Medical Science

pISSN 2321–7359; eISSN 2321–7367

Bending resistance and cyclic fatigue of TRUShape and ProTaper Next rotary instruments in static and dynamic modes

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To Cite:
Merdad K. Bending resistance and cyclic fatigue of TRUShape and ProTaper Next rotary instruments in static and dynamic modes. Medical Science, 2022, 26, ms287e2216.
doi: https://doi.org/10.54905/disssi/v26i125/ms287e2216

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Peer-Review History
Received: 17 April 2022
Reviewed & Revised: 20/April/2022 to 11/July/2022
Accepted: 16 July 2022
Published: 18 July 2022

Peer-review Method
External peer-review was done through double-blind method.

URL: https://www.discoveryjournals.org/medicalscience

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ABSTRACT

Introduction: The goal of this study was to evaluate the bending and fracture resistance of TRUShape and ProTaper Next files in static and dynamic modes. *Method:* A universal testing machine evaluated the bending resistance of ten randomly chosen files from each system. These files were chosen for the present investigation because they were all 0.25-inch in diameter. Custom-built equipment was used to conduct both static and dynamic cycle fatigue testing. An artificial canal was cut with a 60-degree curve and a 6mm diameter in a stainless-steel block. Scanning electron microscopy was utilized to detect the fracture mechanism after the broken segments' lengths had been determined by other means. New TRUShape and ProTaper Next files were subjected to X-ray energy-dispersive spectrometer (EDS) examination to assess their average nickel and titanium contents. The statistical analysis made use of an independent t-test. *Result:* TRUShape files displayed substantially less bending resistance than ProTaper Next files. Moreover, the TRUShape demonstrated significantly better cycle fatigue resistance than the ProTaper Next in both static and dynamic modes. The EDS analysis demonstrated that the alloy composition of both files was highly comparable. *Conclusion:* When evaluated in static and dynamic modes, TRUShape files outperformed ProTaper Next in cycle fatigue resistance. ProTaper Next files displayed much less flexibility than TRUShape files for dynamic cycle fatigue testing.

Keywords: Bending and fracture resistance, TRUShape Next files, ProTaper Next files, Dynamic mode, static mode, root canal.

1. INTRODUCTION

Nickel-titanium (NiTi) rotary devices are a significant advancement in root canal preparation. Maintaining the root canal's geometrical integrity is possible due to greater flexibility and elasticity (Bürklein et al., 2015; Saber et al., 2015). A crack during root canal preparation might affect treatment results because of cyclic fatigue, making them flexible but prone to unexpected fractures (Alapati et al., 2005; Sattapan et al., 2000; Cujé et al., 2010). Composition, design, and heat treatment play a critical part in NiTi instruments' fracture resistance (Shen et al., 2011). New instruments, including the M-Wire, R-phase, and controlled memory wires, have been developed due to the thermomechanical treatment of NiTi alloy. Improved flexibility and cyclic fatigue resistance may be found in the updated generation of NiTi alloys that have been heat-treated (Braga et al., 2014; Shen et al., 2013).

Before these changes, the cross-section and taper of rotating NiTi instruments were altered to increase their shaping capabilities and fracture resistance (Bürklein et al., 2015; Shen et al., 2016). Further improvements in rotary instruments may be found in nonstandard cross sections, S-curve long axes, and self-adjustable file designs. An additional benefit of using these designs is their ability to preserve canal geometry while removing more germs from the root canal, using less dentin removal (Ahmetoglu et al., 2015; Bortoluzzi et al., 2015). An M-Wire alloy is used to make the ProTaper Next rotary file (Dentsply, Sirona, Ballaigues, Switzerland), incorporating a variable taper design. Flexural responses are delivered better with this file's off-center rectangular cross-section, which is the best design (Braga et al., 2014; Topçuoğlu et al., 2016; Elnaghy, 2015; Ha et al., 2017).

TRUShape files (Dentsply Tulsa Dental Special, Tulsa, OK), which are heat-treated NiTi instruments with an S-curve long axis, are on the market. When tested in a double-curved canal, the TRUShape file beats the Vortex blue, Profile, and One Shape instruments in terms of fatigue resistance (Shen et al., 2016). This is the first time that the fatigue resilience of TRUShape files has been evaluated dynamically. To evaluate bending and cyclic fatigue resistance, we tested the ProTaper Next and TRUShape NiTi files in static and dynamic settings. According to the null hypothesis, there is no statistical difference among the two instruments' bending and cycle fatigue resistance when used in the two modes.

2. METHODOLOGY

This experimental procedure was agreed by King Abdulaziz University (REC-FD#198-01-21), the duration of the experiment was 12 weeks from January 2021 to April 2021. Bending resistance of 10 fresh files from each system was tested on universal testing equipment. This experiment required the use of 60 TRUShape and ProTaper Next files with a 0.25-pixel size. Static and dynamic cycle fatigue testing was carried out using specialized equipment. A stainless-steel block was cut with a 60-degree curvature and a 6mm radius artificial waterway. When the shattered segments' lengths had been determined, scanning electron microscopy was utilized to investigate the kind of fracture that had occurred. An X-ray energy-dispersive spectrometer analysis (EDS) was used to assess the average quantities of nickel and titanium in the new TRUShape and ProTaper Next files.

Binding Resistance Test

Ten new TRUShape and ProTaper Next devices were used in the bending resistance test at random. Bending resistance was measured using universal testing equipment (MultiTest 2.5-i, Mecmesin, Newton House, West Sussex, United Kingdom), as mentioned in earlier research (De-Deus et al., 2017; Silva et al., 2016). The universal machine was fitted with a pre-programmed computer algorithm that ensured a consistent 450 position for all instruments (Emperor, Mecmesin, Sinfold, UK). A wire composed of flexible stainless steel was used to attach a 20-N load cell at 15 mm/min at one end of the instrument. The opposite termination of the wire was attached 3mm from the instrument's tip. The machine was turned on until the instrument's tip expressed elastic displacement and reached 450. The computer application recorded the time and load for each file bent.

Cyclic Fatigue Test

A universal machine was fitted with pre-programmed computer software that ensures a consistent location for all instruments in both static and dynamic modes (Emperor, Mecmesin, Sinfold, UK). One operator was responsible for performing the test in both modes. For the static model, 15 new TRUShape files (TSFILE2525, size 25, 0.06 *v*) and ProTaper Next files (X2, size 25, 0.06 *v*) were selected. Under an operating microscope, the files were examined for flaws (Pico; Zeiss, Oberkochen, Germany). A custom-made system was used to test cyclic fatigue, as described in a previous study (Plotino et al., 2009). The curve of the artificial canal was 600 degrees. According to the manufacturer's specifications, both files were tested at 300 rpm and triggered by an ACTEON motor (ENDODUAL, MERIGNAC Cedex, France). Synthetic oil was used to lessen the amount of friction between the canal's wall and the instrument (Super Oil; Singer Co Ltd., Elizabeth Port, NJ, USA).

Another set of 15 new TRUShape and ProTaper Next files was tested in the dynamic mode. In this mode, the starting position was determined by first lowering the file until it touched the inclined surface of the artificial canal lightly. A second position was recorded by lowering the file 3.0 mm from the first position. The hand piece moved axially 1.5mm above and below the starting position at a frequency of 1cycle/sec (Hz) (Ray et al., 2007) to imitate the pecking motion. The computer recorded the pecking motion pattern and reproduced it with all files. Fractures were detected visually with a magnifying lens fixed to the testing machine. A chronometer with a 1/10 second precision was used to record the time to fracture. The total number of cycles to fracture (NCF) was determined by calculating the duration (seconds) till failure by the number of rotations per minute. Digital micro-calipers (Filetta, Schut Geometrical Metrology, Ebnatstrasse, Schaffhausen, Switzerland) were used to measure the length of the cracked sections in both static and dynamic modes.

SEM Evaluation

Each file evaluated had four fragmented segments that were dressed ultrasonically in absolute alcohol at random from the static and dynamic modes. At various magnifications, SEM was utilized to image the lateral views and fracture surfaces (150-1500X).

X-ray energy-dispersive Spectrometer Analysis (EDS)

TRUShape and ProTaper have announced five new models. The average degrees of nickel (Ni), titanium (Ti), and diverse components in the instruments were then discovered utilizing X-ray beam (EDS) analysis.

Power Analysis

An independent sample t-test was utilized to investigate the test's power. With a total sample size of 60, the values from the t-test analysis (**Table 1**) had a power of 0.99 at p<0.05 (15 per group for each outcome: number of cycles in static and dynamic modes).

Table 1 Number of cycles to fracture (Mean± SD) in static and dynamic mode and bending resistance load.

Group		NCF	Segment length (mm)
Static	TRUShape	496.300±52.929	4.6±.156
	ProTaper Next	447.000±58. 533	4.7±.125
Dynamic	TRUShape	1004.400±205.654	3.160±.189
	ProTaper Next	634.900± 68.276	3.310±.117
All tested groups were significantly different from each others (p<.05). NCF, number of cycles to failure; M, mean; SD, standard deviation; N, Newton			

Statistical Analysis

The data were evaluated with SPSS v22 (SPSS, Inc., Chicago, IL), and the Kolmogorov-Smirnov test was performed to assess its normality. In addition to this, the mean values of the two files in the static and dynamic modes were compared by an independent sample t-test. The 0.05 p-value was used.

3. RESULTS

The data for the NCF were confirmed to be normally distributed using the Kolmogorov-Smirnov test. Both instruments displayed much stronger resistance to cyclic breakage in the dynamic mode than in the static mode (p<0.05). In all modes, the TRUShape files demonstrated much stronger resilience to breakage than the ProTaper Next (p0.05) (p0.05). The ProTaper Next files displayed considerably stronger bending resistance than the TruShape files (p<0.05: Table1). The mean lengths of fragmented segments were substantially longer in the static than in the dynamic mode (p<0.05). The SEM topographic appearance of the broken face displayed morphologic traits typical of ductile fracture. The ProTaper Next displayed sluggish propagation of fractures, whereas the TRUShape exhibited many crack sources in the dynamic mode compared to the one in the static approach **(Fig. 1).** No plastic deformation or cracks were observed in the lateral view for either file. According to the EDS study, the alloy composition of both files was highly comparable, as shown in **Fig 2.**

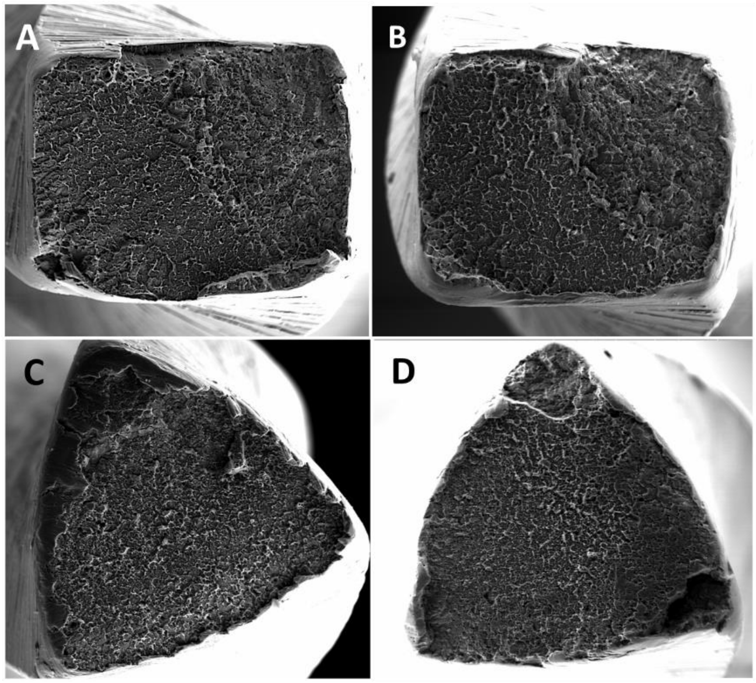

Figure 1 Secondary electron micrograph showing the fractured surface of instruments with morphologic characteristics of ductile fracture: (A) ProTaper Next static test. (B) ProTaper Next dynamic test. (C) TRUShape static test. (D) TRUShape dynamic test (original magnification 750X).

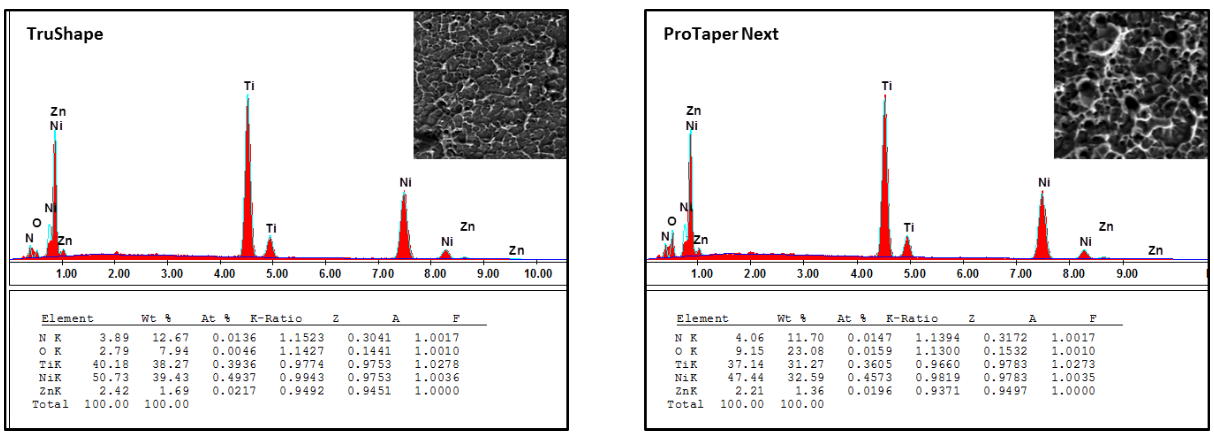

Figure 2 Results of X-ray energy-dispersive spectrometer (EDS) analysis: (A) TRUShape file. (B) ProTaper Next file.

4. DISCUSSION

The fatigue resistance of newly designed NiTi rotary instruments was thoroughly tested using the static mode in single and double canal curvature (Gu et al., 2017). Other research has employed the dynamic mode with a continuous pecking action (Ray et al., 2007; De-Deus et al., 2014). Axial motion is encouraged during cleaning and shaping, and the tool should not remain static in the root canal to avoid the danger of fracture (De-Deus et al., 2014; Li et al., 2002; Dederich and Zakariasen, 1986). Thus, testing instruments represent the pecking motion that is typically used. In contrast, the static mode does not resemble a clinical situation (Ray et al., 2007; Li et al., 2002; Dederich and Zakariasen, 1986). In a previous study, TRUShape files exhibited a unique, slight up and down axial motion during cyclic fatigue tests in a double curvature canal. The authors compared this to its motion in curved canals (Shen et al., 2016). Based on this observation, we selected the dynamic mode to test the cyclic fatigue of TRUShape and used the static mode as a reference test.

Theoretically, in the static mode, the instrument lingers in the area of the highest stress. In contrast, the instrument remains longer in the linear part of the canal in the dynamic mode before passing again through the high-stress area. Both instruments in this investigation exhibited much better fatigue resistance in the dynamic mode than in the static mode, which is consistent with earlier research (Li et al., 2002; Rodrigues et al., 2011). As a result, the null hypothesis was ruled out. Generally, the phase transition and cyclic fatigue resistance of NiTi alloys are affected by heat treatment. TRUShape has a classic R-phase transformation. The R-phase and the martensitic transformation overlap with an austenite finish temperature of approximately 300C, while ProTaper Next has a classic austenite-m phase. This might be due to the heat treatment, flexibility, and various file design (Braga et al., 2014; Hieawy et al., 2015; Govindjee and Govindjee, 2015). Because of heat treatment, flexibility, and other file designs, the TRUshape had better static and dynamic fracture resistance than ProTaper Next files.

In dynamic mode, file designs are considered the most critical factor in contributing to fatigue resistance (Ray et al., 2007). Furthermore, the cross-sectional design and area of the internal core also affect fracture resistance significantly (Shen et al., 2011). In this study, the small, triangular cross-section and the S-curve long axis of TRUShape gave it superior fracture resistance to the ProTaper Next, which has a rectangular cross-section. Similarly, TRUShape exhibited conventional Vortex Blue and ProFile rotary files (Shen et al., 2016). Theoretically, the difference in NCF between the two files should be similar in both modes if they have a similar tip size, taper, and elemental composition. In this study, the percentage difference in NCF of TRUShape and ProTaper Next files was 11%, while the percentage difference in dynamic mode was 58%. The percentage NCF difference of ProTaper Next in static and dynamic modes was 42%, while it was 102% in TRUShape. This statistical difference in the NCF of TRUShape in the two modes might be primarily attributable to the S-curve long axis design, which affects its vulnerability to cyclic failure in dynamic mode (Yao et al., 2006). Moreover, both files have different heat-treatment and fracture resistance (Shen et al., 2013).

Heat-treated files always exhibit a minimum bending load because of changes in the transformation behavior that significantly affect the bending characteristics of the NiTi instrument. The TRUShape file proved less bending resistant than the ProTaper Next in performed tests. These results are attributable to the unique design feature of the S-curve along the TRUShape longitudinal axis, as the bending point was located on the concave side and facilitated bending more than did the linear design of the ProTaper Next (Yahata et al., 2009). However, the current study results showed that the TRUShape rotary files resist dynamic and static cyclic fatigue significantly better than ProTaper Next files. TRUShape files also had the most extended life duration in dynamic cycle fatigue tests and showed more flexibility than the ProTaper Next rotary file.

5. CONCLUSION

Although the authors followed a standardized procedure to test cyclic fatigue of the gadgets in dynamic mode with the assistance of a computer program, it does not depict the mechanical preparatory pecking motion. An interrupted pecking motion is observed more often in the clinical situation, as irrigation and the pecking motion alternate. When evaluated in static and dynamic modes, TRUShape files resist cyclic fatigue better than ProTaper Next. When evaluated for dynamic cycle fatigue, TRUShape files had the most extended lifetime and were substantially more flexible than ProTaper Next files. Appropriate rotating speeds and constant pecking action in the root canals are required to avoid a NiTi rotary tool fracture.

Statement of clinical relevance

The file lifetime represents a great issue for the endodontist, complicating the treatment. Testing the cyclic fatigue resistance in dynamic mode is much closer to the pecking motion in the clinic.

Author contributions

Khalid Merdad conceived the manuscript idea and prepared the original draft.

Ethical approval

This study was approved by King AbdulazizUniversity (REC-FD#198-01-21).

Funding

This study has not received any external funding.

Conflicts of interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Ahmetoglu F, Keles A, Simsek N, Ocak MS, Yologlu S. Comparative evaluation of root canal preparations of maxillary first molars with self-adjusting file, reciproc single file, and revo-s rotary file: A micro-computed tomography study. Scanning 2015; 37(3):218-25. doi: 10.1002/sca.21202.
2. 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(1):40-3. doi: 10.1097/01.don.0000132301.87637.4a.
3. Bortoluzzi EA, Carlon D Jr, Meghil MM, El-Awady AR, Niu L, Bergeron BE, Susin L, Cutler CW, Pashley DH, Tay FR. Efficacy of 3D conforming nickel titanium rotary instruments in eliminating canal wall bacteria from oval-shaped root canals. J Dent 2015; 43(5):597-604. doi: 10.1016/j.jdent.2015.01.001.
4. Braga LC, Faria Silva AC, Buono VT, de Azevedo Bahia MG. Impact of heat treatments on the fatigue resistance of different rotary nickel-titanium instruments. J Endod 2014; 40(9):1494-7. doi: 10.1016/j.joen.2014.03.007.
5. Bürklein S, Mathey D, Schäfer E. Shaping ability of ProTaper NEXT and BT-RaCe nickel-titanium instruments in severely curved root canals. Int Endod J 2015; 48(8):774-81. doi: 10.1111/iej.12375.
6. Cujé J, Bargholz C, Hülsmann M. The outcome of retained instrument removal in a specialist practice. Int Endod J 2010; 43(7):545-54. doi: 10.1111/j.1365-2591.2009.01652.x.
7. Dederich DN, Zakariasen KL. The effects of cyclical axial motion on rotary endodontic instrument fatigue. Oral Surg Oral Med Oral Pathol 1986; 61(2):192-6. doi: 10.1016/0030-4220(86)90186-6. PMID: 3457347.
8. De-Deus G, Leal Vieira VT, Nogueira da Silva EJ, Lopes H, Elias CN, Moreira EJ. Bending resistance and dynamic and static cyclic fatigue life of Reciproc and WaveOne large instruments. J Endod 2014; 40(4):575-579. doi: 10.1016/j.joen.2013.10.013. Epub 2013 Nov 8. PMID: 24666915.
9. De-Deus G, Silva EJ, Vieira VT, Belladonna FG, Elias CN, Plotino G, Grande NM. Blue Thermomechanical Treatment Optimizes Fatigue Resistance and Flexibility of the Reciproc Files. J Endod 2017; 43(3):462-466. doi: 10.1016/j.joen.2016.10.039.
10. Elnaghy AM. Response: Cyclic fatigue resistance of ProTaper Next nickel-titanium rotary instruments. Int endodontic J 2015; 48(11), 1101.
11. Govindjee RG, Govindjee S. Thermal phase transformation in commercial dental files. Structural Eng Mechanics Materials 2015; Report No. USB/SEMM-2015/02.
12. Gu Y, Kum KY, Perinpanayagam H. Various heat-treated nickel-titanium rotary instruments evaluated in S-shaped simulated resin canals. J Dent Sci 2017; 12(1):14-20. doi:10.1016/j.jds.2016.04.006
13. Ha JH, Kwak SW, Versluis A, Lee CJ, Park SH, Kim HC. The geometric effect of an off-centered cross-section on nickel-titanium rotary instruments: A finite element analysis study. J Dent Sci 2017; 12(2):173-178. doi:10.1016/j.jds.2016.11.005
14. 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(7):1134-1138. doi: 10.1016/j.joen.2015.02.030.
15. Li UM, Lee BS, Shih CT, Lan WH, Lin CP. Cyclic fatigue of endodontic nickel titanium rotary instruments: static and dynamic tests. J Endod 2002; 28(6):448-451. doi: 10.1097/00004770-200206000-00007.
16. Plotino G, Grande NM, Cordaro M, Testarelli L, Gambarini G. Measurement of the trajectory of different NiTi rotary instruments in an artificial canal specifically designed for cyclic fatigue tests. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108(3):e152-6. doi: 10.1016/j.tripleo.2009.05.046.
17. Ray JJ, Kirkpatrick TC, Rutledge RE. Cyclic fatigue of Endo Sequence and K3 rotary files in a dynamic model. J Endod 2007; 33(12):1469-72. doi: 10.1016/j.joen.2007.07.041.
18. Rodrigues RC, Lopes HP, Elias CN, Amaral G, Vieira VT, De Martin AS. Influence of different manufacturing methods on the cyclic fatigue of rotary nickel-titanium endodontic instruments. J Endod 2011; 37(11):1553-1557. doi: 10.1016/j.joen.2011.08.011.
19. Saber SE, Nagy MM, Schäfer E. Comparative evaluation of the shaping ability of ProTaper Next, iRaCe and Hyflex CM rotary NiTi files in severely curved root canals. Int Endod J 2015; 48(2):131-6. doi: 10.1111/iej.12291.
20. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod 2000; 26(3):161-5. doi: 10.1097/00004770-200003000-00008.
21. Shen Y, Hieawy A, Huang X, Wang ZJ, Maezono H, Haapasalo M. Fatigue Resistance of a 3-dimensional Conforming Nickel-Titanium Rotary Instrument in Double Curvatures. J Endod 2016; 42(6):961-4. doi: 10.1016/j.joen.2016.02.012.
22. Shen Y, Qian W, Abtin H, Gao Y, Haapasalo M. Fatigue testing of controlled memory wire nickel-titanium rotary instruments. J Endod 2011; 37(7):997-1001. doi: 10.1016/j.joen.2011.03.023.
23. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod 2013; 39(2):163-72. doi: 10.1016/j.joen.2012.11.005.

24. Silva EJ, Rodrigues C, Vieira VT, Belladonna FG, De-Deus G, Lopes HP. Bending resistance and cyclic fatigue of a new heat-treated reciprocating instrument. Scanning 2016; 38(6):837-841. doi: 10.1002/sca.21333.
25. Topçuoğlu HS, Topçuoğlu G, Akti A, Düzgün S.In Vitro Comparison of Cyclic Fatigue Resistance of ProTaper Next, HyFlex CM, OneShape, and ProTaper Universal Instruments in a Canal with a Double Curvature. J Endod 2016; 42(6):969-71. doi: 10.1016/j.joen.2016.03.010.
26. Yahata Y, Yoneyama T, Hayashi Y, Ebihara A, Doi H, Hanawa T, Suda H. Effect of heat treatment on transformation temperatures and bending properties of nickel-titanium endodontic instruments. Int Endod J 2009; 42(7):621-6. doi: 10.1111/j.1365-2591.2009.01563.x.
27. Yao JH, Schwartz SA, Beeson TJ. Cyclic fatigue of three types of rotary nickel-titanium files in a dynamic model. J Endod 2006; 32(1):55-57. doi: 10.1016/j.joen.2005.10.013.