Atatürk Üniv Diş Hek Fak Derg (*J Dent Fac Atatürk Uni*)
Cilt:31, Sayı:3, Yıl: 2021, Sayfa: 385-9

Araştırma/ Research Article

IN VITRO COMPARISON OF CYCLIC FATIGUE RESISTANCE OF PROTAPER NEXT AND TRUSHAPE 3D CONFORMING FILE NICKEL-TITANIUM ROTARY INSTRUMENTS

PROTAPER NEXT VE TRUSHAPE 3D CONFORMİNG FİLE NİKEL-TİTANYUM DÖNER ALETLERİNİN DÖNGÜSEL YORULMA DİRENÇLERİNİN İN VITRO OLARAK KARŞILAŞTIRILMASI

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Makale Kodu/Article code: 4486
Makale Gönderilme tarihi: 06.07.2020
Kabul Tarihi: 26.11.2020
DOI : *10.17567/ataunidfd.831765*

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ABSTRACT

Aim: The purpose of this study was to compare the cyclic fatigue resistance of all instruments of the ProTaper Next (PTN) and TRUShape 3D Conforming File (TRS) systems.
Materials and Methods: A total of 120 nickel–titanium rotary instruments were divided into eight groups: PTN X1, PTN X2, PTN X3, PTN X4, TRS 20/.06v, TRS 25/.06v, TRS 30/.06v and TRS 40/.06v. Each group had 15 instruments. All the instruments were tested for cyclic fatigue resistance in stainless steel artificial canals with 5 mm radius and 60° angle of curvature. They were rotated until they got fractured, and the test was performed in a saline solution at 35°C (±2). The number of cycles to fracture (NCF) was calculated by measuring the time to fracture. The NCF data were analysed statistically using the Kruskal–Wallis H and post hoc Tamhane T2 tests for multiple comparisons (α-level = 0.05).
Results: The PTN X1 group had the highest NCF ($P < 0.05$). There was no statistically significant difference between the X2 and TRS 25/.06 groups ($P > 0.05$). However, there was a statistical difference between the other groups of similar sizes (X1–TRS 20/.06v) (X3–TRS 30/.06v) (X4–TRS 40/.06v) ($P < 0.05$).
Conclusion: Within the limitations of this study, most of the PTN instruments (X1, X3, and X4) have better cyclic fatigue resistance than do TRS instruments (20/.06, 30/.06 and 40/.06) even if they were manufactured with older technology. This result showed that the S-curve design increases the risk of fracture in instruments with large tapers and tip sizes.
Keywords: *cyclic fatigue resistance, S-curve design, TRUShape*

ÖZ

Amaç: Bu çalışmanın amacı ProTaper Next (PTN) ve TRUShape 3D Conforming File (TRS) sistemlerindeki tüm döner aletlerin döngüsel yorulma dirençlerinin kıyaslanmasıdır.
Gereç ve Yöntem: Toplam 120 nikel-titanyum döner alet 8 gruba bölündü: PTN X1, PTN X2, PTN X3, PTN X4, TRS 20/.06v, TRS 25/.06v, TRS 30/.06v and TRS 40/.06v. Her bir grupta 15 alet vardı. Tüm aletler 5 mm yarıçaplı ve 60 ° eğimli açıya sahip paslanmaz çelik yapay kanallarda döngüsel yorgunluk direnci açısından test edilmiştir. Aletler kırılana kadar döndürüldü ve test 35°C (±2) sıcaklıkta serum solüsyonu içinde gerçekleştirildi. Döngüsel Kırılma sayısı (DKS), kırılma zamanı ölçülerek hesaplandı. DKS verileri Kruskal–Wallis H testi ve post-hoc Tamhane T2 çoklu karşılaştırma testleri ile istatistiksel olarak analiz edildi (α-level = 0.05).
Bulgular: PTN X1 grubu en yüksek DKS'ye sahipti ($P < 0.05$). PTN X2 and TRS 25/.06 grupları arasında istatistiksel açıdan bir fark yoktu ($P > 0.05$). Benzer boyutlara sahip diğer gruplar arasında ise istatistiksel olarak fark vardı (X1–TRS 20/.06v) (X3–TRS 30/.06v) (X4–TRS 40/.06v) ($P < 0.05$).
Sonuç: Bu çalışmanın sınırları dahilinde, PTN döner aletlerinin bir kısmı (X1, X3 ve X4) daha eski bir teknoloji ile üretilmiş olmalarına ragmen, TRS döner aletlerinden (20/.06, 30/.06 ve 40/.06) daha yüksek döngüsel yorulma direncine sahiptir. Bu sonuç, S-eğimli tasarımın özellikle büyük konik ve uç boyutlarına sahip döner aletlerde kırılma riskini arttırdığını göstermiştir.
Anahtar Kelimeler: *döngüsel yorulma direnci, S-eğimli tasarım, TRUShape*

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Kaynakça Bilgisi: Uygun AD, Ünal M, Evcil S, Aladağ H. In vitro comparison of cyclic fatigue resistance of ProTaper next and TRUShape 3d conforming file nickel-titanium rotary instruments. Atatürk Üniv Diş Hek Fak Derg 2021; 31: 385-9.
Citation Information: *Uygun AD, Unal M, Evcil S, Aladag H. ProTaper next ve TRUShape 3D conforming file nikel-titanyum döner aletlerinin döngüsel yorulma dirençlerinin in vitro olarak karşılaştırılması. J Dent Fac Atatürk Uni 2021; 31: 385-9.*

INTRODUCTION

Nickel–titanium (NiTi) rotary instruments have become indispensable to root canal treatment with superelasticity and shape memory for many years.[1] They are produced in a variety of design and manufacturing processes, each aiming to improve performance and safety. Nevertheless, the breakage of these instruments by virtue of cyclic fatigue is still a distressing condition in root canal treatment for clinicians.[2, 3] The breakage of NiTi rotary files can be broadly classified into two types: (i) cyclic fatigue and (ii) torsional stress.[4, 5] Many influences—such as alloy, manufacturing technology, cross section, geometric design and speed, torque, and kinematics—have an effect on the cyclic fatigue resistance of NiTi rotary instruments.[6-8] Nowadays, instruments with diverse geometric designs are produced from the currently used NiTi rotary systems.

The ProTaper Next system (PTN; Dentsply Maillefer, Ballaigues, Switzerland) is made of a unique NiTi alloy called M-wire. M-wire is manufactured through a thermal treatment process. The PTN system has an off-centred, rectangular cross-sectional design which diminishes the screw effect, taper lock, and torque on any given file by minimizing the contact between the file and the dentinal wall. A great deal of research has been conducted on the subject.[6, 9-11]

The TRUShape 3D Conforming File system (TRS; Dentsply Tulsa Dental Specialties, Tulsa, OK, USA)—an innovative NiTi rotary system of instruments—has an off-centred, triangular cross-sectional and S-curve design along the cutter part of the instrument recently developed by the same manufacturer. The TRS system is produced by a blue NiTi alloy with proprietary processing. Thanks to the modified cross section with an eccentric centre of mass (off-centred), only two points of the cross section ever touch the dentinal walls at any one time during canal preparation.[12, 13]

The TRS system has attracted attention with its different S-curve design in recent years. Many studies have been conducted comparing the cyclic fatigue resistance of the TRS system with NiTi rotary instruments of other manufacturers.[14-16] However, these studies are related to the size 25/.06v instrument of the system, and there is no study in the literature on the remaining instruments of the system. The objective of this study was, therefore, to evaluate and compare the cyclic fatigue resistance of all the PTN and TRS systems. The null hypothesis of the study was that there is no difference in the cyclic fatigue resistance between PTN and TRS files.

MATERIALS AND METHODS

Two different commercial NiTi rotary systems of the same brand, 60 PTN and 60 TRS, were divided into eight groups (with 15 instruments each). The TRS system exists as a series of instruments that are denoted as TRS 20/.06v, TRS 25/.06v, TRS 30/.06v, and TRS 40/.06v. The PTN system consists of instruments numbered as X1 (17/.04), X2(25/.06), X3 (30/.075), and X4 (40/.06). The X5 (50/.06) instrument was not included in this study because we compared instruments with similar dimensions and there was no equivalent for the X5 instrument in the TRS system. All the instruments were previously examined using an optical stereomicroscope with 20× magnification to test for the signs of a manufacturing defect.

A custom testing device was built to perform cyclic fatigue testing in this study (Figure 1). A 1:16 reduction contra-angle handpiece was mounted so as not to move for standard contact. An artificial stainless steel canal was mounted on a mobile device to allow three-dimensional positioning in the same way as that of other instruments. According to the method of Pruett *et al.*,[17] cyclic fatigue testing was performed on an artificial stainless steel canal at a 60° angle and 5 mm radius of curvature. In this study, the curvature centre was 5 mm from the tip of the instrument. All the instruments were rotated with a low-torque motor (VDW Silver; VDW, Munich, Germany), and according to the manufacturer’s recommendations, the speed and torque settings were 300 rpm and 300 g cm^{-1} for PTN and TRS instruments. A glass block was placed over the artificial stainless steel canal to allow the breakage to be seen and the broken piece to escape. Cyclic fatigue testing was performed in a saline solution at 35°C (±2) heated by a device designed for this experiment, and the temperature was controlled by means of a thermostat.

The instruments were rotated until they were broken, and the time to fracture was recorded in seconds with a chronometer. The number of cycles to fracture (NCF) was calculated. One fractured instrument from each group was examined under a scanning electron microscope (LEO 1430 VP, Zeiss Oberkochen, Germany) (Figure 2). The NCF data were first subjected to the Levene test for equality of variances and then analysed statistically using the Kruskal–Wallis H and post hoc Tamhane T2 tests for multiple comparisons. SPSS (v.23.0; IBM Corp., Armonk, NY, USA) was used to analyse the data statistically. The level of significance was set at 0.05.

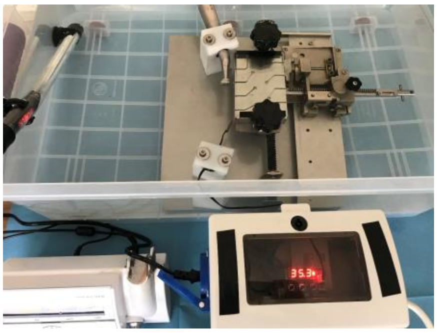

Figure 1. The testing device used for the study.

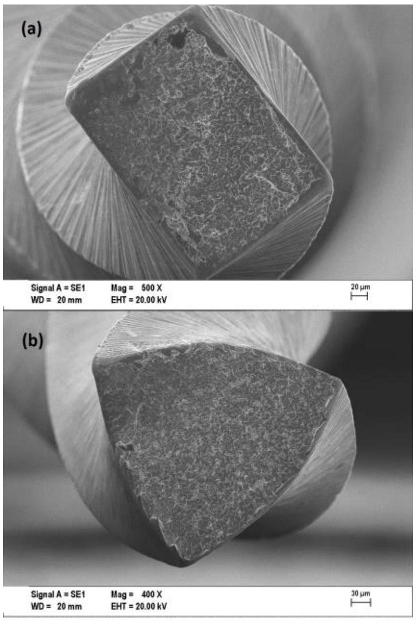

Figure 2. Scanning electron microscope images of ProTaper Next X2 (a) and 25/.06v TRUShape 3D Conforming File (b)

RESULTS

The mean and standard deviations of NCF for PTN and TRS instruments of different sizes are presented in Table 1. The PTN X1 group had the highest NCF ($P < 0.05$). There was no statistically significant difference between the X2 and TRS 25/.06v groups ($P > 0.05$). However, there was a statistical differrrence between the other groups (X1–TRS 20/.06v) (X3–TRS 30/.06v) (X4–TRS 40/.06v) ($P < 0.05$).

Table 1. The Mean and Standard Deviation (SD) Values for the Number of Cycles to Fracture

	MEAN	SD
PTN X1	991,66^{a}	85,78
PTN X2	674,66^{c}	48,34
PTN X3	616,66^{d}	39,80
PTN X4	497,66^{e}	27,50
TRS 20/.06v	766,33^{b}	59,53
TRS 25/.06v	655,33^{cd}	49,36
TRS 30/.06v	552,00^{e}	52,50
TRS 40/.06v	649,79^{f}	37,23

Different symbols indicate a statistically significant difference (P < 0.05).

DISCUSSION

Generally, a fracture resistance study is performed by selecting the instruments of multiple-instrument systems, with only a certain size. However, making inferences about other elements of the system with only one instrument is not the right approach, especially about the TRS system with a unique design. Therefore, in this study, all the instruments of the PTN and TRS systems were compared with their counterparts with similar dimensions. A file system with S-curve design, such as TRS, is not available to our knowledge. Although it is not exactly the same, there is an instrument called Xp-endo Shaper with an offset design similar to it, but it is only a single-instrument system and not a multiple-instrument one. Therefore, it is not known how the S-curve design affects cyclic fatigue resistance in instruments with different tapers and tip sizes. Hence, it should be examined especially in such instruments. In this study, it was compared with the PTN system, which is produced by the same manufacturer.

It is important for clinicians to consider positive and negative aspects of PTN and TRS instruments to prefer a more appropriate file system in different cases. The S-curve design of TRS instruments is able to conserve dentine by limited dentine removal and minimal canal transportation.[12] Another study has shown that TRS instruments are effective in removing calcium hydroxide from artificially created grooves on the canal walls.[18] Despite these advantages, in the present study, the TRS system has lower cyclic fatigue resistance compared with the PTN system produced before it and with old technology. Thus, the null hypothesis of the present study was rejected.

As a result of our work, most (not all) of the PTN instruments have better cyclic fatigue resistance than the similar-size counterparts of the rotary files of the TRS system, even if it was manufactured with newer technology. Likewise, the S-curve design has been shown to reduce cyclic fatigue resistance compared with straight-designed instruments with larger tapers and tip sizes. In particular, TRS instruments (30/.06v and 40/.06v) with larger tapers and tip sizes have been shown to increase the risk of instrument fracture in curved root canals more. Because X1 (17/.04) has the smallest taper and tip-size instrument, it had the highest cyclic fatigue resistance, as expected in this study. V1 (20/.06v) had larger dimensions than X1. There was no statistically significant difference between X2 (25/.06) and V2 (25/.06v) instruments ($P > .05$).

It has been reported in a recent study that PTN X2 instruments had higher cyclic fatigue resistance than TRS 25/.06v instruments had in a stainless steel artificial canal at room temperature.[16] However, according to developments in recent years, it has been shown that the ambient temperature affects the mechanical properties of NiTi rotary instruments, and it is more appropriate to perform these studies at intracanal temperature rather than room temperature.[14, 19] This study was conducted at intracanal temperature, and this result might have occurred because of the difference in experimental set-ups. Instrument fracture due to cyclic fatigue results from the accumulation of compressive and tensile stresses on the curvature area of the root canal. However, in this study and most of the studies in the literature, although the S-curve design of the TRS system distributes the stress instead of collecting it at a point on the curvature area, the design does not have higher cyclic fatigue resistance than do straight-designed files.[14, 16, 20] Nevertheless, Shen *et al.*[20] evaluated the cyclic fatigue resistance of TRS and other NiTi instruments in a single curvature (60°) and two different double curvatures (60°–30°) (60°–60°). They reported that the fatigue resistance of TRS instruments was higher than that of other instruments only in double-curvature canals. They claimed that this result is due to the TRS instrument moving slightly axially within the canal (especially in double-curvature canals) thanks to the S-curve design, reducing stress concentration in the same area. The resistance to fracture is enhanced.[21]

In this study, most of the PTN instruments were found to have higher fracture resistance compared with TRS instruments. This result can be thought to be due not only to the design of the instruments but also to their alloys. The PTN system is produced by a NiTi alloy called M-wire, a material that undergoes a proprietary thermomechanical process to improve cyclic fatigue resistance compared with classic NiTi alloy.[22] As far as known, the TRS system is produced by a NiTi alloy with proprietary processing. In a study comparing the thermal phase transitions of these NiTi instruments, PTN instruments displayed a classic austenite–martensite (presumably cubic–monoclinic) phase transformation centred close to body temperature. On the contrary, TRS instruments showed classic R-phase transformations. However, in both the cooling and heating cycles, the R-phase and martensitic transformations overlap and cannot be separated in terms of transformation temperature. That is, there is no difference in fatigue resistance between conventional (non-heat-treated) NiTi alloy and alloy of the TRS system.[23]

CONCLUSION

Within the limitations of this study, the TRS instruments (30/.06v and 40/.06v) with larger tapers and tip sizes have lower cyclic fatigue resistance than do PTN instruments (X3 and X4). This result showed that the S-curve design increases the risk of instrument fracture in larger tapers and tip sizes. Studies are required in which S-curved instruments are compared with straight-designed NiTi instruments in terms of their fracture resistance.

Conflicts of interest
There are no conflicts of interest.
Acknowledgements
The authors declare that there were no other contributors involved in this work.

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