Cumhuriyet Dental Journal: 2019; 22(1)
e-ISSN 2146-2852
Doi: 10.7126/ cumudj.477218

Original research

COMPARISON OF CYCLIC FATIGUE RESISTANCE OF ONE CURVE, HYFLEX EDM, WAVEONE GOLD AND RECIPROC BLUE NICKEL-TITANIUM ROTARY FILES AT INTRA-CANAL TEMPERATURE

ABSTRACT

Objectives: To compare the cyclic fatigue resistances of One Curve (OC), Hyflex EDM (HEDM), WaveOne Gold (WOG), Reciproc Blue (RPC Blue), and nickel-titanium rotary files at intra-canal temperature (35°C).

Materials and Methods: Twenty OC (25/.06), 20 HEDM (25/.08), 20 WOG (25/.07) and 20 RPC Blue (25/.08) files were tested for cyclic fatigue at intra-canal temperature (35°C). All the instruments were rotated in artificial which were made of stainless steel with an 60° angle of curvature and a radii of curvatures of 5 mm until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer and the number of cycles to fracture (NCF) for each file was calculated. The Kruskal-Wallis test was performed to statistically analyze the data by using SPSS 21.0 software. The statistical significance level was set at $p<.05$.

Results: NCF values revealed that the HEDM had the highest cyclic fatigue resistance at intracanal temperature ($p<.05$) and followed by WOG, RPC Blue and OC. The lowest NCF values were determined in the OC group and statistically significant difference was observed between the OC group the other groups ($p<.05$). No statistically significant difference in the mean length of the fractured fragments in curvature was evident for the instruments ($p>.05$).

Conclusion: Within the limitations of the present *in-vitro* study, HEDM instrument resisted static cyclic fatigue significantly more than RPC Blue, WOG and OC instruments.

Keywords: Endodontics, root canal therapy

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Received : 01.11.2018
Accepted : 04.01.2019

How to Cite: Yilmaz K, Özyürek T, Uslu G. Comparison of Cyclic Fatigue Resistance of One Curve, Hyflex Edm, Waveone Gold and Reciproc Blue Nickel-Titanium Rotary Files at Intra-Canal Temperature. Cumhuriyet Dent J 2019;22:1:42-47.

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INTRODUCTION

Nickel-titanium (NiTi) rotary files are the most popular files used in the preparation during the root canal treatment. Beside of advantages such as effective shaping capability, shortening the treatment duration, and helping in maintaining the original form of root canals, NiTi files may also cause negative outcomes such as postoperative pain, periapical pathologies, and failure of treatment in the long-term because of the unexpected instrument fractures during the use of file.[1]

The unexpected failure of NiTi files during the clinical use arises from two different reasons named cyclic or torsional fatigue.[2] Torsional fatigue failure occurs when the stress, which emerges when the tip of file is stuck at any point in the canal but the shaft keeps rotating, exceeds beyond the elasticity limits of the instrument.[3] In cyclic fatigue failure, however, the fracture occurs as a result of the accumulation of repetitive tensile and compaction stresses that the file is exposed to in curved canals. The cyclic fatigue was shown to be the main reason for instrument failures during the clinic use.[2] The kinematics, alloy, and metallurgical properties of instrument are accepted to be among the factors influencing the cyclic fatigue.[4,5]

In order to minimize the failure incidence of NiTi files during the clinical use, the manufacturers apply various heat treatments to the alloys, of which the instruments are made, and they aim to increase the cyclic fatigue resistance of instruments by changing the design properties.[6,7] One Curve (OC; Micro Mega, Besancon, France) and HyFlex EDM (HEDM; Coltene/Whaledent, Altstatten, Switzerland) are the single file systems working with continuous rotation movement and produced by using different heat treatment procedures. OC is a new-generation root canal file, which was recently introduced to the market by manufacturer and is produced with C-Wire heat treatment technology. The manufacturer declares that this technology offers 33% faster root canal preparation in comparison to the reciprocating single-file systems and thus the clinicians would have more time for irrigation. When compared to OneShape (OS; Micro Mega, Besancon, France), which is the previous-generation single file system of this manufacturer, the cyclic fatigue resistance was reported to be 2.4 times higher.

HEDM, however, works with continuous rotation movement and is made of controlled memory (CM) by using the electronic discharging machining (EDM) technology. This method is based on shaping the file by melting and vaporizing the material through the electrical discharges. EDM technology was reported to give the file a crater-like appearance and an increased resistance to cyclic fatigue.[8,9]

WaveOne Gold (WOG; Dentsply Sirona, Baillagues, Switzerland) and Reciproc Blue (RPC Blue; VDW, Munich, Germany) are the reciprocating single-file systems. WOG is manufactured using gold heat treatment. M-Wire technology is based on the heat treatment before production, whereas the gold heat treatment is performed by heating and then slowly cooling the file after production. The file has a parallelogram cross-section having 2 cutting edges.[10,11]

RPC Blue is manufactured by using a technology (blue heat-treated) altering the molecular structure of file during the production. It was reported that the cyclic fatigue resistance of file increased at the end of this procedure.[12] RPC Blue has an S-shaped cross section with two cutting edges and a noncutting tip.

In the comprehensive literature review made by the authors of present study, on study examining the cyclic fatigue resistance of OC file was found. For this reason, it is aimed in the present study to compare the cyclic fatigue resistances of single-file systems having different kinematics and heat treatment technologies, which were applied in production process, at the intra-canal temperature level. The null hypothesis of present study is that there would be no difference between the cyclic fatigue resistances of NiTi files tested in present study.

MATERIALS AND METHODS

20 pcs OC (25/.06), 20 pcs HEDM **(**25/.08), 20 pcs WOG (25/.07), and 20 pcs RPC Blue (25/.08) files were involved in the present study. Before

using in study, the files were examined by using a stereomicroscope (Olympus BX43; Olympus Co, Tokyo, Japan) in terms of the presence of any defect. Since no defect was found on the files, all of them were involved in the study.

Cyclic fatigue testing was performed in a stainless steel artificial canal manufactured by reproducing the instrument's size and taper. A simulated root canal with a 60° angle of curvature and 5-mm radius of curvature was constructed for both the instruments tested. The centre of the curvature was 5 mm from the tip of the instrument and the curved segment of the canal was approximately 5 mm in length.[13] Twenty files for each instrument type were operated in distilled water at 35°C[14] Evidence for reduced fatigue resistance of contemporary rotary instruments exposed to body temperaturusing a torque-controlled endodontic motor (VDW Gold; VDW Munich, Germany). The OC files were used at 450 rpm and 2.5 gcm^{-1} torque until fracture occurred. The RPC Blue files were used in the "Reciproc ALL" program until fracture occurred. The WOG files were used in the "WaveOne ALL" program until fracture occurred. The HEDM files were used at 500 rpm and 2.5 gcm^{-1} torque until fracture occurred. During experiment, the temperature was measured with an infrared thermometer (GM320, Benetech, CAN) and maintained constant (± 1°C).

The number of cycles to failure (NCF) for each file was calculated using the following formula: (NFC = revolutions per minute (rpm) × time to fracture (sec)/60). The fractured fragment length (FL) was determined by a digital micro caliper.

Statistical analysis

The data were first analyzed using the Shapiro-Wilk test to verify the assumption of normality. The Kruskal-Wallis test was performed for statistically analyze the data by using SPSS 21.0 (IBM-SPSS Inc, Chicago, IL) software. The statistical significance level was set at $p<.05$.

RESULTS

Mean NCF and FL values and standard deviations of the files are presented (Table 1).

Table 1. The Means and Standard Deviations of the Number of Cycles to Failure (NCF) and Fracture Length (FL) of Instruments in Distilled Water at 35° C.

Group	NCF		FL	
	Mean	Standard Deviation	Mean	Standard Deviation
WaveOne GOLD	1355.3 [a]	216.8	5.4	0.3
Reciproc Blue	1245.5 [a]	195.2	5.5	0.5
HyFlex EDM	1647.3 [b]	239.6	5.3	0.2
One Curve	864.2 [c]	129.6	5.7	0.8
p - value		< .05		> .05

* Different superscripts letter was statistically significant (p< .05).

NCF values revealed that the HEDM had the highest cyclic fatigue resistance at intracanal temperature (p=0.001) and followed by WOG, RPC Blue and OC. There were no significant differences between the WOG and RPC Blue (p>.05). The lowest NCF values were determined in the OC group and statistically significant difference was observed between the OC group the other groups (p=0.912).

The mean length of the fractured fragment was also recorded to evaluate the correct positioning of the tested instrument inside the canal curvature and whether similar stresses were being induced. No statistically significant difference in the mean length of the fractured fragments in curvature was evident for the instruments (p>.05).

DISCUSSION

The complication that is most frequently observed by the clinicians during the root canal treatments is the NiTi instrument failures.[15] The previous studies showed that the main reason for these instrument failures is the cyclic fatigue.[16,17] The reciprocal movement decreases the torsional stress, which the instruments are exposed to inside the root canal, and the consequent torsional fatigue[18], and it also positively contributes to the cyclic fatigue resistance of instruments.[19] The canal instruments, which generally work by reciprocating, are produced in single-file form, and they are recommended for using in 2 or 3 canals depending on the anatomic complexity of teeth, in which they are used. For this reason, the cyclic fatigue test is much more important to the

reciprocating files.[13] The manufacturer companies generally apply different heat treatments to the files in order to improve the cyclic fatigue resistance of files, and they aim to minimize the incidence of instrument failures. In the present study, it was aimed to compare the cyclic fatigue resistances of 4 current rotary single file systems named HEDM (CM-Wire), WOG (Gold-Wire), RPC Blue (Blue-Heat Treated), and OC (C-Wire) that are subject to different heat treatments and work with different kinematics.

The cyclic fatigue tests have not been exactly standardized yet and there is no test procedure, on which all the researchers could arrived at a consensus.[20] Plotino *et al.*[21] recommended the use of stainless steel canals, which are specific to the tested files (size and taper) in order for files to follow the same trajectory in the static cyclic test setups. For this reason, the stainless steel artificial canals, which were prepared specific to the sizes and tapers of files tested in the present study, were used.

In their study, de Hemptinne *et al.*[22] reported the intra-canal temperature to be 35ºC and it was reported in previous studies that the NiTi files might be affected from the intra-canal temperature. For this reason, the cyclic fatigue test of heat-treated NiTi canal files was performed at 35±1 °C in order to mimic the clinical conditions.

According to the results obtained in present study, the cyclic fatigue resistance of HEDM files was found to be statistically significantly higher than WOG, RPC Blue, and OC files ($p<.05$). For this reason, the null hypothesis of present study was rejected. Pedulla *et al.*[20] (2016) compared the cyclic fatigue resistances of HEDM, Reciproc (VDW), and WaveOne (Dentsply Sirona), and they reported the cyclic fatigue resistance of HEDM file to be higher. They asserted that this is because HEDM file is made of CM alloy by using EDM technology. Özyürek *et al.*[12] tested the cyclic fatigue resistance of HEDM, WOG, RPC Blue, and 2shape (TS; Micro-Mega, Besancon, France) files in the artificial canals having 45° and 90° slope, and they compared the time-to-fracture (TTF) values obtained in that study. The researchers reported that, when compared to the other files, RPC Blue had higher cyclic fatigue resistance in both of canals having different slope levels. Pedulla *et al.*[8] performed the cyclic fatigue tests at the room temperature, whereas the tests were conducted at the intra-canal temperature in the present study. Similarly, Özyürek *et al.*[12] compared the TTF values, whereas the NCF values were compared in the new study. The authors of present study assert that the results obtained here are different from the literature because of the differences between the methodologies.

According to the results of present study, no statistically significant difference was found between the cyclic fatigue values of RPC Blue and WOG files ($p>.05$). In a study on comparing the cyclic fatigue resistance of RPC Blue, RPC, and WOG files, RPC Blues showed better cyclic fatigue values than the others did.[3] According to the results obtained here, on the contrary with the results of other study, the difference between the cyclic fatigue resistances of RPC Blue and WOG files might be because of the tests performed at the room temperature and the cyclic fatigue resistance and the comparison between cyclic fatigue values by taking the TTF values into consideration.

Since OC file is a newly introduced file, there is no study in the literature, which can be used in directly comparing with the present results. The manufacturer alleges that OC file has 2.4 times higher cyclic fatigue resistance when compared to OneShape (OS; Micro Mega,) file. They assert that this is because of the C-Wire heat treatment used in the production, which is different from OS file[7]. Gündoğar & Özyürek[7] compared the cyclic fatigue resistances of OS, HEDM, RCP Blue, and WOG files. They reported that HEDM file has the maximum cyclic fatigue resistance, whereas the minimum value was observed in OS files. It is thought that, despite the heat treatment applied, the OC file showed lower cyclic fatigue resistance than RPC Blue and WOG because of the different kinematics of the files.

CONCLUSIONS

Within the limitations of the present *in-vitro* study, HEDM instrument resisted static cyclic

fatigue significantly more than RPC Blue, WOG and OC instruments. The novel NiTi rotary instrument OC showed significantly lowest cyclic fatigue resistance compared to the other systems.

ACKNOWLEDGEMENT

Author Dr. Koray YILMAZ declares that he has no conflict of interest. Author Dr. Taha ÖZYÜREK declares that he has no conflict of interest. Author Dr.Gülşah USLU declares that she has no conflict of interest.

CONFLICTS OF INTEREST

None

İçi Sıcaklıkta Döngüsel Yorgunluğa Karşı Dirençlerinin Karşılaştırılması

ÖZ

Amaç: *One Curve (OC), Hyflex EDM (HEDM), WaveOne Gold (WOG) ve Reciproc Blue (RPC Blue) NiTi döner kanal aletlerinin kanal içi sıcaklıkta (35°) döngüsel yorgunluğa karşı gösterdikleri dirençlerin karşılaştırılmasıdır.* ***Gereç ve Yöntemler:*** *Yirmi OC (25/,06), 20 HEDM (25/,08), 20 WOG (25/,07) ve 20 RPC Blue (25/,08) kanal aleti kanal içi sıcaklıkta (35°) döngüsel yorgunluk direnci testine dahil edildi. Tüm kanal aletleri, 60° kurvatur açısı ve 5 mm kurvatur yarıçapına sahip paslanmaz çelik yapay kanallarda kırılıncaya kadar döndürüldü. Kırılıncaya kadar geçen süreler djital kronometre ile ölçülüp saniye cinsinden kaydedildi ve kırılıncaya kadarki tur sayıları (KKTS) hesaplandı. SPSS 21.0 yazılımında Kruskal-Wallis testi ile istatistiksel analiz yapıldı. İstatistiksel anlamlılık değeri p<,05 olarak tespit edildi.* ***Bulgular:*** *KKTS değerlerine bakıldığında HEDM kanal içi sıcaklığında en yüksek döngüsel yorgunluk direnci değerlerini göstermiştir (p<,05) ve onu sırasıyla WOG, RPC Blue ve OC takip etmektedir. Diğer gruplar ile karşılaştırıldığında istatistiksel olarak anlamlı derecede en düşük döngüsel yorgunluk direncini OC göstermiştir (p<,05). Aletlerin kırık uzunlukları açısından istatistiksel olarak aralarında anlamlı bir farklılık yoktur. (p>,05).* ***Sonuç:*** *Çalışmamızın limitasyonları dahilinde döngüsel yorgunluğa karşı en yüksek direnci RPC Blue, WOG ve OC' ile kıyaslandığında HEDM kanal eğesi göstermiştir.*

Anahtar Kelimeler: *Endodonti, kök kanal tedavisi.*

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