provided the amplitude of the oscillating motion within a time unit. Thus, the fatigue resistance of the instruments was evaluated using Ttf instead of the number of cycles to fracture (29). Because there is no study examining the cyclic fatigue resistance of EAB and EAG files, the Ttf values cannot be directly compared with the other study results. Additionally, the mean Ttf values of PTU and PTG files are consistent with other studies (15,27).

Table 1. Time to failure (Ttf) (s) and the fragment length (FL) (mm) of selected file systems during cyclic fatigue testing

File Systems	Ttf (Mean ± SD)	FL
EndoArt Blue	579.9 ± 199.4[a]	5.6 ± 0.7[a]
EndoArt Gold	285 ± 33.7[b]	5.2 ± 1.1[a]
ProTaper Gold	237.5 ± 28.5[c]	5.8 ± 0.5[a]
ProTaper Universal	84.3 ± 11.9[d]	5.3 ± 0.6[a]

SD: Standard deviation. Different upper superscript letters indicate a statistically significant difference ($p < 0.05$).

EAB files showed higher cyclic fatigue resistance than other rotary files. This result can be attributed to these files' increased flexibility, control memory, and blue thermal properties (30). The EAB and EAG files have similar mechanical features (14). However, different heat treatments were used during the production of these files. This difference might be related to the altered molecular structure and higher cyclic fatigue resistance of the blue file. De-Deus et al. (31) investigated the influence of blue thermal treatment on the bending resistance and cyclic fatigue of conventional M-Wire Reciproc files (VDW, Munich, Germany) and reported an improved flexibility and fatigue resistance of Reciproc Blue files.

A statistically significant difference was found between PTG and PTU files in this study which is consistent with previous studies (15,32,33). Although PTG and PTU systems have similar properties such as sizes, taper, and cross-section design, gold thermal treatment increases flexibility and resistance to cyclic fatigue (22). In addition to this, PTG files have a high Af value and 2-stage transformation behavior (33,34). Moreover, PTU files demonstrate lower cyclic fatigue resistance due to their rigidity (35). This knowledge also confirms the results of this study.

Previous studies compared the cyclic fatigue resistance of NiTi files at room temperature. However, environmental conditions also affect fatigue resistance (15). The cyclic fatigue resistance of NiTi files is lower at body temperature than at room temperature (16,36). Therefore, selected NiTi files were used in distilled water heated to 35 ± 1 to imitate clinical conditions. Additionally, a standardized artificial canal was used to mimic clinical conditions and minimize the other variables. In addition, the cyclic fatigue static test was preferred instead of the dynamic test since the dynamic test cannot represent the mechanical behavior of NiTi files (37).

In the present study, FL values of the tested files were not statistically different ($p > 0.05$), and fractures occurred at the center of the curvatures, corresponding to the point of maximum flexure of the shaft. The instruments fractured at approximately 5 mm from the file's tip, and it stated a narrow area of maximum flexure for all files in accordance with the previous studies (2,38). Manufacturers have been working on NiTi file systems with higher mechanical and biological features. Nowadays, in Turkey, the use of EAB and EAG rotary files are increasing. Although these files showed higher cyclic fatigue resistance, further studies are needed for widespread usage of these files in clinical conditions.

Conclusion

Within the limitations of this study, the EAB file system had a significantly higher cyclic fatigue resistance than EAG, PTU, and PTG file systems.

Authorship Contributions: Concept: S.N.U., A.E.; Design: S.N.U., A.E.; Supervision: S.N.U., A.E.; Materials: S.N.U., A.E.; Data: S.N.U., A.E.; Analysis: S.N.U., A.E.; Literature search: S.N.U., A.E.; Writing: S.N.U., A.E.; Critical revision: S.N.U., A.E.

Acknowledgements: The authors would like to thank Inci Dental for providing EAB and EAG rotary file systems.

Source of Funding: None declared.

Conflict of Interest: None declared.

References

1. Tabassum S, Zafar K, Umer F. Nickel-titanium rotary file systems: what's new? Eur Endod J 2019; 4: 111–7. [CrossRef]
2. Higuera O, Plotino G, Tocci L, Carrillo G, Gambarini G, Jaramillo DE. Cyclic fatigue resistance of 3 different nickel-titanium reciprocating instruments in artificial canals. J Endod 2015; 41: 913–5. [CrossRef]
3. Kim JY, Cheung GS, Park SH, Ko DC, Kim JW, Kim HC. Effect from cyclic fatigue of nickel-titanium rotary files on torsional resistance. J Endod 2012; 38: 527–30. [CrossRef]
4. Pedullà E, Lo Savio F, Boninelli S, *et al*. Influence of cyclic torsional preloading on cyclic fatigue resistance of nickel - titanium instruments. Int Endod J 2015; 48: 1043–50.
5. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod 2000; 26: 161–5. [CrossRef]
6. Kitchens GG Jr, Liewehr FR, Moon PC. The effect of operational speed on the fracture of nickel-titanium rotary instruments. J Endod 2007; 33: 52–4. [CrossRef]
7. Bui TB, Mitchell JC, Baumgartner JC. Effect of electropolishing ProFile nickel-titanium rotary instruments on cyclic fatigue resistance, torsional resistance, and cutting efficiency. J Endod 2008; 34: 190–3. [CrossRef]
8. Dosanjh A, Paurazas S, Askar M. The effect of temperature on cyclic fatigue of nickel-titanium rotary endodontic instruments. J Endod 2017; 43: 823–6. [CrossRef]
9. Alapati SB, Brantley WA, Svec TA, Powers JM, Nusstein JM, Daehn GS. SEM observations of nickel-titanium rotary endodontic instruments that fractured during clinical Use. J Endod 2005; 31: 40–3. [CrossRef]
10. Peters OA, Gluskin AK, Weiss RA, Han JT. An in vitro assessment of the physical properties of novel Hyflex nickel-titanium rotary instruments. Int Endod J 2012; 45: 1027–34. [CrossRef]
11. Ullmann CJ, Peters OA. Effect of cyclic fatigue on static fracture loads in ProTaper nickel-titanium rotary instruments. J Endod 2005; 31: 183–6. [CrossRef]
12. DentsplySirona. ProTaper Universal Brochure. Available at: https://www.dentsplysirona.com/content/dam/master/regions-countries/north-america/product-procedure-brand/endodontics/product-categories/files-motors-lubricants/rotary-and-reciprocating-files/protaper-universal/documents/END-Brochure-ProTaper-Universal-Rotary-Files-EN.pdf. Accessed Apr 04, 2022.
13. Elnaghy AM, Elsaka SE. Mechanical properties of ProTaper Gold nickel-titanium rotary instruments. Int Endod J 2016; 49: 1073–8. [CrossRef]
14. Dental I. EndoArt Gold and EndoArt Blue Brochure [Internet] 2020, November. Available at: http://www.incidental.com.tr. Accessed Apr 04, 2022.
15. Uygun AD, Kol E, Topcu MK, Seckin F, Ersoy I, Tanriver M. Variations in cyclic fatigue resistance among ProTaper Gold, ProTaper Next and ProTaper Universal instruments at different levels. Int Endod J 2016; 49: 494–9. [CrossRef]
16. Plotino G, Grande NM, Mercadé Bellido M, Testarelli L, Gambarini G. Influence of temperature on cyclic fatigue resistance of ProTaper Gold and ProTaper Universal rotary files. J Endod 2017; 43: 200–2. [CrossRef]
17. Inan U, Keskin C, Sivas Yilmaz Ö, Baş G. Cyclic fatigue of Reciproc Blue and Reciproc instruments exposed to intracanal temperature in simulated severe apical curvature. Clin Oral Investig 2019; 23: 2077–82. [CrossRef]
18. Pruett JP, Clement DJ, Carnes DL Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod 1997; 23: 77–85. [CrossRef]
19. Gündoğar M, Uslu G, Özyürek T, Plotino G. Comparison of the cyclic fatigue resistance of VDW.ROTATE, TruNatomy, 2Shape, and HyFlex CM nickel-titanium rotary files at body temperature. Restor Dent Endod 2020; 45: e37.
20. Grande NM, Plotino G, Pecci R, Bedini R, Malagnino VA, Somma F. Cyclic fatigue resistance and three-dimensional analysis of instruments from two nickel-titanium rotary systems. Int Endod J 2006; 39: 755–63. [CrossRef]
21. Kim HY. Statistical notes for clinical researchers: assessing normal distribution (2) using skewness and kurtosis. Restor Dent Endod 2013; 38: 52–4. [CrossRef]
22. Gavini G, Santos MD, Caldeira CL, *et al*. Nickel-titanium instruments in endodontics: a concise review of the state of the art. Braz Oral Res 2018; 32: e67. [CrossRef]
23. Cheung GS, Peng B, Bian Z, Shen Y, Darvell BW. Defects

in ProTaper S1 instruments after clinical use: fractographic examination. Int Endod J 2005; 38: 802–9. [CrossRef]
24. Gambarini G. Cyclic fatigue of nickel-titanium rotary instruments after clinical use with low- and high-torque endodontic motors. J Endod 2001; 27: 772–4. [CrossRef]
25. Souter NJ, Messer HH. Complications associated with fractured file removal using an ultrasonic technique. J Endod 2005; 31: 450–2. [CrossRef]
26. Özyürek T. Cyclic fatigue resistance of Reciproc, WaveOne, and WaveOne Gold Nickel-titanium instruments. J Endod 2016; 42: 1536–9. [CrossRef]
27. Hou XM, Yang YJ, Qian J. Phase transformation behaviors and mechanical properties of NiTi endodontic files after gold heat treatment and blue heat treatment. J Oral Sci 2020; 63: 8–13. [CrossRef]
28. Ruiz-Sánchez C, Faus-Llácer V, Faus-Matoses I, Zubizarreta-Macho Á, Sauro S, Faus-Matoses V. The influence of NiTi Alloy on the cyclic fatigue resistance of endodontic files. J Clin Med 2020; 9: 3755. [CrossRef]
29. Keskin C, Sivas Yilmaz Ö, Keleş A, Inan U. Comparison of cyclic fatigue resistance of Rotate instrument with reciprocating and continuous rotary nickel-titanium instruments at body temperature in relation to their transformation temperatures. Clin Oral Investig 2021; 25: 151–7. [CrossRef]
30. Sobotkiewicz T, Huang X, Haapasalo M, *et al*. Effect of canal curvature location on the cyclic fatigue resistance of reciprocating files. Clin Oral Investig 2021; 25: 169–77.
31. De-Deus G, Silva EJ, Vieira VT, *et al*. Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the reciproc files. J Endod 2017; 43: 462–6.
32. Hieawy A, Haapasalo M, Zhou H, Wang ZJ, Shen Y. Phase transformation behavior and resistance to bending and cyclic fatigue of ProTaper Gold and ProTaper Universal instruments. J Endod 2015; 41: 1134–8. [CrossRef]
33. Özyürek T, Yılmaz K, Uslu G. The effects of autoclave sterilization on the cyclic fatigue resistance of ProTaper Universal, ProTaper Next, and ProTaper Gold nickel-titanium instruments. Restor Dent Endod 2017; 42: 301–8. [CrossRef]
34. Shen Y, Gao Y, Qian W, *et al*. Three-dimensional numeric simulation of root canal irrigant flow with different irrigation needles. J Endod 2010; 36: 884–9. [CrossRef]
35. Lee MH, Versluis A, Kim BM, Lee CJ, Hur B, Kim HC. Correlation between experimental cyclic fatigue resistance and numerical stress analysis for nickel-titanium rotary files. J Endod 2011; 37: 1152–7. [CrossRef]
36. Gündoğar M, Özyürek T. Cyclic fatigue resistance of OneShape, HyFlex EDM, WaveOne Gold, and Reciproc Blue Nickel-titanium instruments. J Endod 2017; 43: 1192–6.
37. Keleş A, Eymirli A, Uyanık O, Nagas E. Influence of static and dynamic cyclic fatigue tests on the lifespan of four reciprocating systems at different temperatures. Int Endod J 2019; 52: 880–6. [CrossRef]
38. Topçuoğlu HS, Demirbuga S, Düzgün S, Topçuoğlu G. Cyclic fatigue resistance of new reciprocating files (Reciproc Blue, WaveOne Gold, and SmartTrack) in two different curved canals. J Investig Clin Dent 2018; 9: e12344.