Original Article

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Effect of different torques in cyclic fatigue resistance of K3 rotary instruments

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Abstract

Aim: To assess the effect of different torque values on cyclic fatigue resistance of K3 rotary nickel-titanium (NiTi) files. **Methods:** Eighty K3 files, size 25 mm, taper 0.04 were divided in 4 groups according to different torques (0.5, 1, 2 and 6 Ncm) and were submitted to a cyclic fatigue test. This test was performed with a device that allowed the file to rotate inside a stainless steel artificial curved canal, simulating the pecking motion. Files rotated until fracture occurred and time to failure was recorded in seconds with a stopwatch. Data were analyzed by ANOVA and Tukey tests ($p<0.05$). **Results:** All groups were compared and only the group of 6 N.cm showed statistically significant difference ($p=0.0002$). **Conclusions:** For #25.04 K3 files, the evaluated torques up to 2 N.cm had no influence on cyclic fatigue resistance. Using 6 N.cm torque value resulted in lower resistance to cyclic fatigue.

Keywords: dental instruments; endodontics; fatigue; root canal preparation; torque.

Introduction

Endodontic file fracture is a catastrophic accident that may occur during root canal therapy. Despite greater flexibility and torsion resistance of NiTi files, fracture is the major concern in these files, especially after prolonged use[1]. Unfortunately, most of these fractures occur unexpectedly, with no sign of permanent deformation. Cyclic alloy fatigue, with successive tension and compression loads on the curved areas of the root canal can be the most destructive form of cyclic load. Therefore, most cases of mechanical failure of NiTi rotary files during clinical use have been associated with cyclic fatigue[2].

Many factors can affect the cyclic fatigue behavior of NiTi files, such as radius[3,4] and root canal curvature[5], number of uses of the files, motor torque[3-,4], dentist's expertise[6-8], motor speed, sterilization method[9] and surface treatment of files[10].

The frequency of use of rotary NiTi files and the motor torque setting are parameters that might affect the cyclic fatigue resistance of these files. Studies have investigated the dynamic cyclic fatigue using an apparatus[3,10-14] that simulates the pecking motion, and use of this movement during instrumentation by NiTi rotary files appears to significantly extend the life span of the file.

As there is close relationship between torque and file separation by cyclic fatigue, the aim of this study was to assess the cyclic fatigue behavior of K3 files (SybronEndo, Orange, USA) submitted to different torques using an experimental cyclic fatigue testing apparatus that simulates the pecking motion in curved canals. The null hypothesis was that different torque values have no influence on cyclic fatigue resistance during instrumentation in simulated curved canals.

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Material and methods

A total of 80 K3 files #25.04 were divided into four groups of 20 files each, based on torques of 0.5, 1.0, 2.0 and 6.0 N.cm to which they would be subjected. The files were used with an electric motor (X-Smart; Dentsply Maillefer, Ballaigues, Switzerland) at 300 rpm.

Cyclic fatigue test was performed with a custom-made apparatus specifically designed to allow dynamic testing by simulating the pecking motion, made essentially of aluminum (Figure 1), according to previous studies[10-13].

Platforms were moved using a ring with internal sulcus until reaching a position that allowed the file to remain curved and free to rotate between the cylinder and the steel jig, thus simulating rotary instrumentation of a canal with a 40-degree, 5-mm radius curvature. Care was taken to ensure that the file was well positioned in the cylinder groove to avoid file displacement. The file tip remained visible throughout the experiment, touching the sensor when the maximum displacement of the pneumatic system was achieved.

Thus, the whole micromotor/contra-angle/file set was powered by the pneumatic system, reproducing the pecking motion, with a 2 mm forward and backward movement, where the file slides in the groove created on the ring made of tempered steel. This movement was repeated at the speed of one cycle per second. A sensor detected the instrument fracture at the moment the counter and timer were stopped. Testing time was registered with a digital stopwatch (Casio, Tokyo, Japan), which started at the moment the motor was turned on and stopped by fracture detection. This procedure was sequentially repeated for all groups.

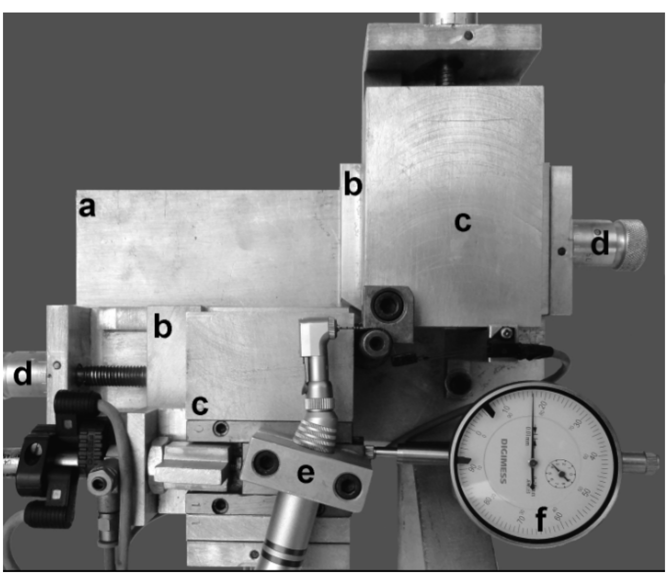

Fig 1. Cyclic fatigue testing apparatus. Letters *a*, *b* and *c* – Rectangular platforms; *d* – Grading rings; *e* – Mechanical arm with locking ring to support micromotor/contra-angle/file; *f* – pneumatic cylinder to produce the pecking motion.

After completion of all tests, the mean time to failure observed in each group was recorded in seconds. Due to the fact that this study included an independent set of samples with normal distribution and equal variances, ANOVA and Tukey tests were used to check statistically significant differences ($p<0.05$). Statistical analysis was performed with SPSS 17.0 statistical software (SPSS, Chicago, IL, USA).

Results

Fatigue resistance data were assessed with regard to central tendency (mean) and dispersion (standard deviation). ANOVA revealed that the torque affected significantly the cyclic fatigue resistance ($p=0.0002$). Table 1 shows fracture data obtained from each group and Tukey test results for the used torques, respectively. It was observed that torques of 0.5, 1.0 e 2.0 had no influence on the cyclic fatigue resistance ($p>0.05$). However, the 6.0 N.cm torque influenced significantly the cyclic fatigue resistance ($p<0.05$).

Discussion

In the present study, the null hypothesis was rejected, since the torque values affected the cyclic fatigue resistance in NiTi files. The present study assessed the cyclic fatigue resistance of K3 files submitted to different torques, using an experimental cyclic fatigue testing apparatus that simulates the pecking motion. File size (#25) and taper (0.04) were chosen since they are compatible with instrumentation of apical thirds in curved canals, mainly due their flexibility for cleaning and shaping these root canals. The option for K3 files is based on the idea that the file cross-sectional area is strongly related to cyclic fatigue resistance which occurs along the 16 mm of the working portion of these files[15].

Mechanical stress of NiTi files is strongly related to the root canal curvature and dentin hardness[5], but it is also proportional to the motor torque[3-4] and the cyclic fatigue resistance decreases with prolonged clinical use[3,16]. Cyclic fatigue occurs at the instrument's maximal flexure rotating freely inside curved canals, without prior indication of failure[17]. Continuous traction and compression cycles in

Table 1. Means of cycles to fracture, standard deviations and time to failure, expressed in seconds, for the different groups

Torque	n	Time to failure (s)	Standard Deviation	Mean cycles to fracture	Standard Deviation
0.5 N.cm	20	143.6^a	6.87	718.0^a	34.37
1.0 N.cm	20	146.3^a	5.87	731.5^a	29.37
2.0 N.cm	20	156.0^a	6.44	780.0^a	32.24
6.0 N.cm	20	112.9^b	5.17	564.5^b	25.86

Different letters indicate statistically significant difference (p<0.05).

curved canals are the most destructive form of cyclic fatigue and fracture for endodontic files[2,4,8,14,18]. Although many studies have assessed cyclic fatigue and the dynamics of NiTi rotary files[3-4,19], the relationship between force exerted during preparation of the root canal and clinical risk of distortion and fracture of files has not yet been properly studied.

This study aimed to investigate the pecking motion mechanisms associated with cyclic fatigue test in the fracture of K3 NiTi rotary files. The methodology allowed the files to rotate freely at a standardized curvature. Other studies[3-4,16,18] have also indicated that these methodological characteristics are the most suitable for cyclic fatigue assessment in rotary NiTi files, since static tests do not reproduce the real conditions faced in clinical practice: automated instrumentation systems have been designed to enter the root canal in motion, with previously determined torque and speed values, whereas load distribution over a large area prolonged the life span of file. Recently, Gambarra-Soares et al.[20] (2013) reported that despite the fact that the static test complies with the no. 28 ANSI/ADA specifications, the dynamic cyclic fatigue test provides more reliable data regarding the lifespan determination of endodontic files and a better representation of clinical practice. Occurrence of maximum flexion in the same location, in the same point, will decrease the lifespan of the file. Continuous tension and compression in the curved area of the root canal promote a destructive load on NiTi rotary files[3,14].

During the pecking motion, the files were always stressed in the curved canal, but the pecking distance provides the files a time interval before it is once again subjected to the area of highest stress. According to Li et al.[11] (2002) the pecking motion may be a crucial factor in preventing the fracture of NiTi rotary files. The pecking motion minimizes the stress on files in curves, decreasing the chance of occurring fracture. To avoid rupture of the NiTi rotary file, Li et al.[11] (2002) advise the use of appropriate rotational speed and continuous pecking motion in root canals.

In the present work, it was also observed that the effect of high torque (6 N.cm) on cyclic fatigue resistance was statistically significant ($p=0.0002$). A possible explanation for this result is that the mechanical stress on the NiTi files is also proportional to motor torque. If a high torque motor is used, the maximum torque limit of file is often exceeded, increasing mechanical stress and risk of plastic deformation or file fracture. Even though some good results were obtained with high torques[12,18], instrumentation technique and the dentist's expertise play an important role in file failure[19]. Gambarini[13] (2001) also observed that the endodontic motor with lower torque values reduced cyclic fatigue of nickel-titanium rotary instruments.

The results of this *in vitro* study must be critically interpreted, and comparisons with clinical practice must be made with caution, because only two of the many variations of root canal preparation were assessed. During this procedure, there are different types of stress from different mechanisms, which are correlated and can affect the lifespan of NiTi rotary files.

Although there is still no consensus regarding the maximum torque allowed for each file system, according to results of this study, it may be concluded that 25.04 K3 files can be used with a maximum torque of 2 N.cm without affecting their cyclic fatigue behavior. Further studies should be carried out in dynamic pecking motion, with torques ranging from 2 to 6 N.cm in order to prevent accidents that may occur during preparation of root canals.

New designs and alloys, and different motions have been introduced to increase the cyclic fatigue resistance of nickel-titanium (NiTi) files[10,21]. A recent research showed that the reciprocating motion improved significantly the resistance of K3 files to cyclic fatigue[21]. Therefore, it is important to develop strategies to improve the resistance to fracture of endodontic files in order to avoid a catastrophic file separation that may contribute negatively to success of treatment. Further works should be performed to better understand the behavior of files inside the root canal.

The analysis of the results obtained in the present study allowed concluding that for K3 files, torques up to 2 N.cm had no influence on cyclic fatigue resistance. The use of 6 N.cm torque value resulted in lower resistance to cyclic fatigue.

References

1. Spanaki-Voreadi AP, Kerezoudis NP, Zinelis S. Failure mechanism of ProTaper Ni-Ti rotary instruments during clinical use: fractographic analysis. Int Endod J. 2006; 39: 171-8.
2. Haïkel Y, Serfaty R, Bateman G, Senger B, Allemann C. Dynamic and cyclic fatigue of engine-driven rotary nickel-titanium endodontic instruments. J Endod. 1999; 25: 434-40.
3. Pruett JP, Clement DJ, Carnes-Jr DL. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod. 1997; 23: 77-85.
4. Zelada G, Varela P, Martín B, Bahillo JG, Magán F, Ahn S. The effect of rotational speed and the curvature of root canals on the breakage of rotary endodontic instruments. J Endod. 2002; 28: 540-2.
5. Mesgouez C, Rilliard F, Matossian L, Nassiri K, Mandel E. Influence of operator experience on canal preparation time when using the rotary Ni-Ti ProFile system in simulated curved canals. Int Endod J. 2003; 36: 161-5.
6. Yared G, Bou Dagher FE, Kulkarni K. Influence of torque control motors and the operator's proficiency on ProTaper failures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003; 96: 229-33.
7. Yared GM, Bou Dagher FE, Machtou P. Influence of rotational speed, torque and operator's proficiency on ProFile failures. Int Endod J. 2001; 34: 47-53.
8. Melo MCC, Bahia MGA, Buono VTL. Fatigue resistance of engine-driven rotary nickel-titanium endodontic instruments. J Endod. 2002; 28: 765-9.
9. Gavini G, Pessoa OF, Barletta FB, Vasconcellos MAZ, Caldeira CL. Cyclic fatigue resistance of rotary nickel-titanium instruments submitted to nitrogen ion implantation. J Endod. 2010; 36: 1183-6.
10. Gavini G, Caldeira CL, Akisue E, Candeiro GTM, Kawakami DAS. Resistance to Flexural Fatigue of Reciproc R25 Files under Continuous Rotation and Reciprocating Movement. J Endod. 2012; 38: 684-7.
11. Li UM, Lee BS, Shih CT, Lan WH, Lin CP. Cyclic fatigue of endodontic nickel-titanium rotary instruments: static and dynamic tests. J Endod. 2002; 28: 448-51.
12. Yao JH, Schwartz SA, Beeson TJ. Cyclic fatigue of three types of rotary nickel-titanium files in a dynamic model. J Endod. 2006; 32: 55-7.

13. Gambarini G. Cyclic fatigue of nickel-titanium rotary instruments after clinical use with low and high-torque endodontic motors. J Endod. 2001; 27: 772-4.
14. Eggert C, Peters O, Barbakow F. Wear of nickel-titanium lightspeed instruments evaluated by scanning electron microscopy. J Endod. 1999; 25: 494-7.
15. Sattapan B, Nervo GJ, Palamara JEA, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod. 2000; 26: 161-5.
16. Yared GM, Bou Dagher FE, Machtou P. Cyclic fatigue of ProFile rotary instruments after clinical use. Int Endod J. 2000; 33: 204-7.
17. Sattapan B, Nervo GJ, Palamara JEA, Messer HH. Torque during canal instrumentation using rotary nickel-titanium files. J Endod. 2000; 26: 156-60.
18. Pessoa OF, Silva JM, Gavini G. Cyclic Fatigue Resistance of Rotary NiTi Instruments after Simulated Clinical Use in Curved Root Canals. Braz Dent J. 2013; 24: 117-20.
19. Cho OI, Versluis A, Cheung GS, Ha JH, Hur B, Kim HC. Cyclic fatigue resistance tests of Nickel-Titanium rotary files using simulated canal and weight loading conditions. Restor Dent Endod. 2013; 38: 31-5.
20. Gambarra-Soares T, Lopes HP, Oliveira JCM, Souza LC, Vieira VTL, Elias, CN. Dynamic or static cyclic fatigue tests: which best determines the lifespan of endodontic files? Endod Pract Today. 2013; 7: 101-4.
21. Pérez-Higueras JJ, Arias A, de la Macorra JC. Cyclic fatigue resistance of K3, K3XF, and twisted file nickel-titanium files under continuous rotation or reciprocating motion. J Endod. 2013; 39: 1585-8.