sciendo
10.2478/bjdm-2019-0007

BALKAN JOURNAL OF DENTAL MEDICINE | BaSS | ISSN 2335-0245

Comparative Evaluation of Resistance to Cyclic Fatigue of Three Rotary Endodontic Ni-Ti Instruments

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SUMMARY

Background/Aim: *The present study examined the resistance to cyclic fatigue of three different rotary Ni-Ti instruments: K3XF (Kerr, Orange, CA), HyFlex CM (Coltene/Whaledent, Altstätten, Switzerland) and X7 EdgeFile (EdgeEndo, Albuquerque, New Mexico).* ***Material and Methods:*** *Thirty instruments (n=30) of each type were used with tip size 25 and 0.04 taper. All instruments were constrained to* 60^0 *of curvature with a radius of 5 mm by the use of two grooved stainless steel rods and rotated at a speed of 300 rpm and 3.0 Ncm of torque. The time until separation was recorded for each of the instruments and the number of cycles to fracture (NCF) was calculated. Statistical analysis was performed using R Programming language.* ***Results:*** *The X7 EdgeFile instrument showed significantly greater resistance to cyclic fatigue when compared to the HyFlex CM and the K3XF with mean NCF for each instrument 1046 ± 311, 707 ± 219 and 360 ± 96 respectively. HyFlex CM performed significantly better than K3XF.* ***Conclusions:*** *The X7 EdgeFile Ni-Ti file appears to be significantly more resistant to fracture, due to flexural fatigue, than the HyFlex CM and the K3XF.*

Key words: Cyclic Fatigue, Nickel-Titanium Rotary Instruments, K3xf, Hyflex Cm, X7 Edgefile

ORIGINAL PAPER (OP)
Balk J Dent Med, 2019;36-39

Introduction

There are indisputable advantages in using nickel-titanium (Ni-Ti) rotary instruments[1], resulting in their almost universal use among clinicians. However, during preparation, separation of these instruments can occur, exacerbating the difficulty of the case. Ni-Ti file separation is mostly associated with two phenomena; torsional failure and flexural fatigue of the instrument[2,3]. Torsional failure can occur due to the relatively low tensile strength of Ni-Ti alloy in comparison to stainless steel[4]. In this case, the jamming of the tip of the instrument in the root canal, while its shank continues to rotate, will lead to fracture when the torque applied by the handpiece exceeds the instrument's torsional limit[5]. On the other hand, when a Ni-Ti instrument rotates within a curved canal, at any moment, the inner instrument surface is subjected to compression and the outer to tension. This will result in crack propagation and failure due to cyclic flexural fatigue[6].

Advances in the metallurgy of Ni-Ti instruments have significantly improved the resistance to flexural fatigue[7]. In our study three different Ni-Ti instruments were used; K3XF (Kerr, Orange, CA), HyFlex CM (Coltene/Whaledent, Altstätten, Switzerland) and X7 EdgeFile (EdgeEndo, Albuquerque, New Mexico). K3XF files are the development of the earlier K3 files (Kerr, Orange, CA), maintaining the same design geometry, but now composed of R-phase heat treated Ni-Ti alloy[7,8]. The Ni-Ti alloy R-phase is an intermediate transformation phase with a rhombohedral crystalline structure between the austenite and martensite phases[9]. This crystalline structure is characterized by increased flexibility and reduced stresses on the instrument when rotating in curved canals, thus enhancing cyclic fatigue resistance[10].

The EdgeFile is a relatively new rotary Ni-Ti file made of thermally treated nickel-titanium alloy, which does not rebound to its original shape after sterilization. The manufacturer claims that the EdgeFile instruments are mechanically compatible, therefore can be used interchangeably, with the files of other instrument systems such as Vortex, Profile (Densply-Maillefer, Ballaigues, Switzerland), Sequence (Brasseler, USA) and K3 (and K3XF in extent).

Hyflex CM rotary files (Coltene/Whaledent Altstätten, Switzerland) are fabricated from an alloy subjected to special proprietary thermomechanical process resulting in more flexibility and resistance to flexural fatigue (Controlled Memory/CM wire)[11,12,13]. Due to their unique manufacturing process, they do not rebound to their original shape when mechanical stress is applied[12]. Deformed instruments partially or fully recover their original shape after sterilization[14,15].

The purpose of this study is to compare the resistance to cyclic fatigue between K3XF, HyFlex CM and EdgeFile (X7). The null hypothesis is that, under continuous rotation there will be no difference in resistance to flexural fatigue between the three file systems.

Material and Methods

For this study, thirty rotary nickel-titanium instruments were used for each system (K3XF, HyFlex CM and EdgeFile X7). All instruments were of equal length (25 mm), tip size 25 and a constant 0.04 taper. To test the resistance to fracture of each instrument under continuous rotation, the following model (Figure 1) was constructed: Two grooved stainless steel rods with a diameter of 2 mm, were used to constrain the apical part of each instrument in a curvature of 60^0 and a radius of 5 mm (Figure 2), in accordance with previous research model[16]. Each instrument was rotated at a constant speed of 300 rpm and 3 Ncm of torque with the use of an X-Smart endodontic motor handpiece (Dentsply-Maillefer, Ballaigues, Switzerland). The time of rotation until fracture for each instrument was recorded with the use of a VMS-001 USB microscope (Veho, Hampshire, UK) connected to a computer with an Ubuntu (Canonical Ltd, London, UK) Linux operating system and measured in seconds with the use of VLC media player software (Softonic International, S.A., Barcelona, Spain). All the instruments in this study were tested at room temperature. Finally, the number of cycles to fracture (NCF) was calculated according to the mathematical formula: *Number of Cycles to Fracture = Time until separation (in seconds) * 300 (rpm) / 60.*

In this study, no wear was observable in the rods, and this correlated with no progressive change in the time to fracture over the 90 tests.

The results were analyzed with the use of the R programming language. Data were analyzed for normal distribution and then statistical analysis was performed with independent samples t-test. The selected level of significance was 0.05.

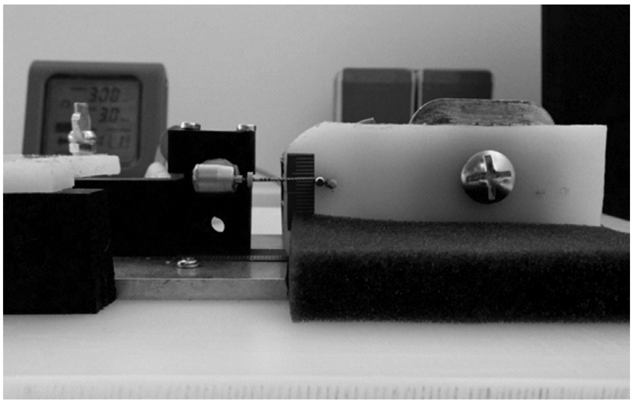

Figure 1. The flexural fatigue testing model

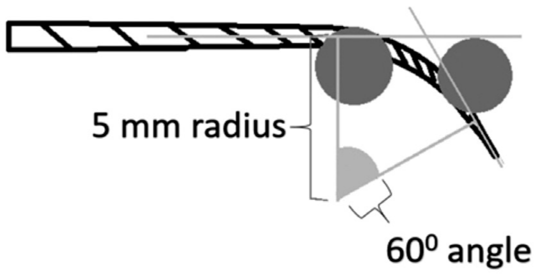

Figure 2. Each instrument was constrained to rotate at a 600 angle and 5 mm radius of curvature

Results

All instruments separated within the curved part of the file. The analysis of the data confirmed normal distribution (Shapiro-Wilk normality test). The mean NCF for the K3XF, HyFlex CM and X7 EdgeFile instruments were 360 (± 96), 707 (± 219) and 1046 (± 311), respectively. The independent samples t-test showed a statistically significant difference ($p<0.05$) between the NCF of all instruments tested, hence the null hypothesis was rejected.

Discussion

The ideal test model for flexural fatigue in clinical use should be the human tooth. However, the root canal morphology would be altered after instrumentation, thus rendering the conditions of the study different for each instrument. Testing in different canals would encounter the same problem. Therefore, it seems reasonable to test Ni-Ti instruments *in vitro* in order to investigate resistance to flexural fatigue[17]. The testing rig constructed for our study was similar to that of Zinelis *et a.l*[18]. Alterations included a 60° curvature according to Pruett[16] with a radius of 5 mm and a higher rotational speed (300rpm). In our model, special care was taken to ensure that the different instruments were constricted in exactly the same position, which is not the case when a relatively wide (1.2 – 2 mm) metal tube is used to simulate the canal[19,20]. In that case, the individual bending properties and cross section design of different files lead to differing positioning in the artificial canal. Some newer study models use artificial canals that follow the size and taper of the instrument at a given curvature[21]. However, the superiority of one laboratory study model design over another is relevant when attempting to extrapolate in vitro results to indicate potential clinical performance. K3XF rotary Ni-Ti files are known to exhibit improved results when tested for flexural fatigue in comparison with its predecessor K3[7, 22].

The results of our study showed that the X7 EdgeFile and Hyflex CM demonstrate greater resistance to flexural fatigue than K3XF. Earlier research has shown that files made from controlled memory Ni-Ti alloy are extremely flexible when compared with conventional superelastic Ni-Ti files[23,11]. The specific mechanical properties of X7 EdgeFile and HyFlex CM could be a possible reason for their superiority to K3XF. The X7 EdgeFile instrument can be deformed by light pressure, the characteristic also found in Hyflex CM, which exists in a martensitic state in use[24]. Due to their crystalline structure, HyFlex CM instruments, when deformed, partially or fully recover their original shape after sterilization[14,15]. However, X7 EdgeFile instruments do not regain their original shape when heated above 125° C. That fact has led us to assume that the X7 EdgeFile instruments exhibit a martensite/ austensite composition, with the former constituent being in a greater proportion. This fact could explain the superior performance of X7 EdgeFile over HyFlex CM in this study. Up to date, the specifics of the metallurgy of the two aforementioned instruments remain, as yet, unpublished, and therefore our assumptions remain unverified.

Conclusions

Under the conditions of this in vitro study, it can be concluded that the X7 EdgeFile Ni-Ti file is significantly less susceptible to fracture due to flexural fatigue than the HyFlex CM and the K3XF. The HyFlex CM appeared significantly less susceptible to fracture when compared to the K3XF.

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Conflict of Interests: Nothing to declair.

Financial Disclosure Statement: Nothing to declair.

Human Rights Statement: All the procedures on humans were conducted in accordance with the the Helsinki Declaration of 1975, as revised 2000. Consent was obtained from the patient/s and approved for the current study by national ethical committee. None reguired.

Animal Rights Statement: None reguired.

Received on January 5, 2019.
Revised on February 20, 2019.
Accepted on February 21, 2019.

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