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Cyclic fatigue resistance of ProTaper Universal, Twisted File Adaptive, Reciproc and WaveOne systems

Hüseyin Ertaş,[1] İsmail Davut ÇAPAR,[1] Hakan ARSLAN[2]

[1]Department of Endodontics, İzmir Katip Çelebi University Faculty of Dentistry, İzmir, Turkey
[2]Department of Endodontics, Atatürk University Faculty of Dentistry, Erzurum, Turkey

Objective: The aim of this study was to compare the cyclic fatigue resistance of ProTaper Universal, Twisted File Adaptive, Reciproc and WaveOne systems.

Methods: Four groups of nickel-titanium (Ni-Ti) endodontic instruments were tested in steel canals. The cyclic fatigue of the following Ni-Ti instruments was tested: ProTaper F2, Twisted File Adaptive ML 1, Reciproc R25 and WaveOne primary. The mean rpm of each system was evaluated in the testing block, and the number of cycles to failure was recorded for each instrument.

Results: The Reciproc had the highest fatigue resistance ($p<0.001$) in the tested systems. There was no significant difference between the mean number of cycles to fracture of the WaveOne and the Twisted File Adaptive ($p=0.124$), and the ProTaper Universal showed the least cyclic fatigue resistance ($p<0.001$).

Conclusion: The latest Twisted File Adaptive system could not outclass tested instruments other than ProTaper Universal by means of the cyclic fatigue resistance.

Keywords: Cyclic fatigue; ProTaper; Reciproc; Twisted File Adaptive; WaveOne.

Nickel-titanium (Ni-Ti) rotary files have become an indispensable tool to shape root canals because of their high efficiency. However, during root canal treatment, Ni-Ti rotary instruments may fracture inside the root canal as a result of cyclic fatigue.[1] In clinical practice, the fracture of Ni-Ti rotary instruments occurs via two different mechanisms: torsional fracture and flexural fatigue.[2] Torsional fracture occurs when part of the instrument binds to the dentin while the file continues to rotate.[3] Flexural fatigue fracture of the file occurs when the instrument rotates freely in a curvature, generating tension/compression cycles in the region of maximum şexure until fracture occurs.[1]

Technological advancements in Ni-Ti alloys that increased the cyclic fatigue resistance of the instruments have led to new concepts of use and different kinematics. The Twisted File Adaptive (Sybron Endo, Orange, CA, USA) is a novel system that generates adaptive motion (combination of rotation and reciprocating motion). The motor performs rotation when the file is exposed to minimal or no applied load (600/0 degree intermittent rotation in the clockwise (CW) direction) and performs a modified reciprocal motion (modifying CW/counter clockwise [CCW] angles from 600/0 up to 370/50 degrees) when the file engages dentin and load is applied.

WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc (VDW GmbH, Munich, Germany) files are

Correspondence: Dr. Hüseyin Ertaş. İzmir Katip Çelebi Üniversitesi Diş Hekimliği Fakakültesi, Aydınlıkevler Mah., Cemil Meriç Bulvarı, 6780 Sok., No: 48, 35640 Çiğli, İzmir, Turkey.

Tel: +90 232 325 40 41 e-mail: dentisthuseyin@yahoo.com

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single-file reciprocating systems that have been developed with M-Wire technology. M-Wire is one of a new generation of heat-treated Ni-Ti alloys with increased cyclic fracture resistance.[4] The blades of WaveOne and Reciproc instruments are designed to be active in the CCW direction.[5] However the rotational angles of these instruments are different.

Previous studies comparing the cyclic fatigue resistance of reciprocating instruments used the rpm values claimed by the manufacturers.[4–6] According to the manufacturer, the "WaveOne ALL" mode generates a rotation of 170° CCW and 50° CW, with an approximate velocity of 350 rpm, and the "Reciproc ALL" mode generates a rotation of 150° CCW and 30° CW, with an approximate velocity of 300 rpm.[7] The manufacturer of the Twisted File Adaptive claimed that this system generates approximately 600 rpm. The rotational speed of reciprocating instruments might not be constant. The electrical engine has mechanical limitation for converting the rotation direction, resulting in acceleration and deceleration in both directions of rotation.[7] Moreover, the reciprocation angle of the Twisted File Adaptive systems is not constant. Thus, in the present study, different from the previous literature, the mean rpm of each system was evaluated in a testing block before NCF calculations.

To the best of our knowledge, there are limited data in the literature evaluating cyclic fatigue resistance of the Twisted File Adaptive system. Thus, the purpose of this study was to compare the cyclic fatigue resistance of ProTaper Universal, Twisted File Adaptive, Reciproc and WaveOne systems. The null hypothesis of this study was that there would be no difference in the cyclic fatigue resistance among the tested files.

Materials and methods

The cyclic fatigue of the following rotary Ni-Ti instruments was tested: ProTaper Universal F2 (Dentsply Maillefer), Twisted File Adaptive ML1, Reciproc R25 and WaveOne primary. Twenty instruments from each brand were evaluated in air at a temperature of 23° C. Using a dental operating microscope, each instrument was inspected for defects or deformities before the experiment. All defective instruments were discarded and replaced with new ones.

Artificial canals with an inner diameter of 1.5 mm were created in 100 mm × 66 mm × 10 mm testing blocks made of stainless steel. A glass top face cover was used to prevent the file from slipping out of the artificially created root canal and to allow visualisation of the rotation of the file in the canal. The cyclic fatigue testing was performed on a 60° angle of curvature and a curvature radius of 3 mm. The working length was standardised to 19 mm for all the files. To reduce the friction of the file as it contacted the artificial canal walls, a special oil (WD-40 Company, Milton Keynes, England) was used for lubrication.

Except for the Twisted File Adaptive groups, all the instruments were operated with a low-torque motor (VDW Silver; VDW, Munich, Germany) at their pre-set programs. The Twisted File Adaptive instruments were operated with their own motor (Elements Motor; Sybron Endo, Orange, CA, USA). All the instruments were operated according to the manufacturer's recommendations as follows: ProTaper at 250 rpm and 200 gcm torque, Twisted File Adaptive in its own mode, Reciproc in the Reciproc ALL mode, and WaveOne in the WaveOne ALL mode. The instruments were operated until fracture occurred, and the time to fracture was recorded in seconds. Representative SEM images of the fracture surfaces of the tested instruments were shown in Figure 1a-c and d.

Determination of the mean rpm and number of cycles to fracture (NCF)

To evaluate the mean rpm of each system, the tip of a thin thread was bonded onto the shaft of the instrument. First, all the systems were rotated in the artificial canal of the testing block for 60 sec, and the cycles of the thread was counted via uncoiling thread one by one. The number of the cycles of the thread per minute was recorded as the mean rpm. The mean rpm in cyclic test block was 250, 170, 200 and 400 for the ProTaper, Reciproc, WaveOne and Twisted File Adaptive systems, re-

Table 1. Comparison of mean NCF values

Groups	NCF	SD	Minimum	Maximum
Protaper	457[a]	74	313	613
TFA	580[b]	56	466	680
Reciproc	867[c]	48	771	949
WaveOne	543[b]	47	450	650

*Different superscript letters indicate a significant difference between groups.
NCF: Number of cycles to fracture; SD: Standart deviation; TFA: Twisted file adaptive

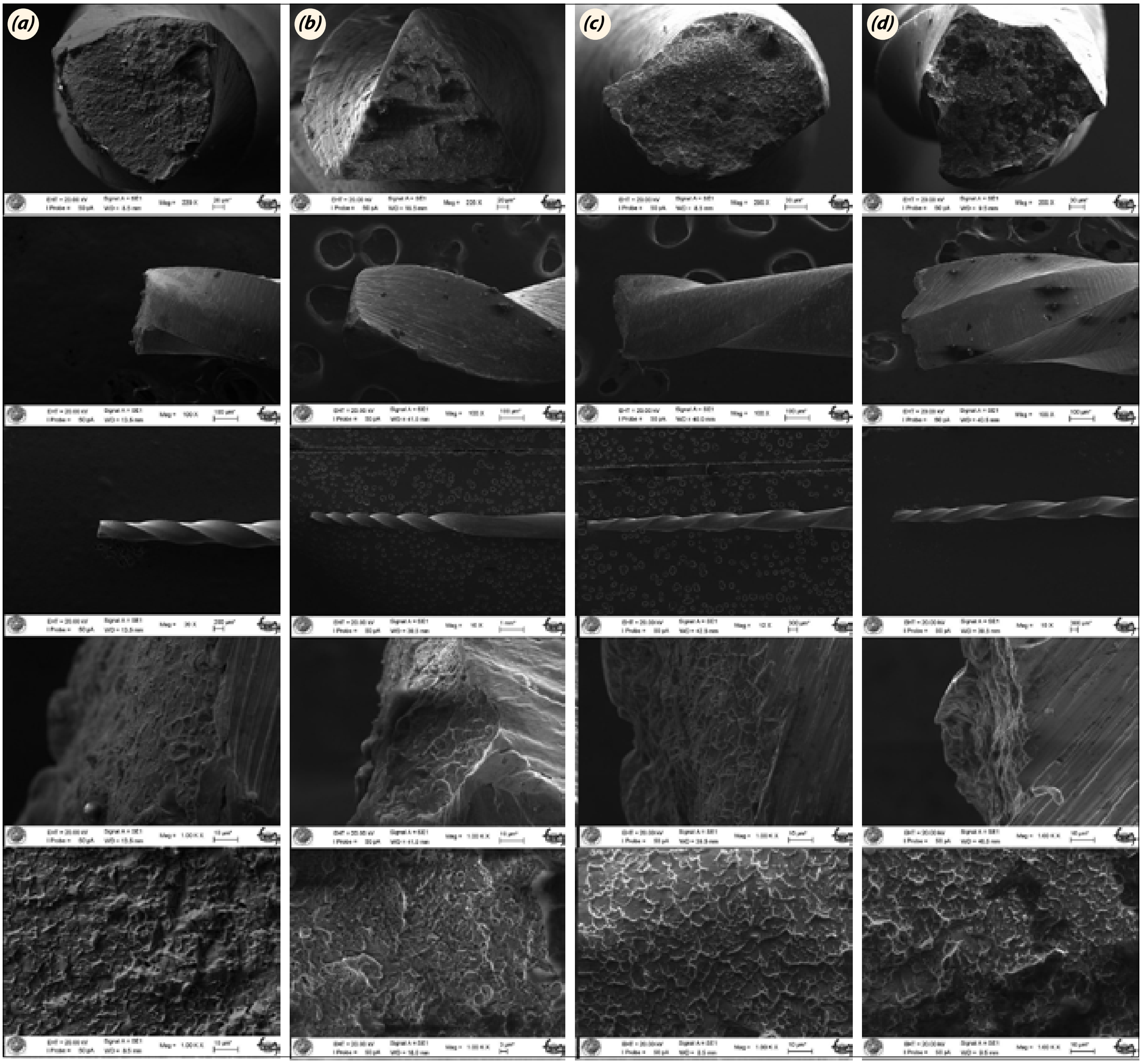

Fig. 1. **(a)** ProTaper Universal, **(b)** Twisted File Adaptive, **(c)** Reciproc and **(d)** WaveOne systems.

spectively. Then, the NCF was calculated using the following formula: NCF = time to failure (second) × "the mean rpm"/60.

Data were then subjected to the Shapiro–Wilk test to analyse the normality of the continuous variables (p>.05). The data were statistically analysed using a one-way ANOVA and posthoc Tukey test (α=0.05).

Results

The NCF for each brand are presented in Table 1. The Reciproc had the highest fatigue resistance (p<0.001). There was no significant difference between the mean NCF of the WaveOne and the Twisted File Adaptive (p=0.124), and the ProTaper Universal showed the least cyclic fatigue resistance (p<0.001).

Discussion

The mechanical behaviour of Ni-Ti alloys is related to the proportions and the characteristics of the microstructural phases. The fatigue resistance of Ni-Ti endodontic files is affected by the transition temperatures of the Ni-Ti alloys that are mainly adjusted with heat treatment.[8,9] In recent years, several novel thermomechanical processing and manufacturing technologies, such as the twisting method, M-wire and CM wire, have been developed to optimise the microstructure of Ni-Ti alloys. These technologies have enabled the development and commercialisation of instruments from alloys with improved mechanical properties. This study compared the cyclic fatigue resistance of a range of such instruments: ProTaper Universal, Twisted File Adaptive system, Reciproc and WaveOne systems.

According to the results of the present study, the Reciproc had the highest fatigue resistance, the WaveOne and Twisted File Adaptive had the second highest fatigue resistance, and the ProTaper Universal had the least fatigue resistance. The null hypothesis of this study that there would be no difference in the cyclic fatigue resistance among the tested files was rejected. This result is in accordance with that reported in previous studies, which found that Reciproc files showed higher cyclic fatigue resistance than ProTaper Universal and WaveOne files.[5–7,10,11]

Pedullà, Grande[11] reported that the use of Ni-Ti rotary instruments in reciprocation motion increases cyclic fatigue resistance when compared to continuous rotation. Similarly the results of this study showed that the reciprocating instruments had higher cyclic fatigue resistance compared to the continuous rotary instrument. Moreover, among the reciprocating instruments, the Reciproc instrument had the highest cyclic fatigue resistance, and there were no significant differences between the Twisted File Adaptive and WaveOne systems. This finding could be explained by the different kinematics or the different cross-sectional designs of the instruments.[12] Both the Twisted File Adaptive and WaveOne have a triangular cross-sectional design. In contrast, the Reciproc has a double-cutting edge S-shaped geometry.

Previous studies comparing the cyclic fatigue resistance of reciprocating instruments used the rpm values claimed by the manufacturers.[4–6] According to the manufacturer, the “WaveOne ALL” mode generates a rotation of 170° CCW and 50° CW, with an approximate velocity of 350 rpm, and the “Reciproc ALL” mode generates a rotation of 150° CCW and 30° CW, with an approximate velocity of 300 rpm.[7] The manufacturer of the Twisted File Adaptive claimed that this system generates approximately 600 rpm. In the present study “the mean rpm”(total 360° rotations in a minute) in cyclic test block was 250, 170, 200 and 400 for the ProTaper, Reciproc, WaveOne and Twisted File Adaptive systems, respectively which were different from the manufacturer’s claim for reciprocating systems. Because manufacturers give the rpm calculated from angular velocity (the rpm at a rotation moment). The rotational speed of reciprocating instruments might not be constant. The electrical engine has mechanical limitation for converting the rotation direction, resulting in acceleration and deceleration in both directions of rotation.[7] Moreover, the reciprocation angle of the Twisted File Adaptive systems is not constant. Thus, in the present study, the mean rpm’s of each system evaluated in the testing block were used in the calculations.

Several different methods have been used to evaluate the cyclic fatigue resistance of Ni-Ti files.[13–15] The method we used, rotating the Ni-Ti files until fracture in a simulated canal machined in a steel block with a 60° curvature, has frequently been used in many studies.[4,6,10,11,15] We used this method to enable comparisons with the results of current studies. Increasing the diameter of the instrument[16] and the metal mass of the instrument at the diameter of maximum stress are important factors with regard to the cyclic fatigue life of rotary instruments.[17] Therefore, in the present study, the fatigue behaviour of Ni-Ti instruments having a similar taper and tip size was examined.

Conclusion

Within the limitations of this study, the latest Twisted File Adaptive system could not outclass tested instruments other than ProTaper Universal by means of the cyclic fatigue resistance.

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

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