Original Article

Cyclic fatigue resistance of three Nickel-Titanium rotary files in single curvature canals: An in-vitro analysis

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Abstract

Objective: This study aimed to evaluate the cyclic fatigue resistance (CFR) of three different heat-treated nickel-titanium (NiTi) files in rotary motion utilizing a cyclic fatigue testing device.

Methods: Three NiTi rotary systems, Hero Gold, NeoEndo Flex, and T-Pro were used in this study. Ten files from each system (4% taper, #25 size, 21mm length) were tested for CFR. The test was conducted in an artificial canal in a customized cyclic fatigue device. The canal system comprised of a 60° angle of curvature located 8 mm from the orifice. All files were rotated until fracture at the rotation per minute (RPM) and torque settings according to the manufacturer's recommendation. The time to fracture (TTF) was recorded in seconds for each instrument and then multiplied by (RPM/60) to obtain the number of cycles to fracture (NCF). The fracture length of each instrument fragment was recorded. Data were analyzed by one-way ANOVA and Tukey test and P-value <0.05 was considered statistically significant.

Results: The NiTi rotary systems demonstrated significantly different TTF values (P=0.001). Hero Gold exhibited a significantly higher TTF (114.13±4.21), followed by NeoEndo Flex (65.24±2.20) and T-Pro (40.50±3.45). The difference in TTF was also significant between NeoEndo Flex and T-Pro groups (P<0.05). There was no statistically significant difference in the length of the fractured fragments between the three groups (P=0.08).

Conclusion: The Hero Gold file system demonstrated significantly superior CFR compared to the NeoEndo Flex and T-Pro systems, possibly due to differences in manufacturing processes for different file systems.

Keywords: Endodontics, Fatigue, File fracture, Root canal preparation, Root canal therapy, Rotary files

Introduction

The introduction of nickel-titanium (NiTi) rotary instruments into clinical practice has enhanced the effectiveness of endodontic treatment by their greater accuracy, reduced procedural errors, and decreased treatment time (1). Cyclic fatigue is caused by the excessive stresses of the repetitive compression and tension that occurs during the rotation of a file around a curvature.

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A prime shortcoming of NiTi root canal instruments is their high fracture potential especially in curved canals, primarily due to concentrated fatigue and torsional shear stresses (2). Sattapan et al (3) reported that torsional fracture occurred in 55.7% of all fractured files, whereas flexural fatigue occurred in 44.3% of cases. Several factors affect cyclic fatigue resistance (CFR) of a file including the radius, the angle and length of curvature, and the diameter and the design of the instrument.

Cyclic fatigue is reported to be one of the major factors for instrument separation in curved canals (4). This implied the need for studies comparing the CFR of various file systems. Although there are many tests to evaluate CFR, rotational bending test using artificial canals is the most common method of fatigue testing for NiTi rotary instruments (5).

To enhance safety and decrease the chances of fracture, several attempts have been made by manufacturers in

Figure 1: The cyclic fatigue testing device with a supported handpiece

recent years to improve the thermomechanical characteristics of NiTi rotary endodontic files. These improvements aim to enhance the flexibility, metallurgy, design, kinematics, and fracture resistance of NiTi files. Attempts to achieve this goal include surface modification by electro-polishing and the enhancement of mechanical properties by adding new alloys and new designs, including cross-sectional modifications (6, 7). Hero Gold file (One Flare Micro Mega, Besancon, France) is made of an annealed, heat-treated NiTi alloy called Fire-Wire. This system features an innovative pitch design that avoids screwing effects and a substantial inner core for excellent breakage resistance. NeoEndo Flex file (Orikam Healthcare, Gurugram, India) represents the third generation of rotary files and includes a two-file shaping system. This file undergoes a specialized heat treatment process, providing it with unique flexibility characteristics so that its flutes do not deform when stress levels increase. The T-Pro file (D perfect, Guangdong, China) is a new generation of files that combine heat activation and super flexibility.

Several studies have shown enhanced CFR due to recent advancements in file technology. However, to the best of our knowledge, no study has yet compared the effects of different heat-treated file types together. Therefore, the present study aimed to compare the CFR of three different NiTi rotary file systems, namely Hero Gold, NeoEndo Flex, and T-Pro, using a cyclic fatigue testing device.

Materials and Methods

Three NiTi rotary instruments (Hero Gold, NeoEndo Flex, and T-Pro) were used in this study. Ten files from each system (4% taper, #25 size, and 21 mm length) were tested for CFR. All files were examined for any defects or deformities under a stereomicroscope (Lawrence and Mayo, Mumbai, India) at 20 X magnification. The rotary files were divided into 3 experimental groups (n = 30) as follows: Group A: Hero Gold files, Group B: NeoEndo Flex files, and Group C: T- Pro files.

Cyclic fatigue testing device

This study utilized a custom-fabricated, static cyclic fatigue testing device. All components of the device were made from a hard metal, with a simulated canal and a handpiece attached. The simulated canals were manufactured with the following measurements: single curvature of 60° angle and a 5-mm radius with the center of the curve positioned 8 mm from the tip of the instrument. The endomotor handpiece was mounted on the support which ensured the correct positioning and placement of files to an appropriate depth for all the samples (Figure 1).

All files were rotated until fracture using an endodontic motor (X-smart; Dentsply Mallifer, Ballaigues, Switzerland) with a 16:1 reduction handpiece at the rotation per minute (RPM) and torque settings according to the manufacturer's recommendation. The time to fracture (TTF) was recorded (with a synchronized digital stopwatch) in seconds for each instrument and then multiplied by (RPM/60) to obtain the number of cycles to fracture (NCF). The mentioned method was similar to the procedure described by Kiefner et al. (8) The fracture length of each instrument fragment was recorded using an electronic digital Vernier calliper (Thermomate, South Carolina, USA) (Figure 2).

Figure 2: Measurement of the fractured fragment using a digital Vernier caliper

Statistical Analysis

The normality of the data was evaluated using Kolmogorov– Smirnov test. The data were then analyzed by one-way analysis of variance (ANOVA) and the Tukey post hoc test to identify statistical differences in TTF, and fragment length among the groups. A P-value of less than 0.05 was considered to indicate statistical significance. All the tests were done using SPSS software (ver. 22, IBM, USA)

Results

Table 1 presents the mean values and standard deviations for TTF and fragment length. ANOVA revealed a significant difference in TTF among the groups (P=0.001; Table 1). Hero Gold exhibited a significantly higher TTF (114.13±4.21), followed by NeoEndo Flex (65.24±2.20) and T-Pro (40.50±3.45). The difference in TTF was also significant between NeoEndo Flex and T-Pro groups (P<0.05; Table 1). Hero Gold demonstrated significantly greater NCF compared to NeoEndo Flex and T-Pro (P<0.05). There was no significant difference in the lengths of the fractured file fragments among Hero Gold, NeoEndo Flex, and T-Pro groups (P =0.08; Table 1).

Discussion

In this study, we compared the CFR of heat-treated rotary file systems (NeoEndo Flex, Hero Gold, and T-Pro files) in simulated root canals. To minimize errors, all files were tested by a single operator. The speed and RPM of rotary instruments vary and they should be operated at a rate that minimizes the incidence of fracture while maintaining efficiency. In this study, we conducted continuous rotations based on the manufacturer's recommendations using an Endomotor with a 16:1 reduction handpiece.

The NCF for each instrument was calculated by multiplying TTF in seconds by the number of rotation cycles per second (RPM/60) (9). According to the results of the present study, the TTF and CFR of Hero Gold is significantly higher compared to the NeoEndo Flex and T-Pro file systems. This indicates that Hero Gold instruments are likely to withstand a greater number of cycles before fracture in the clinical settings.

While all three systems are fabricated from heat-activated materials, they each employ distinct production methods and technologies. A significant difference lies in

Table 1: The mean and standard deviation (SD) of time to fracture (TTF), and fragment length of the tested nickel-titanium file systems.

Groups	TTF (seconds)	NCF	fragment length (mm)
	Mean ± SD	Mean ± SD	Mean ± SD
Hero Gold	114.13 ± 4.21[a]	618.2 ± 22.8[a]	5.26 ± 0.40
NeoEndo Flex	65.24 ± 2.20[b]	380.56 ± 12.83[b]	5.32 ± 0.25
T-Pro	40.50 ± 3.45[c]	185.62 ± 15.81[c]	4.56 ± 0.54
p-value	0.001	<0.001	0.08

Statistically significant differences were noted at P<0.05.

Hero Gold's manufacturing process, wherein the file is not subjected to twisting during rotation. This may be attributable to the flexibility of Hero Gold that results from the thermal treatment, the surface electro-polishing, and the big inner core (10). The surface electro-polishing produces a smooth surface with fewer defects, which enhances the fracture resistance of the file. This finding is in accordance with a study by Bonaccorso et al (11).
There was no significant difference in the mean length of the broken fragments of tested instruments. The instruments typically fractured at or just below the center of curvature. This is consistent with previous studies (12), and further validates the precision of the instruments. In the clinical settings, there will be less chances of instrument separation if the clinician is already aware of the CFR of particular file systems, resulting in better and more efficient endodontic treatment.

Cyclic fatigue testing assesses the durability of rotary instruments inside a curved root canal. The thermal treatment of different NiTi alloys, surface electropolishing, cross-sectional designs, diameters, and tapers all contribute to a NiTi instrument’s tendency for cyclic failure (13, 14). The mechanical properties of endodontic files using the finite element analysis method (FEA) have shown that as the area of the inner core of the cross-section increased, the model was more torque-resistant (15). Furthermore, heat treatment of files is shown to influence the flexibility and increase the life span of instruments (16).

The use of natural teeth is not recommended because it is difficult to standardize root canal length, degree of curvature, and dentin hardness (5). The simulated root canals with an angle of curvature of 60° in the present study were based on the study by Pruett et al (9). They believed that the stress levels induced by curvatures less than 30° angle did not result in instrument separation (9). Although this simulated canal was unable to replicate clinical conditions, it minimizes the impact of other variables that may influence file fracture, thus facilitating standardization. As described by Pruett et al (9), the maximum area of stress in the instrument is close to the arc midpoint of the canal. In the present study, this area was approximately 8 mm from the orifice of the simulated canal.

The rotary instruments used in this study have comparable tapers and sizes. A study employing FEA demonstrated that instruments with a triangular cross-section design exhibited higher CFR than those with square or rectangular cross-section designs (17). This difference is related to the reduced metal mass of the instruments with a triangular cross-section compared with that of instruments with other cross-section designs (18). Since rotary files with triangular cross-sections are anticipated to show higher CFR rates, we chose to evaluate Hero Gold, NeoEndo Flex, and T-Pro files; all designed with triangular cross sections.

The limitations of our study are the absence of irrigation and lubricants, which makes it impossible to assess their effects on the file fractures. It is worth mentioning that this *in vitro* study was performed in an artificial canal, with different structural properties compared to human dentin and the induced (simulated) file motion in this study did not not represent the dynamic pecking motion performed during the routine mechanical preparation. Since we were only able to test and compare three different rotary file systems, we recommend that future studies investigate both *in vivo* and *in vitro* fatigue resistance in a greater number of rotary file systems. Such investigations will be crucial in guiding clinicians in their choice of NiTi rotary files, with the ultimate goal of improving patient outcomes in endodontic treatments.

Conclusions

The Hero Gold file system exhibited significantly higher CFR compared to the NeoEndo Flex and T-Pro systems, possibly due to differences in manufacturing processes for different file systems.

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