

Comparison of the Fracture Resistance of Hyflex EDM and WaveOne Gold Rotary System Instruments in Abrupt Apical Curvature

Hyflex EDM ve WaveOne Gold Döner Sistem Eğelerinin Ani Apikal Kurvatürde Kırılma Dirençlerinin Karşılaştırılması

Cangül KESKİN
Uğur İNAN
Hande AKGÜN

<https://orcid.org/0000-0001-8990-4847>

<https://orcid.org/0000-0001-8899-2152>

<https://orcid.org/0000-0001-7526-4334>

Ondokuz Mayıs Üniversitesi Diş Hekimliği Fakültesi Endodonti Anabilim Dalı, Samsun

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ABSTRACT

Current developments in restorative dentistry have been recorded theoretically and practically in recent years. Short and long term evaluation in the dental practice in consideration of the developments of conventional knowledge and current studies will ensure the continuity of scientific progress. Regular monitoring of old restorations is very important in terms of evaluating the materials and techniques used in dentistry. As a result of the evaluation of posterior direct composite restorations, it may be decided to repair, retreatment or solely follow the restoration. Correspondingly, the quality of treatment and patient satisfaction will increase. This review aims to make evaluations based on scientific criteria and to be expressed in a universal language.

Objective: This study aimed to compare the cyclic fatigue resistance of Hyflex EDM and WaveOne Gold rotary instruments in simulated abrupt apical curvature at body temperature.

Methods and Materials: A total of 10 Hyflex EDM OneFile (25/04-08) and 10 WaveOne Gold Primary (25/07) instruments free of visible defects were selected after inspection. Instruments were tested in an artificial canal having an angle of curvature of 90° and a radius of curvature of 2 mm. The instruments were rotated at speed and torque values recommended by manufacturers at 37°C until fracture occurred. Time required for fracture (TF) was recorded with a 1/100 s digital chronometer. The TF and fractured fragment length data were statistically analyzed using t-test with significance threshold of 5%.

Results: The mean TF value was 98.40 ± 19.93 seconds for WaveOne Gold group and 183.50 ± 35.33 seconds for Hyflex EDM group. Hyflex EDM OneFile instruments fractured in a longer time period than WaveOne Gold instruments and the difference between them was statistically significant (p<0.05).

Conclusion: Hyflex EDM OneFile instruments, which are produced with electric discharge machining, were found to be more resistant to cyclic fatigue than WaveOne Gold instruments.

Keywords: Temperature, reciprocation, continuous Rotation, cyclic Fatigue

ÖZ

Restoratif dişhekimliğinde son yıllarda teorik ve pratik açıdan güncel gelişmeler kaydedilmiştir. Geleneksel bilgi ve güncel çalışmaların ışığında dişhekimliğindeki gelişmelerin kısa ve uzun dönemde değerlendirilmesi bilimsel ilerlemenin sürekliliğini sağlayacaktır. Eski restorasyonların düzenli olarak takip edilmesi dişhekimliğinde kullanılan malzeme ve tekniklerin değerlendirilmesi açısından çok önemlidir. Posterior direkt kompozit restorasyonların değerlendirilmesi sonucu tamir, yenileme veya yalnızca takip kararı verilebilir. Buna bağlı olarak tedavi kalitesi ve hasta memnuniyeti artacaktır. Bu derleme, yapılacak değerlendirmelerin bilimsel kriterlere dayanması ve evrensel dille ifade edilmesini amaçlamaktadır.

Amaç: Bu çalışmanın amacı, Hyflex EDM ve WaveOne Gold döner sistem eğelerin döngüsel yorgunluğa bağlı kırılma dirençlerinin simüle ani apikal kurvatürde karşılaştırılmasıdır.

Yöntem: Bu çalışmada 10 adet Hyflex EDM OneFile (25/04-08) ve 10 adet WaveOne Gold Primary (25/07) eğe kullanıldı. Eğeler kurvatür açısı 90°, kurvatür yarıçapı 2 mm olan yapay kanallarda test edildi. Tüm eğeler önerilen hız ve tork değerlerinde 37°C sıcaklıkta kırılıncaya kadar kullanıldı. Kırılma zamanı 1/100 s dijital kronometre yardımıyla ölçüldü. Veriler kaydedildi ve %5'lik anlamlılık eşiği ile bağımsız örneklem t-testi kullanılarak karşılaştırıldı.

Bulgular: Kırılıncaya kadar geçen ortalama süre WaveOne Gold grubu için 98.40 ± 19.93 ve Hyflex EDM grubu için ise 183.50 ± 35.33 saniye olarak bulundu. Hyflex EDM OneFile eğeler, WaveOne Gold Primary eğelere göre daha uzun sürede kırıldı ve aralarındaki fark istatistiksel olarak anlamlı bulundu (P<0.05).

Sonuç: Elektrik boşaltımı ile işleme yöntemi ile üretilen Hyflex EDM NiTi eğeleri, WaveOne Gold eğelerine göre döngüsel yorgunluğa karşı daha dirençli bulundu.

Anahtar Kelimeler: Sıcaklık, Resiprokasyon, Devamlı Rotasyon, Döngüsel Yorgunluk

Sorumlu yazar/Corresponding author*: canglikarabulut@gmail.com

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INTRODUCTION

The introduction of nickel-titanium (NiTi) alloys enabled more favourable and safer root canal preparation due to the superior flexibility and mechanical strength of NiTi compared to stainless-steel hand instruments.¹ However, separation of NiTi instruments without a clinically detectable warning is an ongoing problem for endodontic practice.² Disposable use of the NiTi instruments is suggested for prevention of this problem and also cross contamination, however preparation of a molar tooth means that instrument would be used to prepare 3 to 4 root canals. Therefore, evaluation of mechanical properties of motor driven NiTi instruments is important.

Separation of NiTi instruments occurs via torsional failure, cyclic fatigue and their combination during clinical use. Torsional failure results when the instrument tip is screwed into the canal and its shank continuous to rotate producing a torque value exceeding the plastic limit of the material.³ Failure due to cyclic fatigue occurs by continuous stresses of tension and compression in the area of maximum root canal curvature.⁴ Cyclic fatigue resistance of a NiTi instrument depends on numerous factors related to design, kinematics and alloy of the instrument including taper, manufacturing process, cross-sectional shape and type of rotation.^{5,6} Recent studies emphasized that cyclic fatigue testing of an instrument should be conducted under body temperature to simulate clinical use as possible since the instruments show different behaviours under different conditions depending on their phase transformation temperatures.^{7,8}

WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland), which was introduced in 2015, is an upgrade of WaveOne system by maintaining its reciprocating movement while changing the size and cross-sectional shape of the instruments. Moreover, the NiTi alloy underwent thermal treatment after machining, which also contributed to instrument's higher mechanical properties compared to its predecessor.⁹ WaveOne Gold has a primary instrument with 0.25 mm apical tip diameter and .07 taper.¹⁰

Hyflex EDM (Coltene/Whaledent, Altstätten, Switzerland) instruments are produced from controlled memory (CM) wires manufactured by electrical discharge machining (EDM) to improve mechanical properties.¹¹ The instrument also shows variable cross-sectional shapes changing from triangular to rectangular from shaft to tip to optimize flexibility, cyclic and torsional resistance.⁹ Hyflex EDM OneFile has a tip diameter of 0.25 mm and variable taper from .08 at apical 4 mm decreasing to .04 along the remaining part.¹²

Root canal anatomy presents challenges for endodontic treatment not only by presenting complex

configurations but also showing abrupt curvatures in both mesiodistal and buccolingual directions.¹³ The frequency of abrupt curvatures could be underdiagnosed due to their buccolingual position, angulation of X-ray and superimposition of different canals in preoperative periapical radiographs. Preparation of root canals showing abrupt curvatures might exert great stresses on root canal instruments leading to distortion and failure.¹⁴ The present study aimed to compare cyclic fatigue resistances of WaveOne Gold Primary and Hyflex EDM OneFile in a simulated abrupt apical curvature at body temperature. The null hypothesis was that there would be no difference between the instruments regarding their cyclic fatigue resistances.

MATERIALS AND METHODS

A priori sample size calculation was performed by the selection of t-test family (difference between two independent means) using the effect size calculated from a previous study (3.68) by G*Power 3.1 (Heinrich Heine University, Dusseldorf, Germany) with 0.05 type I error and 0.99 power and resulted that the sample size should be a minimum of 8 instruments.¹⁴ Therefore, 10 WaveOne Gold Primary (25/07) and 10 Hyflex EDM OneFile (25/04~08) free of visible defects were selected after inspection under magnification using a stereomicroscope (Nikon SMZ 745T, Tokyo, Japan).

A stainless-steel artificial canal with an inner diameter of 1.5 mm showing an angle of curvature 90° and radius of curvature of 2 mm was immersed in a water bath, which temperature was maintained at 37°C by a submersible heater and thermostats (Figure 1).

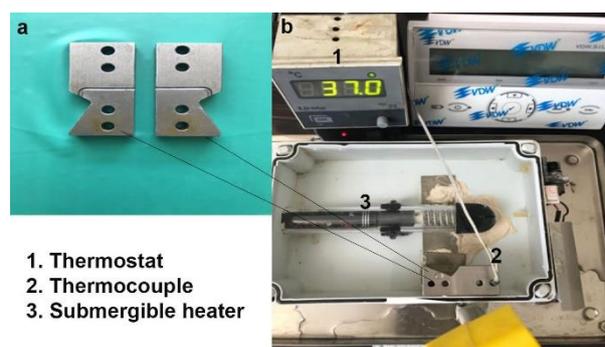


Fig. 1. Artificial canal block with abrupt apical curvature (a) Static cyclic fatigue test device simulating body temperature (b)

WaveOne Gold instruments were operated with VDW Silver endodontic motor (VDW, Munich) using the pre-set "WaveOne ALL" mode, whereas Hyflex EDM OneFile instruments were operated with the device in continuous rotation at 2.5 Ncm torque and 500 rpm speed parameters. All instruments were used until fracture, which was detected both audibly and visually. Time required for fracture (TF) was measured by 1/100

seconds chronometer and fractured fragment length was measured by a digital calliper with 10^{-2} accuracy. Number of cycles to failure (NCF) values were calculated by multiplying the TF value with recommended speed of each instrument (500 rpm for Hyflex EDM OneFile and 350 rpm for WaveOne Gold) and dividing the result by 60.

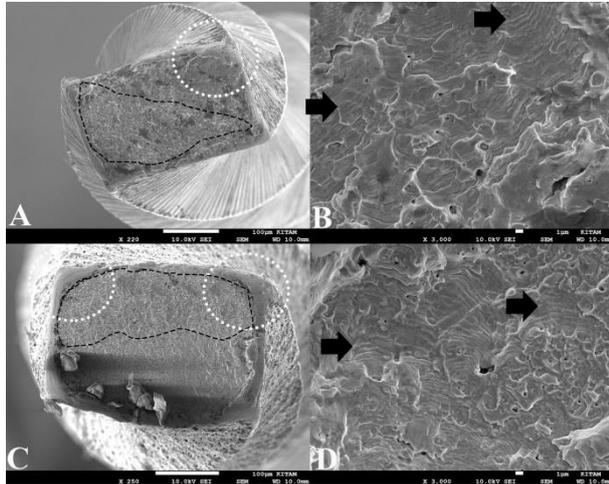


Fig. 2. Scanning electron microscopic images of fractured surfaces of WaveOne Gold Primary (A-B) and Hyflex EDM OneFile (C-D) instruments show typical features of cyclic

fatigue failure such as striation marks (arrows) in the 3000x magnification and crack origins (white dotted circles) with fracture zones (black dashed lines) in 200-220x magnifications.

Fractured surfaces of two instruments were visualized with scanning electron microscope (SEM; JEOL JSM-7001F; JEOL, Tokyo, Japan), and photomicrographs of the fractured surfaces were obtained at 200-220x and 3000x magnifications (Figure 2).

Since Shapiro-Wilk test revealed that the data showed normal distribution ($P > 0.05$), Student t-test was used to analyse TF and fragment length data with 5% significance threshold using SPSS (IBM, SPSS Inc., Chicago, IL, USA). TF data was also analysed using Weibull reliability estimation for the calculation of 99% survival probability as described in a previous paper.¹⁴

RESULTS

Table 1 presents descriptive statistics of TF, NCF and fragment length with Weibull analysis data. Hyflex EDM OneFile instruments showed significantly greater cyclic fatigue resistance than WaveOne Gold Primary instruments ($p < 0.05$). Weibull analysis indicated that Hyflex EDM OneFile instruments also exhibited higher reliability and Weibull modulus than WaveOne Gold Primary.

Table 1. Mean \pm standard deviation values of TF and fractured tip lengths of the tested instruments and Weibull calculations

	TF (s)	NCF	Weibull modulus	Predicted TF for 99% survival	Fragment length (mm)
WaveOne Gold Primary	98.40 \pm 19.93	574.00 \pm 116.2	4.76	40	2.84 \pm 0.50
Hyflex EDM OneFile	183.50 \pm 35.33	1529.16 \pm 294.4	4.82	76	2.62 \pm 0.49

TF, time required for fracture; NCF, number of cycles to failure

DISCUSSION

Single file systems have been advocated for preparation of suitable root canals with minimum number of instruments however in an average molar this means preparation of 4 root canals, which might show different curvatures and configurations. An abrupt apical curvature might exert greater stresses on instruments designed for single file systems since a single instrument encounters stresses while enlarging apical, middle and coronal third of root canals. The present study aimed to compare cyclic fatigue resistances of Hyflex EDM OneFile and WaveOne Gold Primary instruments in static cyclic fatigue model using artificial block with an angle of curvature 90° and radius of curvature of 2 mm. The null hypothesis was rejected due to the higher cyclic fatigue resistance of Hyflex EDM OneFile instruments.

Alloy properties have been reported to influence the cyclic fatigue resistance of NiTi instruments primarily.¹⁴ Hyflex EDM instruments are manufactured from CM wire that underwent a unique treatment termed electric discharge machining that improves the cutting ability and fatigue resistance, whereas WaveOne Gold instruments are manufactured from Gold wire that received a thermomechanical treatment after machining.⁹ Post-machining thermomechanical treatment of both CM and Gold wires resulted in a mixed phase which consists mainly of martensite providing increased flexibility and cyclic fatigue resistance.^{15,16} Hyflex EDM instruments have been compared with Gold wire and reported to show superior cyclic fatigue resistance of Hyflex EDM instruments.¹⁷ Another study, which compared the effect of different working lengths on the cyclic fatigue resistance of Hyflex EDM and WaveOne Gold

instrument in an abrupt curvature model reported superiority of Hyflex EDM irrespective of working length.¹⁸ In the present study Hyflex EDM OneFile instruments showed significantly greater fracture resistance and higher reliability than WaveOne Gold when tested in an abrupt curvature. The findings of the present study are in accordance with the findings of the previous ones.^{17,18} On the other hand, another previous study reported similarity between the cyclic fatigue resistance values of Hyflex EDM and WaveOne Gold when tested at 90° curvature and also superiority of Hyflex EDM over WaveOne Gold when the curvature angle was 45°.¹⁹ The differences of the findings might be attributed to the differences in the evaluation methods such as different radius of curvature values and ambient temperature.

The designs of Hyflex EDM OneFile and WaveOne Gold Primary instruments are different apart from their tip diameters. Hyflex EDM OneFile instruments show variable taper between .04 and .08 and different cross sectional shape along their cutting surface changing from triangular near to shaft to quadrangular near the tip, whereas WaveOne Gold instruments have a constant .07 taper and parallelogram cross sectional shape along the cutting surface.^{10,20} Instrument taper, cross sectional shape and area have been regarded to effect cyclic fatigue resistance of NiTi instruments.^{21,22} However it would be difficult to attribute superior cyclic fatigue resistance of Hyflex EDM OneFile to a single variable since the tested instruments showed differences regarding their design and metallurgy. This inability to eliminate the effect of different variables constitutes a major drawback of most laboratory studies.⁴

Movement kinematic has also been considered to influence cyclic fatigue resistance of NiTi

instruments.^{23,24} Reciprocating movement has been developed to prevent screw in effect to improve torsional resistance of instruments, and then it was reported to increase cyclic fatigue resistance also.^{23,25} However, in the present study Hyflex EDM OneFile instrument operated with continuous rotation movement showed significantly greater cyclic fatigue resistance than WaveOne Gold instruments operated with reciprocating motion. Time required for fracture (TF) values are reported to be more clinically relevant and informative for clinicians to express the performance of instruments rather than number of cycles to failure (NCF) values when a reciprocating instrument is compared with an instrument operates with continuous rotation.^{26,27} NCF values have been associated with the mechanical properties of the instruments, therefore in the present study NCF values were also calculated.²⁸ The results of the NCF analysis indicated similarity with TF findings.

The Weibull analysis presents the capacity of tested instruments in extreme-value distribution and the lower values that might be clinically important for operators.²⁹ Hyflex EDM OneFile instruments showed a higher Weibull modulus, which is an indicative of a higher reliability of the material.³⁰ The lengths of fractured fragments were similar between groups, which indicated the correct position of the instruments within artificial blocks and formation of similar stresses during testing.³¹

CONCLUSIONS

The comparison of two post-machining thermally treated NiTi instruments exhibited higher cyclic fatigue resistance of Hyflex EDM OneFile, which are produced with EDM than WaveOne Gold Primary instruments.

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