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Araştırma/ Research Article

CYCLIC FATIGUE RESISTANCE OF ROTATE, EDGETAPER PLATINUM, AND K3XF FILES EXPOSED TO INTRACANAL TEMPERATURE IN AN S-SHAPED CANAL

S ŞEKİLLİ BİR KANALDA KANAL İÇİ SICAKLIĞA MARUZ BIRAKILAN ROTATE, EDGETAPER PLATINUM VE K3XF EĞELERİNİN DÖNGÜSEL YORGUNLUK DİRENCİ

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ABSTRACT

Aim: This study compared the cyclic fatigue resistance (CFR) of ROTATE, EdgeTaper Platinum, and K3XF used in an artificial S-shaped canal at an intracanal temperature.
Materials and methods A total of 120 files were tested in an artificial S-shaped canal (n=40 each file system). All files placed in experimental setup were rotated in the canal until fracture occurred. For each instrument, the number of cycles to fracture was calculated, and the fractured fragment was measured. The CFR was determined by recording the time to fracture in the canal. The fractured surfaces of the files were scanned at electron microscope to determine the morphologic characteristics of fracture. Data were statistically analyzed ($P < 0.05$).
Results The ROTATE and EdgeTaper Platinum exhibited significantly greater CFR than the K3XF system ($P < 0.05$). The ROTATE and EdgeTaper Platinum files had similar CFR values ($P > 0.05$). The fractured fragment lengths were similar among the files ($P > 0.05$).
Conclusions The CFR of the ROTATE and EdgeTaper Platinum in S-shaped canals was found to be higher than that of the K3XF file.
Keywords ROTATE , EdgeTaper Platinum, K3XF , Cyclic fatigue resistance, S shaped canal

ÖZ

Amaç: Bu çalışmanın amacı, yapay S şekilli bir kanalda kanal içi sıcaklıkta kullanılan ROTATE, EdgeTaper Platinum ve K3XF'nin döngüsel yorgunluk direncini karşılaştırmaktır.
Gereç ve yöntem: Bu çalışmada toplam 120 adet kanal eğesi kullanıldı. (her bir grupta n=40) Kırık meydana gelene kadar tüm eğelere rotasyon hareketi yaptırıldı. Her bir kanal eğesinde kırık oluşana kadar geçen dönme sayısı hesaplandı ve oluşan kırık parçanın uzunluğu ölçüldü. Döngüsel yorgunluk direnci kanal içinde eğe kırılana kadar geçen süre kaydedilerek belirlendi. Kırığın morfolojik özelliklerini göstermek için, eğelerin kırık yüzeyleri elektron mikroskobunda tarandı. Elde edilen verilerle istatistiksel analiz yapıldı. ($P < 0.05$).
Bulgular: ROTATE ve EdgeTaper Platinum eğeleri, K3XF eğesinden anlamlı biçimde daha yüksek döngüsel yorgunluk direnci sergiledi ($P <0.05$). ROTATE ve EdgeTaper Platinum eğeleri benzer döngüsel yorgunluk değerlerine sahipti ($P > 0.05$). Kırılan eğe uzunlukları, eğeler arasında benzerdi ($P > 0.05$).
Sonuç: ROTATE ve EdgeTaper Platinum eğelerinin S şeklindeki kanallardaki döngüsel yorgunluk dirençlerinin K3XF eğesinden daha yüksek olduğu bulundu.
Anahtar kelimeler: ROTATE , EdgeTaper Platinum, K3XF , Döngüsel yorgunluk direnci, S şekilli kanal

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INTRODUCTION

Fracture of rotary nickel-titanium (NiTi) files are described as failing either as a result of flexural fatigue, torsional failure, or a combination of both. It has been stated that cyclic fatigue is the main reason for file fracture in curved root canals. [1] Cyclic fatigue is a result of undergoing alternating compressive and tensional stresses across the cross-section when the file rotates in a curved canal. [2-3]

Recently, heat-treated NiTi file systems have gained popularity in endodontics. The heat treatment increases the file's flexibility without compromising its cutting efficiency. Thanks to the special heat treatment that makes them more flexible, the files will follow the natural canal anatomy smoothly.[4-5] Several studies have shown that heat-treated files have higher cyclic fatigue resistance (CFR) than conventional NiTi files.[6-7]

EdgeEndo has produced a file system that mimics the ProTaper® Gold NiTi file in size and cross-sectional design. The foundation of EdgeTaper Platinum (ETP) (EdgeEndo, Albuquerque, NM) designed file systems is to provide clinicians with the same file size and design while claiming greater flexibility and resistance than ProTaper Gold. The thermo-mechanical process completed on the ETP files leads to an irregular gold-purple-green color. The files present with a curve showing a more martensitic composition when taken from the package. [8]

K3XF (SybronEndo, Orange, CA) instruments have a constant taper design with an asymmetrical three-fluted cross-section with unequally spaced flutes and recessive surfaces. Mechanical properties of K3XF files have been improved using R-phase technology, and in favor of this innovative manufacturing process, K3XF files exhibited higher CFR than that of K3 files.[9,10]

ROTATE (VDW GmbH, Munich, Germany) has recently been launched on the dental market as a rotary file system with an increased file flexibility due to its special heat-treated NiTi alloy. The manufacturers of the file claim that the combination of wire, design, and heat treatment increase cyclic fatigue resistance of the file and reduces the risk of file breakage. [11]

No study has compared the CFR of ETP, K3XF, and ROTATE files in an S-shaped canal. Therefore, the objective of the current study was to evaluate the CFR of ETP, K3XF, and ROTATE files in an S-shaped canal at an intracanal temperature. The null hypothesis was that there would be no difference in the CFR of the ETP, K3XF, and ROTATE files.

MATERIAL AND METHOD

A power analysis was performed to calculate the minimum sample size for the cyclic fatigue testing based on previously performed research with similarities to this project. [12] Based on this power analysis, 40 files of each type allowed for detection of quite small mean differences at a high power (the power as 0.80, effect size = 0.72, and significance level as a = 0.05).

A total of 120 new ROTATE (#25, .06 taper), K3XF (#25, .06 taper), and ETP (#25, .06 taper) files were used for CFR testing. Before the test, each file was examined for defects under a stereomicroscope at x24 magnification.

All files were tested inside the canal with a double curvature. The angle of the first curve in the coronal area was 60°, and the diameter of the curvature was 5 mm in an artificial double-curvature canal. The distance between the center location of the coronal curvature and the tip of the canal was 8 mm. The apical curvature angle was 70°, and its diameter was 2 mm. The distance between the centers of curvature was 2 mm.[13-14] The CFR testing was performed with files immersed in saline at 35.1 ± 1.0°C. A digital thermometer measured the temperature of the saline solution. ROTATE files (2 N/cm torque, 350 rpm) , K3XF files (3 N/cm torque, 350 rpm) and ETP files (3 N/cm torque,350 rpm) were used according to the manufacturers' instructions with endodontic motor (X-Smart; Dentsply Sirona). For simulating a clinical situation, all tested files were freely rotated inside the artificial canal through a mechanical device until file fracture occurred. (Fig. 1) The time to failure in seconds was recorded as soon as a fracture was detected visually. The number of cycles to fracture (NCF) was then calculated using the following formula: NCF = time (seconds) to failure x rotational speed/60. Moreover, in the canal, if the fracture occurred first in the apical curve, the time to fracture and NCF were also registered for the coronal fragment. A digital caliper was used to measure the length of each fractured tip. The fractured files were analyzed using a scanning electron microscope (SEM) (Leo-440, Cambridge, UK) to determine the type of fracture. Two observers, not related to the present

study, examined the SEM images with different magnification of the fractured surface.

Statistical analysis

Data were analyzed using one-way analysis of variance (SPSS for Windows 20.0; SPSS, Chicago, IL) at a significance level of $p < 0.05$.

RESULTS

Table 1 summarizes the findings of the cyclic fatigue tests. In the S-shaped canal, all of the files broke first in the apical curvature, followed by the coronal curvature. The ROTATE and ETP had significantly higher NCF values than the K3XF files ($p < 0.05$). However, there was no significant difference between ROTATE and ETP regarding NCF values ($p > 0.05$). Moreover, there was no significant difference among the file groups at fragment length ($p > 0.05$). All the files had fractured surfaces with microvoids, morphologic characteristics of ductile fracture (Fig. 2).

Table 1. Mean values of NCF, Fragment lengths and Standard Deviations (SD) of each file tested.

	Apical curvature		***Coronal curvature***	
Groups	NCF±SD	FL (mm) ±SD	NCF±SD	FL(mm) ±SD
ROTATE	1144.3±262.3	2.12±0.52	1435.2±322.4	6.04±1.24
K3XF	816.3±214.5	2.13±0.47	1067.3±313.6	5.61±1.16
ETP	1097.1±356.2	2.16±0.41	1376.4±279.4	5.57±1.34

FL, Fracture length
ETP, EdgeTaper Platinum
SD, Standard deviation

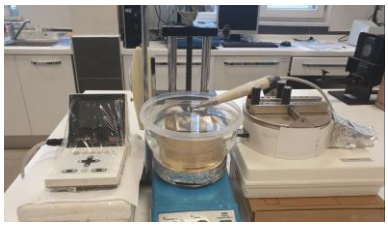

Figure 1. Experimental setup

DISCUSSION

File breakage is the main concern throughout canal preparation procedures. As previously seen, there are several factors responsible for file breakage during clinical use, and cyclic fatigue is reported as a major cause.[15]

The S-shaped canals create more stress on NiTi rotary files than in single curvature canals, and consequently the file fracture occurs due to cyclic fatigue. Therefore, the preparation of the S-shaped canal is one of the most challenging conditions in clinical situations.[16]In many cases, moreover, the S-shaped canal anatomy is not detected in periapical radiographs.[17]

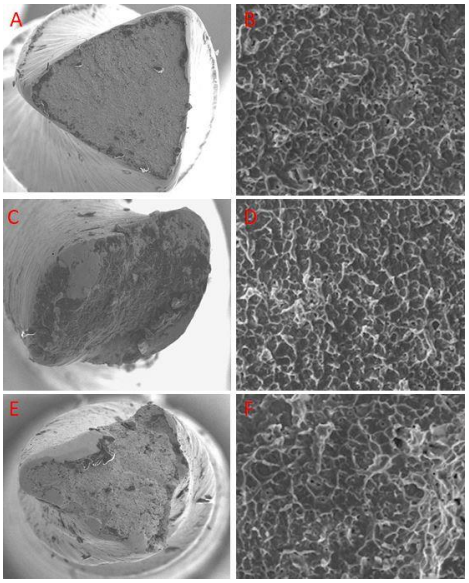

Figure 2. Scanning electron micrographs of files. A, C, and E show fracture surfaces for the EdgeTaper Platinum, ROTATE, and K3XF files, respectively (magnification × 300). (B, D, and F show the fractured surfaces of the EdgeTaper Platinum, ROTATE, and K3XF files, respectively (magnification ×1500).

A drawback of the CFR testing of NiTi files is the inability to eliminate several confounding factors that can arise from different material properties, cross-sections, and sizes of the files. [18] In the present study, therefore, all tested instruments had the same taper and size. In the present study, an artificial canal with an S-shape was used to determine the CFR of the new rotary files. Previous studies exhibited that the root canal temperature was found to range between 31°C and 35°C.[19-20] Some studies evaluating the CFR of files at both room temperature and body temperature have revealed that the fatigue life of the files was reduced at simulated body temperature.[21-22] Therefore, in the present study, all instruments were also tested for CFR at 35.1 ± 1.0°C to simulate clinical conditions on the contrary room temperature.

The development of heat-treated files has achieved a significant breakthrough in modern endodontics and at the same time, provided reduced risk of fractured of endodontic files during the instrumentation of curved and narrow canals.[23] The current study evaluated the CFR of new instruments that work with a rotary motion (ROTATE, K3XF, and

ETP). Based on the findings of the study, the null hypothesis was rejected because there was a significant difference in CFR among the files in an S-shaped canal**.**

In the current study, files with different heat-treated were evaluated for the CFR. These file designs were chosen because they had different cross-sectional shapes and different metallurgical properties. Previous studies showed that the Blue wire was exhibited that superior cyclic fatigue resistance than the conventional NiTi and M-wire.[13, 24-25] A study evaluating CFR of reciprocating instruments made of Fire-Wire, Gold wire and M wire showed that instrument made of Fire-Wire exhibited higher CFR at body temperature than made of Gold wire and M-Wire.[23] Gündoğar et al. evaluated that the CFR of 4 different NiTi rotary files in their study and ROTATE showed higher CFR than all the tested files.[26] A study comparing of the CFR of ROTATE with both reciprocating and continuous rotary NiTi instruments showed that ROTATE showed higher CFR than the Mtwo and Reciproc files, but lower CFR than Reciproc Blue file.[25] The findings of these studies revealed that files which had different metallurgical properties could show different CFR. The results of the present study revealed that ROTATE and ETP had significantly higher CFR than K3XF files. This could be due to metallurgical differences between the files. It has been stated that files with a triangular cross-sectional design possessed greater CFR than those with a square cross-sectional design. This difference could be attributed to the reduced metal mass of the files with a triangular cross-section compared to files with a square cross-section and similar diameter. The K3XF, ROTATE, and ETP have a – modified triple U, S-shaped, and triangular cross-section design with a progressive changing taper, respectively.

In the S-shaped canal, the files fractured first in the apical curvature followed by the coronal curvature. This could be due to the sudden curvature (2 mm radius) in the apical area compared with the coronal curvature (5 mm radius), which is compatible with some studies. [13, 27] In current study, the fractured surface of files tested was observed the dimpled rupture which are indicative of ductile fracture. (Fig. 2.) Also, some studies which evaluated the CFR of NiTi files, each having a different cross-sectional design exhibited that all files tested displayed ductile morphologic characteristics.[28-29] These result are also consistent with previous studies.[30-31]

CONCLUSIONS

The ROTATE and ETP were more resistant to cyclic fatigue than the K3XF in an S-shaped canal. Further research is necessary to verify the findings of the current experiment. Dental practitioners should be aware that the S-shaped canal anatomy in many teeth is not visible in two dimensional radiographs.

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

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