Cyclic Fatigue Resistance of K3, K3XF, and Twisted File Nickel-Titanium Files under Continuous Rotation or Reciprocating Motion

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Abstract

Introduction: New designs and alloys and different motions have been introduced to increase the cyclic fatigue (CF) resistance of nickel-titanium (NiTi) files. The aim of this study was to compare the CF resistance of K3 (SybronEndo, Orange, CA), K3XF (SybronEndo), and TF (SybronEndo) files under continuous rotation and reciprocating motion. **Methods:** A total of 210 files (30-tip diameter, 0.06 fixed taper), 60 K3, 60 K3XF, and 90 TF files, were divided into 7 groups (30 files each): K3-C, K3XF-C, and TF1-C were rotated at 300 rpm; TF2-C was rotated at 500 rpm; and K3-R, K3XF-R, and TF1-R were used in a reciprocating motion. CF resistance was tested in stainless steel, curved canals (60°, $r = 3$ mm) until fracture, and the time to fracture was recorded. The mean half-life, beta, and eta were calculated for each group and were compared with Weibull analysis. **Results:** The probability of a longer mean life was greater under reciprocating motion for all of the files (100% for K3, 87% for K3XF, and 99% for TF). Under continuous rotation, K3XF was more resistant than K3 and TF. TF lasted significantly longer than K3. TF was more resistant to CF when rotated at 300 rpm instead of 500 rpm. Under reciprocating motion, there were no significant differences between K3XF and TF mean lives, but both were significantly longer than the K3 mean life (78% for TF and 86% for K3XF). **Conclusions:** Reciprocating motion and R-phase increase CF resistance. *(J Endod 2013;39:1585–1588)*

Key Words

Cross-section, R-phase, reciprocation, rotational speed, Weibull analysis

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Since 1988, when nickel-titanium (NiTi) was proposed for use in the manufacturing of endodontic instruments (1), NiTi rotary files have become popular (2) because of their greater flexibility, cutting ability, and more rapid and centered root canal preparation (3, 4). However, these files tend to break unexpectedly because of cyclic fatigue (CF), which is induced by the alternating tension-compression cycles to which they are subjected when flexed in the maximum curvature region of the canal and are rotated (5).

To improve the CF resistance of files, manufacturers have introduced different designs and improved alloys. R-phase is an intermediate phase with a rhombohedric distortion of the cubic austenite phase created by a process of heating and cooling in which the final shape of the file is achieved, and different series of cooling and heating then convert the wire back to the austenite crystalline structure (5–8).

K3, Twisted File (TF), and K3XF are different NiTi rotary files developed by SybronEndo (Orange, CA). K3 was the first file developed (2002), and it was manufactured with a traditional grinding process. TF was developed in 2008 with a different manufacturing process including 3 new methods: heat treatment (R-phase), twisting of the metal wire, and special surface conditioning (9). In 2011, K3XF was developed with the same R-phase heating and cooling protocol as TF, but instead of being twisted, it was ground like K3 (10).

On the one hand, K3 and K3XF are made of a different NiTi alloy (K3 is made of conventional NiTi alloy and K3XF of R-phase); however, they have the same cross-section (a modified triple U: 2 reduced radial lands with a reduced zone to minimize friction and a third complete radial land), they undergo the same manufacturing method (grinding), and the same protocol of use is recommended by the manufacturer (continuous rotation at 300–350 rpm) (11, 12). On the other hand, TF has a different cross-section (triangular), it undergoes a different manufacturing method (twisting), and the manufacturer recommends that it be rotated at 500 rpm (5). TF and K3XF are made of the same R-phase alloy.

The thermal treatment of NiTi (9, 13, 14), cross-section of files (15, 16), speed in continuous rotation (17, 18), and manufacturing methods (5, 9, 19, 20) are parameters that are known to influence the CF resistance of files. Testing the CF resistance of these 3 different systems allows for analysis of the relative importance of these parameters that supposedly influence the behavior of NiTi rotary files in clinical situations because each of these systems has characteristics that make it different from the others but, at the same time, somewhat comparable.

Debate continues regarding the best motion of action for NiTi rotary files. Clinicians and researchers have suggested reciprocating motions instead of continuous rotation (21, 22), and scientific studies have shown a greater CF resistance of files when they are used with reciprocating movements (23–27).

No studies have compared CF resistance using 2 different motions (continuous rotation and reciprocation) among these 3 types of files, which have similar morphologies but are made of different alloys and undergo different manufacturing methods. Therefore, the aim of this study was to compare the CF resistance of K3, K3XF, and TF files at 5 mm from the tip under continuous rotation or reciprocating motion.

Materials and Methods

A sample of 210 new files (60 K3, 60 K3XF, and 90 TF) was used. All of the files had the same tip diameter (30) and a fixed taper (0.06). CF resistance was tested at 5 mm from the tip. The diameter at the tested length was 0.60 mm.

The files were divided into 7 groups (30 files each, Table 1). Continuous rotation at 300 rpm was used with the files in groups K3-C, K3XF-C, and TF1-C, and 500 rpm was used in group TF2-C. The files in groups K3-R, K3XF-R, and TF1-R were used with reciprocating motion in an ATR Tecnika Vision electric motor (Dentsply Maillefer, Ballaigues, Switzerland). Clockwise and counterclockwise rotations were set at four tenths and two tenths of a circle (144°–72°) as described by other authors (21–25).

The experiment was performed using a previously described device (28). The canal of 1-mm width was used because it was the width (to the nearest 0.1 mm) immediately beyond the diameter of the file at the entrance of the canal (0.9 mm) (Fig. 1*B*).

The device had a hardened stainless steel piece with 11 carved, open semicanals with 2 straight open portions joined by a 60° curvature with a 3-mm radius, with diameters ranging from 0.4–1.4 mm and a depth of 0.1 mm greater than each width. This piece was attached to a base that allowed for adjusting the positions of the files on the 3 axes of space(Fig. 1*A*). The x-axis held the dental handpiece and was approached or separated from a second platform, which held the stainless steel carved piece. This second platform adjusted the vertical (y-axis) and depth (z-axis) positions of the canals. A swiveling top face cover allowed for the visualization of the files and protected the operator (Fig. 1*B*).

Both the canal and the file were lubricated with synthetic oil (Singer All-Purpose Oil; Singer Sewing Company, Barcelona, Spain) to minimize friction. The motor and a 1/100-second chronometer were simultaneously activated, the file was monitored through the face cover until fracture, and the time (seconds) to fracture was registered.

Weibull analysis (Weibull++7; Reliasoft Corporation, Tucson AZ) was used to calculate different parameters and their 95% confidence intervals for each group including the following:

1. *Mean life (seconds)*: The expected or average time to failure
2. *Beta*: The slope or shape parameter (dimensionless), the values of which are equal to the slopes of the regressed lines in the Weibull probability plot and are particularly significant because they provide a clue to the physics of the failure
3. *Eta (seconds)*: Characteristic life or scale parameter. Eta is the typical time to failure in Weibull analysis related to the mean time to failure. It is defined as the expected time that 63.2% of the files will attain without breakage (ie, the probability of failure being 0.63 at this time point).

Comparison between the groups allowed for the determination of whether items from 1 set would outlast those of the others.

TABLE 1. Files and Conditions in the Study

Group	File	*n*	Speed (rpm)	Kinematics
K3-C	K3	30	300	Continuous rotation
K3XF-C	K3XF			
TF1-C	TF			
TF2-C	TF		500	
K3-R	K3		300	Reciprocation
K3XF-R	K3XF			
TF1-R	TF			

Results

The distribution of reliability versus time by group is shown in Figure 2. Table 2 presents the results and 95% confidence intervals for beta, eta, and mean life parameters.

Comparison of the datasets showed that mean life was significantly longer for all files when used with reciprocating motion compared with continuous rotation. The probability that the files used in reciprocation motion would last longer than the files used with continuous rotation was 100% for K3, 87% for K3XF, and 99% for TF.

When mean life was compared among the brands under continuous rotation (300 rpm), K3XF will last longer than K3, with a probability of 94%, and longer than TF, with a probability of 83%. In addition, TF will last longer than K3, with a probability of 93%.

When different rotational speeds were used, the probability that TF, rotated at 300 rpm, will last longer than if rotated at 500 rpm was 97%. Under reciprocating motion, there were no significant differences in mean life between K3XF and TF, but both will last longer than K3 (probability of 78% for TF and 86% for K3XF).

Discussion

The CF device and the statistical approach used in this study were previously discussed in a recent report (28). There are no standardized specifications to test the CF of rotary NiTi instruments—only to test the torsional load of .02 NiTi files used for hand instrumentation (29). An effort should be undertaken to minimize uncontrolled variables and to reproduce the same conditions when the CF resistance of files is tested (30).

This study tested static CF in a hardened steel canal. The design of the canals were not intended to simulate clinical conditions but rather to allow for precise testing of CF resistance at a given level of the file through the application of pure tension-compression cycles and excluding variables that cannot be reproduced in a tooth model.

Many studies have tested CF in metal devices with different designs including constricting the file into a curvature delimited by stainless steel pins (31, 32) or using different types of simulated canals (10, 14, 24, 33, 34). The device used in this study allowed for the selection of the exact point at which CF resistance was to be tested (5 mm). The device used different sizes of open-ended semicanals and provided a firm platform that allowed for the placement of the instrument in a curved and reproducible situation to test all of the files. All

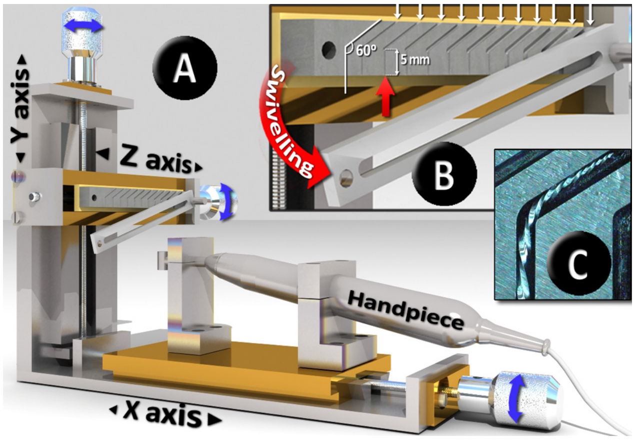

Figure 1. A cyclic fatigue testing device. A, A general view. Three axes are shown. B, The swiveling motion of grooved stainless steel top face cover and carved open semicanals (*white arrows*). A *red arrow* indicates the entrance of a canal. C, An image of the bending point of a file before testing.