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COMPARISON OF THE CYCLIC FATIGUE RESISTANCE OF NEOLIX, K3XF AND PROTAPER NITI ROTARY INSTRUMENTS

Dental Science

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ABSTRACT

Recent improvements in alloys, cross sectional design and concepts have been combined to increase the cyclic fatigue resistance of nickel-titanium (NiTi) instruments. The aim of this study was to compare the CF resistance of Neolix (25 08%, K3XF(25 08%), and protaper F2 files at 5 mm from the tip under continuous rotation. A total of 15 (N=15) new rotary Neolix, 15 K3XF instruments and F2 Protaper universal files were selected. A static cyclic fatigue testing device with a 600angle of curvature and the curvature started at 5 mm from the tip of the canal. The instruments were rotated freely inside the metal canal. The duration for failure and number of rotations before failure recorded. Within the limitations of this in vitro study, it was found that the cyclic fatigue resistance was higher for the Neolix instruments than for the K3XF files and Protaper instruments.

KEYWORDS

Cyclic Fatigue, Instrument separation, Neolix, Fractographic analysis.

INTRODUCTION:

Nickel-titanium (NiTi) rotary files have become a standard tool to shape root canals because of their high flexibility with good cutting ability and as they create centered preparations more rapidly.[1] Major drawback of NiTi instrument is that they fracture without any visible defects of previous deformation.[2] Fracture of NiTi instruments incidence ranges between 0.26%-21%.[3] The main reason for these fractures is the cyclic fatigue (CF), when the instrument rotates inside a curved root canal and is affected by an excessive number of tension - compression strain cycles in the region of maximum root canal curvature.[4] Increasing the resistance to file separation has been the main goal for ensuring safety during endodontic instrumentation.

ProTaper rotary system (Dentsply Maillefer, Ballaigues, Switzerland) has a convex triangular cross-section with variable taper. Conventional NiTi rotary endodontic files are manufactured by machining starting wire blanks that are in the superelastic austenitic phase.[5] Under stress, it changes to the martensitic phase.

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. Cyclic fatigue resistance and flexibility of the file is improved by the R-Phase. K_3XF are the files manufactured with R phase NiTi.

Neolix is a single and universal rotary NiTi system which is manufactured by electric discharge machining (EDM) process. This process consists of sparks produced by high energy and high frequency electric discharges between the metal workpiece and an electrode, leading to melting and evaporation of the work-piece material locally resulting in the finished product of desired geometry.[6,7]

No studies have compared Cyclic Fatigue resistance using 3 different 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 Neolix (25 08%, K3XF(25 08%), and protaper F2 files at 5 mm from the tip under continuous rotation.

Materials and Methods:

A total of 15 new rotary Neolix (Neolix, NeoNiTi, France), 15 K_3XF instruments (Sybron endo Mexico) (ISO tip size = 25, taper = 0.08, length = 25 mm) and F_2 Protaper universal files (Dentsply, Switzerland) were selected. All the instruments were previously inspected under an optical stereo microscope with 20x magnification for any visible signs of deformation. None of the instruments were discarded. All the files were then subjected to cyclic fatigue testing.

Cyclic Fatigue Testing Device:

A static cyclic fatigue testing device was used in this study. It consisted of a main metal frame made of iron to which an artificial canal system and a support for the handpiece were being attached. The canal system, which simulated a root canal with a 60^0angle of curvature and the curvature started at 5 mm from the tip of the canal. The marathon handpiece was mounted over the support, which also ensured the correct positioning and placement of files to the same appropriate depth for all the samples.

Cyclic Fatigue Test:

Forty five samples were randomly divided into 3 groups (n = 15) according to the type of rotary files used.

Fifteen files from each group were used. Cyclic fatigue resistance was tested by placing the file in an artificial canal that was milled in a stainless steel block using a laser micromachining technique. The canal had a curvature angle of 60^0angle and 5 mm radius of file curvature with dimensions larger than the dimensions of the file used for testing by 0.1 mm in width.[8] The maximum curvature was set at 5 mm from the tip of the file. To determine the file fracture's time and prevent slippage of the file, the canal was covered with glass. An endodontic motor was mounted in a way that allowed downward movement of the file until tip was inserted inside the canal. Then, the motor rotated the file at 300 rotations per minute (rpm) until fracture occurred. The time to fracture was recorded in minutes. Once fracture was noticed audibly and/or visually, the time recording was stopped. The number of cycles to fracture was calculated by multiplying the time to fracture in (in minutes) by 300. One of the fractured instruments in each group was examined under a scanning electron microscope

Results:

The mean time taken (in seconds) for Neolix was 115.60 ± 3.80, Protaper F2 was 45.27 ± 5.06 and K3XF was 64.80 ± 3.12. This difference in the mean Time Taken (in secs) for file separation between 03 groups was statistically significant at P<0.001. (Table 1 and Graph 1)

The mean no. of rotations for Neolix was 578.00 ± 18.97, Protaper F2 was 226.33 ± 25.32 and Revo S was 324.00 ± 15.61. This difference in the mean no. of Rotations before file separation between 03 groups was statistically significant at P<0.001. (Table 3 and Graph 2)

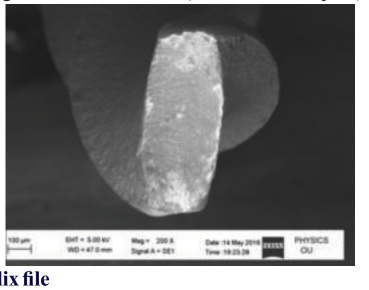

Image 1 Neolix file

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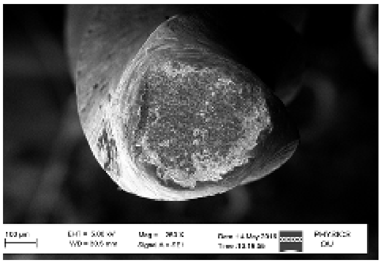


Image 2 Protaer Universal File

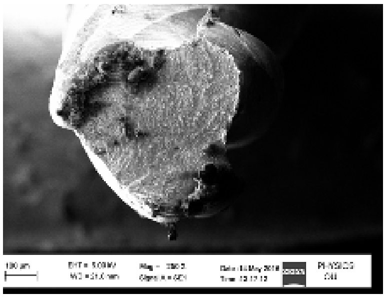


Image 3 K3XF file

Table 1: Comparison of mean Time taken (in secs) for file separation among 25-08 size different rotary files using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Neolix	15	115.60	3.80	108	120	<0.001*
Protaper F2	15	45.27	5.06	38	54	
K3XF	15	64.80	3.12	60	70	

Table 2: Multiple comparison of mean time taken for file separation between 25-08 sized rotary files using Tukey's Post hoc Analysis

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Neolix	Protaper F2	70.33	66.72	73.95	<0.001*
	K3XF	50.80	47.19	54.41	<0.001*
Protaper F2	K3XF	-19.53	-23.15	-15.92	<0.001*

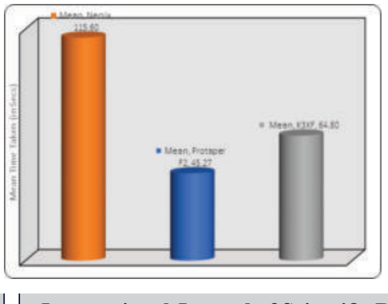
Table 3: Comparison of mean no. of Rotations before file separation among 25-08 size different rotary files using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Neolix	15	578.00	18.97	540	600	<0.001*
Protaper F2	15	226.33	25.32	190	270	
K3XF	15	324.00	15.61	300	350	

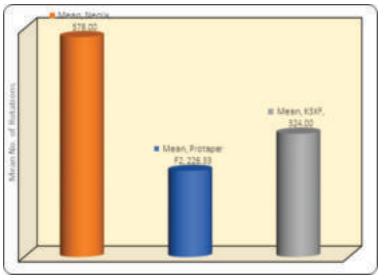
Table 4: Multiple comparison of mean no. of rotations before file separation b/w 25-08 sized rotary files using Tukey's Post hoc Analysis

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Neolix	ProtaperF2	351.67	333.60	369.74	<0.001*
	K3XF	254.00	235.93	272.07	<0.001*
Protaper F2	K3XF	-97.67	-115.74	-79.60	<0.001*

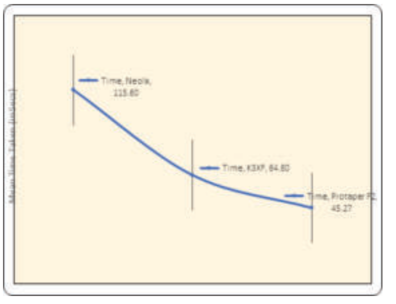
Graph 1: Mean Time taken (in secs) for file separation among 25-08 size different rotary files



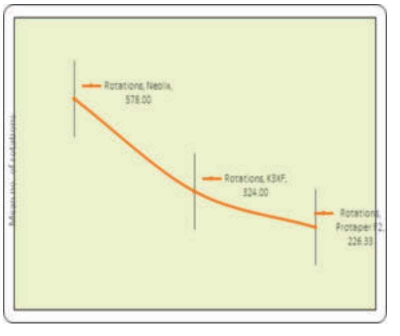
Graph 2: Mean no. of Rotations before file separation among 25-08 size different rotary files



Graph 3:Mean Time taken (in secs) for file separation among 25-08 size different rotary files [Arranged in Descending Order]



Graph 4: Mean no. of Rotations before file separation among 25-08 size different rotary files [Arranged in Descending Order]



DISCUSSION:

The separation of the rotary NiTi instrument is of particular importance as it affects the success of endodontic treatment. Separation of rotary instruments may be caused by torsional or cyclic fracture. Cyclic fatigue often occurs when a metal is subjected to repeated cycles of tension and compression that cause its structure to break down, ultimately leading to fracture. It is the main reason for the majority (93%) of broken instruments. The fracture caused by cyclic fatigue of NiTi endodontic instruments is difficult to detect during clinical practice due to the invisible signs of permanent deformation during cyclic fatigue.[9] Removing a fractured instrument is difficult and requires extensive armamentarium.

Resistance to cyclic fatigue depends on various factors such as diameter, metal mass, flexibility, cross-sectional shape, and surface finish of rotary files.[10] The aim of this study was to evaluate the cyclic fatigue resistance of the heat-treated Neolix file, K3XF file and compare them with the Pro-taper universal file.

In this study, cyclic fatigue of the instruments was evaluated by time and also by the number of cycles to fracture (NCF) . In continuous rotation motion, the assessment of the number of cycles to fracture can be obtained by multiplying the rotational speed by the time elapsed until fracture occurred.

Multiple comparison of mean difference in the time taken for file separation between groups revealed that Neolix showed significantly highest mean time taken for file separation as compared to other 2 study groups at P<0.001. And this was followed by K3XF showing significantly higher mean time taken for file separation as compared to Protaper F2 at P<0.001. The results infer that Neolix had highest significant mean time taken for file separation, followed by K3XF & the least with Protaper F2 group. (Table 2 and Graph 3)

In this study, an artificial canal was fabricated with a 60° of curvature with the maximum point of curvature at 5 mm from the tip of the instrument. [11]

Multiple comparison of mean difference in the mean number of Rotations before file separation between groups revealed that Neolix showed significantly highest mean no. of Rotations before file separation as compared to other 2 study groups at P<0.001. And this was followed by K3XF showing significantly higher mean no. of Rotations before file separation as compared to Protaper F2 at P<0.001. The results infer that Neolix had highest significant mean no. of rotations before file separation, followed by K_3XF & the least with Protaper F2 group. (Table 4 and Graph 4)

The results may be explained by the fact that Neolix files are manufactured by electric discgharge maching process which results in less surface cracks and has unique cross section. The K3XF files have manufactured with the R phase NiTi have better cyclic fatigue than conventional protaper Universal files.

Examination of unused files before testing showed structural defects and imperfections in all samples. The defects on the surface, serving as notches that would concentrate the stress thus weaken the cutting efficiency of instruments and make them susceptible to fracture. [12]

In this study a non-tooth model was used made of hardened steel, and their design did not simulate exact clinical conditions. As files have different diameters at different levels, a device suitable to test files at different levels should have different diameters, thus producing very similar clinical conditions at any chosen point. In this study cyclic fatigue evaluated by static method as files were tested at fixed lengths because the goal was to analyze CF at specific levels in each instrument. This type of method has been shown to yield lower results than dynamic methods because axial movements of the files allow for the distribution of stresses. [13]

The SEM analysis showed typical fractographic appearances of cyclic fatigue fractures in all three groups. After the cyclic fatigue tests, instruments showed the presence of crack initiation areas overload fast fracture zones and fatigue zones appeared similar among all three file systems. [14]

Fatigue zones appear at the periphery and overload zones appear at the core of the file in all samples. (Image 1 to 3)

The results of the study lead to the consideration that surface and alloy features of NiTi instruments should be considered as fundamental characteristics that can influence fatigue resistance of the files. Thus, the quantity of superficial defects should be reduced during manufacturing processes, and the quality of the NiTi alloy should be improved in order to obtain a diminished risk of fracture.

CONCLUSION:

Within the limitations of the study it can be concluded that Neolix file has the highest cyclic fracture resistance followed by K3XF file which is followed by Protaper file.

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