CYCLIC FATIGUE OF REVO-S NICKEL-TITANIUM ROTARY INSTRUMENTS IN ARTIFICIAL CANALS WITH TWO DIFFERENT RADII OF CURVATURE

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ABSTRACT

Background and Aim: Rotary nickel-titanium (NiTi) instruments allow for more predictable instrumentation of curved canals with a lesser risk of transportation, ledging, and perforations than stainless-steel instruments. Nevertheless, despite all the aforementioned benefits, there is a higher risk of instrument separation with rotary NiTi instruments, specifically during the instrumentation of curved canals. To assess the resistance to cyclic fatigue of Revo-S NiTi files, artificial canals with 5mm and 10mm curvature radii were operated on.

Materials and Methods: A total of 120 new Revo-S files (Micro Mega, Besancon, France) were used. Revo S of tip sizes SU, AS30, AS35, and AS40 were subjected to cyclic fatique testing in stainless-steel artificial canals with curvature radii of 5 and 10 mm until fracture occurred (n=15 for each group). The mean fragment length (MFL [in millimeters from the shaft to the fracture point]) was measured under 10x magnification with an electronic gauge to assess the location of the fracture. The number of cycles for each instrument until the time of fracture (NCF) was recorded. Statistical analysis was performed using two way ANOVA test, followed by Tukey HSD post hoc test.

Results: Revo-S files were associated with a significantly higher cyclic fatique resistance at the 10-mm radius group than that of the 5-mm radius group ($P < 0.001$). For the 10-mm radius group, AS30 had the highest NCF, followed by AS40, AS 35 and SU.

Conclusions: Cyclic fatigue resistance of Revo-S files was dependent on both the curvature radius of the canal and the instrument size.

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Keywords: Curvature Radius, Cyclic Fatigue, File Sizes, Nickel-Titanium, Revo-S Files

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REVO-S NİKEL-TİTANYUM DÖNER ALETLERİN İKİ FARKLI EĞRİLİK ÇAPINDAKİ DÖNGÜSEL YORGUNLUĞU

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ÖZ

Amaç: Döner nikel titanyum (NiTi) aletler, eğri kanalların paslanmaz-çelik aletlere göre daha az transportasyon, basamak ve perforasyon riskiyle daha merkezde şekillendirilmesini sağlar. Revo-S NiTi eğelerin 5 mm ve 10 mm eğrilik çapında kullanıldığı zamanki döngüsel yorgunluğunun değerlendirilmesidir.

Gereç ve Yöntemler: Toplam 120 yeni Revo-S eğesi (Micro Mega, Besancon, Fransa) kullanıldı. Revo S uç çapları SU, AS30, AS35 ve AS40, 5 ve 10mm eğrilik çapındaki paslanmaz çelik yapay kanallarda kırık olana dek döngüsel yorgunluk testine maruz bırakıldı (n=15, her bir grup için). Ortalama kırık parça uzunluğu (MFL [saptan kırılma noktasında dek milimetre cinsinde]) x10 büyütmede elektronik kumpas ile ölçülerek kırığın yeri değerlendirildi. Herbir eğe için kırık olana dek olan dönme sayısı (NCF) kaydedildi. İstatistiksel analiz two way ANOVA testi, takibinde de Tukey HSD post hoc testi kullanılarak yapıldı.

Bulgular: Revo-S eğeleri 10-mm çaplı grupta 5-mm çaplı gruptan anlamlı derecede daha yüksek döngüsel yorgunluk direncine sahipti ($P < 0.001$). 10-mm çaplı grupta, AS30 en yüksek NCF'sini, sırasıyla AS40, AS 35 ve SU takip etmektedir.

Sonuçlar: Revo-S eğelerin döngüsel yorgunluk direnci hem eğrilik çapı hem de eğe boyutuna bağlıdır.

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INTRODUCTION

Nickel-titanium (NiTi) rotary files have become popular to shape root canals due to their elasticity, shape memory and cutting capacity.[1] They have a combination of the unique mechanical properties of alloy, innovative file design, greater tapers and a crown down instrumentation procedure.[2]

Despite these advantages, unexpected fractures of these NiTi rotary instruments are a major concern. One of the main reasons for the fracture of NiTi instruments is torsional or cyclic fatigue.[3,4] Torsional fatigue occurs when the tip of the instrument binds in the canal while the shank continues to rotate. Cyclic fatigue of an instrument occurs due to the repetitive alternating compressive and tensile stresses inside the curvature of the canal, which ultimately results in the fracture of NiTi instruments.[4,5] Parameters such as curvature radius, curvature angle, instrument taper and size, and the point where maximal instrument flexure occurs are all found to have significant effects on the number of cycles to failure (NCF) and location of breakage. Increased severity in the angle[6] and radius[7] of the curvature, around which the instrument rotates, decreases the instruments lifespan.[6,7]

There are now many systems available commercially, that uses NiTi rotary instruments of different designs and dimensions. Revo-S (Micro-Mega, Besancon, France), one of these systems, has been introduced with features designed to reduce the amount of stress on the instrument. Its manufacturer claims that its asymmetric cross-sectional geometry facilitates canal preparation, eases upward removal of debris, and increases the flexibility of the instrument. While these features may help lower the stress on the instrument, a recent study found that Revo-S SU was not more resistant to cyclic fatigue compared to other instruments such as Twisted File and Mtwo.[8] Similar results were found with regards to torsional fracture as well. In another study, Basrani et al.[9] assessed the torsional profile of Revo-S SU instruments and reported that the mean torque at fracture for Revo-S SU instruments was 0.69 Ncm, which was lower than GTX, K3, and ProTaper F2 instruments. Despite these studies, little is known about the cyclic fatigue behavior of other Revo-S instrument sizes (e.g., AS30, AS35, and AS40). Hence, this study aims to address this need by evaluating the cyclic fatigue resistance of four different sizes of Revo-S NiTi rotary instruments.

MATERIALS AND METHODS

One-hundred twenty new NiTi Revo-S files (Micro-mega, Besançon, France) (all 25 mm in length with 06 tapers) were used in this study. Fifteen instruments of each size (SU, AS30, AS35, and AS40) were tested within two types of artificial canals having curvature radiuses of 5 or 10 mm (n=15). The NiTi system included four instruments, all of which were used to the working length: 1) universal shaper SU was a #25/.06 taper, 2) AS30 was a #30/.06 taper apical enlargement instrument, 3) AS35 was a #35/.06 taper apical enlargement instrument, and 4) AS40 was a #40/.06 taper apical enlargement instrument.

Fatigue testing of Revo-S instruments was performed with a cyclic fatigue testing (CFT) device using a procedure previously described by Gambarini.[10] The CFT device allowed the instruments to rotate freely inside an artificial stainless steel canal with a 5 mm curvature radius. The CFT device held together a concave tempered-steel block, and a convex tempered cylinder on a steel plate to maintain the curvature of the instruments. The same procedure was repeated to test the instruments in another artificial canal with a radius curvature of 10 mm. The instruments were rotated at a nominal speed of 300 rpm using the Dentaport Tri Auto ZX device (J Morita, Japan) until fracture occurred. A lubricant (WD-40 Co., Milton Keynes, U.K.) was used to reduce the friction of the file while it was rotating inside the artificial canal.

The time of fracture was measured using a 1/100 second digital chronometer and based on the audiovisual observation of the fracture by a researcher. The time to fracture was multiplied by the number of rotations per minute to obtain the number of cycles to fracture (NCF) for each instrument. Mean values were then calculated for each group (NCF= Time to fracture × Number of rotations per minute). The length of the broken fragments was measured using a Vernier caliper by observing under a microscope (×10 magnification). The fractured surfaces of representative samples of instruments were evaluated using SEM (JSM 6400, Joel, Tokyo, Japan).

Statistical analysis

The data were analyzed by using two way ANOVA test, followed by Tukey HSD post hoc test. Significance was determined at the 95% confidence level.

RESULTS

The 5-mm radius group had significantly fewer NCF than the 10-mm radius group for all instrument sizes except the SU group (Table 1, Figure 1, Figure 2). Statistically significant differences in NCF and instrument sizes were found ($p < 0.001$, two way ANOVA test).

Table 1. Revo-S instruments' NCF of both 5-mm and 10-mm radius groups

Groups	5mm (Mean ± SD)	10mm (Mean ± SD)	p valuea
SU	204 ± 32.1	458 ± 77.0	0.339
AS30	282 ± 108	1332 ± 396	0.000
AS35	164 ± 69.4	555 ± 163	0.022
AS40	139 ± 32.4	950 ± 384	0.000

[a]Tukey HSD post-hoc test

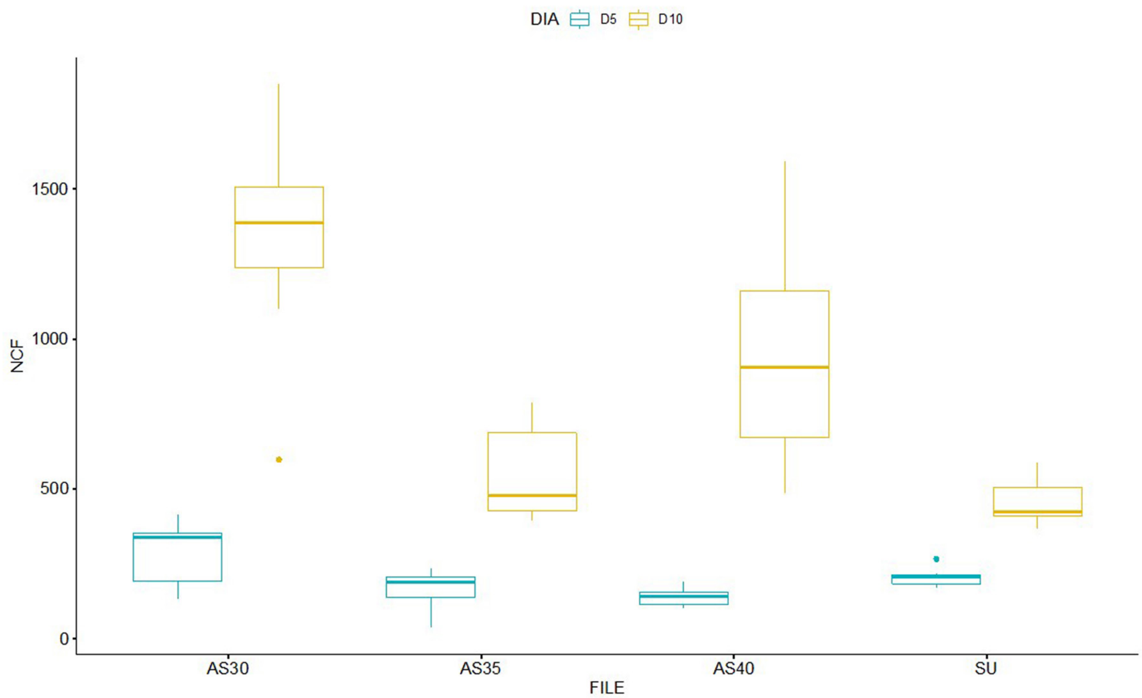

Figure 1. Box plot NCF 5vs 10 mm diameter

There was no significant difference between instrument groups in the 5-mm radius group (Tukey HSD post hoc test). Within the 10 mm radius group, the AS30 group was significantly different from all other groups, and there was also a difference between AS40 and AS35 (p=0.020). The Tukey HSD test showed that significant differences were found between instrument sizes according to curvature radius (p<0.0001).

The mean fragment length (MFL) was recorded in millimeters (Table 2). All fractures, regardless of file size, occurred within the area of the curvature in both curvature groups. A shorter MFL was found for small sized instruments (e.g., SU) than that of the larger sized files (e.g., AS30, AS35, and AS40).

The two way ANOVA test demonstrated that, regardless of the instrument size, the MFL values were significantly affected by the curvature radius (p<0.0001). Significant differences between 5-mm radius and 10-mm radius were found for MFL of AS30, AS35 and AS40 (p= 0.015, p= 0.014 and p= 0.000, respectively). However, no statistically significant difference was found for MFL of SU between 5-mm radius and 10-mm radius (p= 0.156).

DISCUSSION

In the present study, cyclic fatigue tests were performed on Revo-S NiTi instruments in simulated canals with curvature radii of 5 and 10 mm. In our study, we have chosen 5 mm and 10 mm radii of curvature, as this was deemed to be within the clinically relevant values to simulate an abruptly

Table 2. Mean and SD of length of fractured segments of Revo-S instruments in radius of curvature 5mm and 10 mm.

Revo-S	SU	AS30	AS35	AS40
10 mm	5.66 ± 0.52	8.86 ±0.54	8.67 ± 0.53	8.46 ± 0.64
5 mm	4.55 ± 0.10	7.38 ± 1.84	7.17 ± 0.34	6.56 ±0.15
p value	0.156	0.015	0.014	0.000

curved canal as suggested by Pruett et al.[7] in their study. The Revo-S system features six instruments, four of which were tested in this study. The SC1 file was excluded from the test due to the following reasons: First, SC1 is designed for efficient shaping of the coronal 2/3; hence, not used at the whole canal length. Second, this file is shorter than that of the other Revo-S files (21 mm) and is therefore not comparable with the other files tested in the study. The SC2 file was excluded from the test due to its lower taper (4%).

A key finding of this study is that the radius of curvature has a significant effect on cyclic fatigue resistance for all instrument sizes. It was found that the shorter the radius of curvature, the greater the chance of fatigue breakage. These results are consistent with prior studies.[7,11-13] For example, Inan et al.[14] compared the NCF of ProTaper instruments in simulated canals with curvatures of 5 and 10 mm. In this study, the number of cycles to failure significantly decreased from 10- to 5-mm curvatures. Pruett et al.[7] compared Lightspeed instruments in simulated canals with curvatures of 2 and 5 mm and also found a reduction in the number of cycles to failure with 2-mm curvatures compared to 5 mm. Grande et al.[12] found similar results indicating significantly fewer NCF in the more abrupt 2-mm radius group than the 5mm group. Despite these agreements, other researchers such as Martin et al.[15] argue that the radius of curvature is not a significant factor that influences instrument fracture. However, their study is different from the current study in several methodological aspects such as the use of extracted teeth and reciprocating motion during the shaping of the canals.

In the present study, AS30 was found to be more resistant to cyclic fatigue than SU, AS35, and AS40 in the 10-mm radius group. Although SU was expected to be more resistant than the other .06 tapered instruments because of its smaller diameter,[7,12] in the 10-mm radius group, SU was significantly less resistant to cyclic fatigue compared to AS30 and AS40. On the other hand, there was no significant difference between the instruments in the 5-mm group.

It has been reported that the resistance of rotary instruments to cyclic fatigue decreases with increasing instrument diameters[5] and tapers.[16] Gambarini[17] suggested that .04 tapered instruments were more resistant to cyclic fatigue testing than .06 tapered instruments. This argument is supported by Haikel et al.[16] who found when dynamic stress testing three types of nickel-titanium rotary systems that as the taper increased the time to fracture decreased, and also by Sattapan et al.[18] who found that the torque generated during canal instrumentation with rotary instruments increased as the taper increased. Yared et al,[19] reported that no differences were found between the different file sizes of ProFile NiTi instruments. However, in contrast, Pruett et al.[7] demonstrated that the instrument life span is inversely proportional to instrument size. In contrast, Di Fiore et al.[20] suggested that a tip size alone may not be as important as taper for fracture. Their study also implies that an instrument with a rapid increase in diameter along its shaft creates a remarkably high torsional stress that may be more than the material strength of the alloy.

There were three major drawbacks to this study. One was that the simulated canal did not duplicate the in vivo situation; it only allowed the comparative testing of different instruments in a standardized environment. The second drawback was that the effects of irrigation solutions and chelating agents on NiTi were not investigated. The third one was the absence of a control group. We did not prefer including a control group, because there have been two studies evaluating cyclic fatigue resistance of Revo-S SU comparing with that of other widely used instruments.[8,9] Despite these studies, little is known about cyclic fatigue behavior of other Revo-S instrument sizes (e.g., SC1, AS30, AS35, and AS40). Therefore, we aimed to address this need by evaluating the cyclic fatigue resistance of four different sizes of Revo-S NiTi rotary instruments.

Most clinical guidelines and manufacturers' recommendations for instrumentation with rotary NiTi instruments call for the reduction of the canal curvature by creating straightline access and the reduction of interference in the middle and coronal third by classic or modified crown-down techniques.[13] These recommendations are largely based on in vitro investigations that showed that a stronger curvature and a smaller radius of the root canal increases the risk of rotary instrument fracture.[7] In the light of the present study's findings, we can recommend the use of small taper instruments in the preparation of severely curved root canals (e.g. AS30).

CONCLUSION

The results of the present study confirmed that the radius of curvature has a significant effect on cyclic fatigue resistance for all instrument sizes. In addition, the taper of the instrument at the point of maximum curvature influence resistance to fracture for cyclic fatigue.

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