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Study Cyclic Fatigue Resistance in Vitro of Three Different Rotary Files in S Shape Canal

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Abstract

This research aimed to evaluate and contrast the cycle fatigue resistance of protaper universal, V-taper gold, and AF Blue R3 endodontic files in an S-shaped canal. In this study, cyclic fatigue assessment, thirty NiTi files were used (n=10) for each group (A, B, C), group A; ProTaper Universal files, group B; V-Taper gold \ and group C; AF Blue R3. The files undergo testing in double curvature custom-made artificial canals; the Time taken for the file fragmentation and length of the broken fragment were measured, and the fatigue duration of each file was determined. After that, a statistical analysis was conducted on the data using ANOVA, and a post hoc Tukey's test was performed. The NCF of AF Blue R3 files (753.59±109.09) was statistically significantly higher than V-taper Gold and pro-taper universal ($p<0.001$). At the same time, the NCF of V-taper gold (427.52±44.80) was greater than protaper universal (252.90±50.00) ($p<0.001$).

Introduction:

There are several benefits to using rotating instruments made of nickel-titanium (NiTi) for endodontic use rather than stainless steel. These include increased speed, more flexibility, and less canal aberration. An essential issue during root canal preparation is the possibility of intracanal instrument fracture, which can be caused by torsional or cyclic fatigue(1). A torsion fracture happens when the shank keeps turning, but the instrument tip or other portion is locked in a canal. The tip will inevitably fracture when a handpiece applies torque exceeding the metal's elastic limit. One indicative indication of a torsional force fractured instrument is plastic deformation. Fatigue in metals can lead to flexure fractures. Forces of tension-compression that surpass the elastic limit of the instrument in the canal of the curved root(2). cause cyclic fatigue. Without binding in a canal, the instrument rotates unrestrictedly following the curve, creating tensile/compressive cycles at the maximum flexure until the point of the fracture happens (3).
The ProTaper Universal (PTU) is a well-documented NiTi rotary set of instruments made by Dentsply Tulsa Dental in Tulsa, OK. These instruments are designed with noncutting tips, convex triangular cross-sections, and a progressive taper extending along the cutting blade's length. The fundamental sequence for shaping curved root canals with PTU consists of six instruments. These instruments are SX, S1, and S2, used to prepare the middle and coronal third of the canal, and F1, F2, and F3, used to increase the apical third of the canal (4, 5).
AF Blue R3 manufactured by Shanghai-based Dental Materials Co., Ltd. Fanta, is a unique wire that has been heat-treated makes rotating files for endodontics. Stainless steel files are more likely to exhibit plastic deformation than NiTi files, which reveal a high likelihood of undetected fracture inside root canals. A NiTi alloy with superior mechanical strength qualities is called AF^{TM}-Wire. The NiTi alloy used to generate AF^{TM}-Wire's flexibility has specific properties. Its hardness is sufficient to enable good cutting efficacy in the interim. Depending on the AF BLUE R3's rectangular cross-section and the crystallographic phases found in the alloy, Fanta AF^{TM}-Wire provides three levels of flexibility(6).
Fanta Gold V-Taper Files (Fanta Dental, Shanghai, China) are new rotary instruments with an advanced metallurgical process characterized by high AF-H memory control and triangular cross-section, providing increased flexibility and the cut(7).
The null hypothesis is that there is no observable difference in the cycle fatigue resistances of the tested rotating NiTi instruments.
The purpose of this in vitro experiment is to compare and evaluate the cyclic fatigues of three different systems with rotating instruments: protaper universal, V-taper gold, and AF blue R3 NiTi, Two-curved canals have been utilised as examples in this research study because these canals present a more significant challenge to instrumentation, and to overcome this problem used superior flexibility NiTi rotary instruments have acquired considerable popularity.

Materials and Methods

Three distinct rotary instruments were employed in this study, with 10 instruments examined for each type throughout the three groups.

Group A: protaper universal (F2 #25.08), NiTi rotary instruments (300 rpm/2 N cm), and 25 mm length.
Group B: V-taper Gold (F2 #25.08), NiTi rotary instruments (350 rpm/2 N cm), and 25 mm length.
Group C: AF Blue R3 (#25.06), NiTi rotary instruments (350 r.p.m.), and 25 mm length.
The instruments undergo testing using artificial canals that simulate double curves. The first curve, located 8 mm from the instrument tip, had a 60-degree angle of curvature and a radius of 5 mm. The second curve, located 2 mm from the tip, had a 70-degree angle of curvature and a radius of 2 mm(8). The artificial canals were milled in stainless steel, which

consists of two pieces. The first piece is a stainless steel sheet with a thickness of 1.5 mm, which has a machined canal. The second component adds the necessary thickness to the block. The two components are connected using two screws— As shown in Figure (1).

To prevent obstruction in the simulated canal, the canals were designed to have a width of 0.1 mm more than the instruments(9).

The artificial canal was subsequently enclosed with tempered glass to prevent the instrument from falling out and facilitate inspection of the instrument while it's operating. This also enabled easy detection of fractures through the glass window (10).

For standardization, an electric motor (X-Smart plus; Dentsply Maillefer) was made of HDF wood (high-density fibreboard) on a wooden basis. The base has the following dimensions: the vertical movable part measures 29 cm in length and 31 cm in width, while the horizontal moveable part measures 29 cm in length and 31 cm in width. The wooden base has two primary components. The vertical movable element, comprising the rotary handpiece, moves perpendicularly, up and down towards the second component. The horizontal movable part, including the stainless-steel block, as shown in Figure (2), Enables precise and consistent positioning of each instrument within the simulated canal (9), as shown in Figure (3). Each canal was filled with glycerin to reduce heat generation(11). The files in each group were utilized in the artificial canals without any pecking motion till a fracture happened (8). The button on the electric motor (X-Smart plus; Dentsply Maillefer) was activated to start rotation. Simultaneously, a digital stopwatch was also utilized. The operator observed the rotation of the instrument until it fractured and recorded the associated Time. The electric motor button again clicked to cease the rotation while fracturing the file. The slide was opened, and the broken file was substituted with another one.The duration of rotary file fracture, measured seconds from the start of the rotation, was converted into minutes by dividing it by 60. Subsequently, the duration of Time (T) in minutes was multiplied by the rate of revolutions per minute (RPM) to determine the total number of cycles required for each rotary file to fracture (NCF), as represented by the following equation (Equation1) (11): Equation 1: The number of cyclic fatigues to fracture (NCF) was measured by multiplying the speed of rotation per minute (RPM) by the Time to fracture (TTF)

NCF = RPM × Time to fracture (TTF)

The length of fractured fragments for each instrument was determined by measuring the instrument's length after fracturing using a digital Vernier caliper. as depicted in the subsequent equation (Equation 2) (12): Equation 2: The file's fracture length (FL) after cyclic fatigue fracture was calculated by subtracting the original file length from the length of the file after a fracture**.**

Fractured fragment(FL) = Original length – Length of instrument after

The statistical measures, including the maximum, mean, minimum, and standard deviation (S.D.), were computed for the cycle numbers required to cause fracture in each file. The data collected and recorded using SPSS was utilized for statistical analysis. To compare the average number of cycles required for fracture incidence among the various rotary instruments, we used a one-way analysis of variance (ANOVA). A Post hoc Tukey test was done to compare between each group. In a current experiment, P values more than 0.05 were deemed statistically insignificant, while P values equal to or less than 0.05 were considered significant. Conversely, P values below 0.01 were supposed to be highly important.

Results and Discussion

Mean values, maximum, minimum, and standard deviation (SD) of NCF are present in Table 1, which showed that The AF Blue R3 group exhibited the highest average cycle-to-fracture values compared to all other groups, whereas the protaper universal group had the lowest values; Normal distributions of the data were evaluated using the Shapiro- Wilk test. The results of the ANOVA test revealed a significant difference in resistance to cyclic fatigue among three groups of the tested instruments (P<0.001), As shown in Table (2). Post hoc Tukey tests were done; the data indicates a highly significant variation among all groups (P<0.01), As shown in Table (3). The mean length of the fractured segment was also recorded, as shown in Table (4). no statistical difference was found in fragment length among the tested instruments (p > 0.05) (13), As shown in Table (5).

One of the most frequent complications during root canal preparation was a fracture of the rotating NiTi instrument (14). By modifying the files' metallurgy, kinematics, and design, as well as subjecting them to heat treatments, the producers hoped to increase the cyclic fatigue resistance of NiTi rotary files(15).

This study utilized an artificial model to standardize the conditions and minimize the effects of other failure causes (torsional) besides cycle fatigue. Since no two root canals were the same, the extracted tooth model was not optimal for studying the pure physical properties of NiTi files, even if it was more representative of the clinical condition (16). This study showed that the highest NCF for all file groups was represented by AF Blue R3, followed by V taper gold, while PTU represented the lowest NCF. This could be generated from different reasons:

In the Reciproc AF Blue R3 group, its high NCF may be because it's demonstrated that cyclic fatigue is lessened by the NiTi rotary instrument's reciprocating motion and also has been shown to prolong the lifespan, in comparison with continuous rotation (17-20), blue thermal properties, Instruments made of thermally treated NiTi exhibit phase transformation changes that increase their cyclic fatigue resistance and flexibility (21, 22), Reciproc Blue is produced using a unique alloy that is covered by an oxide layer due to the thermomechanical procedure(23, 24), it also. This improved cyclic fatigue resistance might be attributable the smaller taper size taper (06) of the instruments compared to the larger apical taper (0.08) of both PTU and V-taper Gold (25, 26). Furthermore, the AF-R Wire Technique relies on the specific crystallographic phases that are present in the alloy to increase wire flexibility; it also improved cyclic fatigue resistance (6); these findings were consistent with previous studies (Portillo-Martínez MA et al.,2023(27), Abdul-Ameer ZM et al.,2020(6), in which the AF Blue R3 have highest cyclic fatigue resistance than other tested files in these studies. Although V Taper Gold and PTU systems have similar properties, such as sizes, taper, and cross-section design, the thermal treatment of gold improves the material's flexibility and cyclic fatigue resistance (28). PTU files demonstrate lower cyclic fatigue resistance than other instruments in previous studies(Usta SN et al.,2022(29); pérez-higueras JJ et al.,2014(4); Lee M-H et al.,2011(30); the stiffness and hardness of the instruments were identified as the cause. This knowledge also confirms the results of previous studies. The present study found no statistically significant variation in the mean length of fragments of broken pieces among the evaluated endodontic rotary files. The instrument's separation occurs either at or slightly below the midpoint of the curve, ensuring that the file is positioned accurately(13, 31).

Conclusion

With the limitations of this study, the reciprocating and blue heat-treated AF Blue R3 file had the highest cyclic fatigue resistance than V-taper Gold and protaper universal rotary files significantly, while the gold heat-treated rotary file V-taper gold had greater NCF than conventional NiTi of protaper universal, the conventional NiTi rotary file protaper universal had the lowest cyclic fatigue resistance among them.

Conflict of interest

The authors deny any conflicts of interest related to this study.

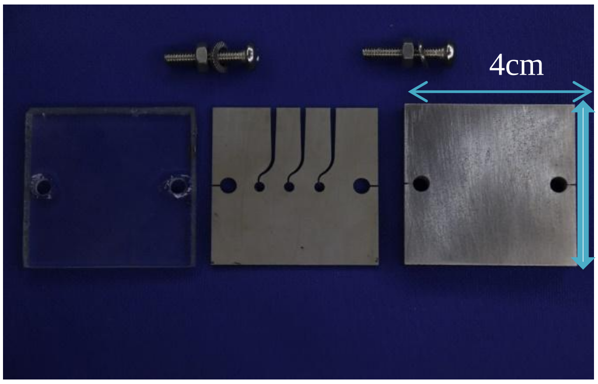

Fig.1: Cyclic fatigue testing device

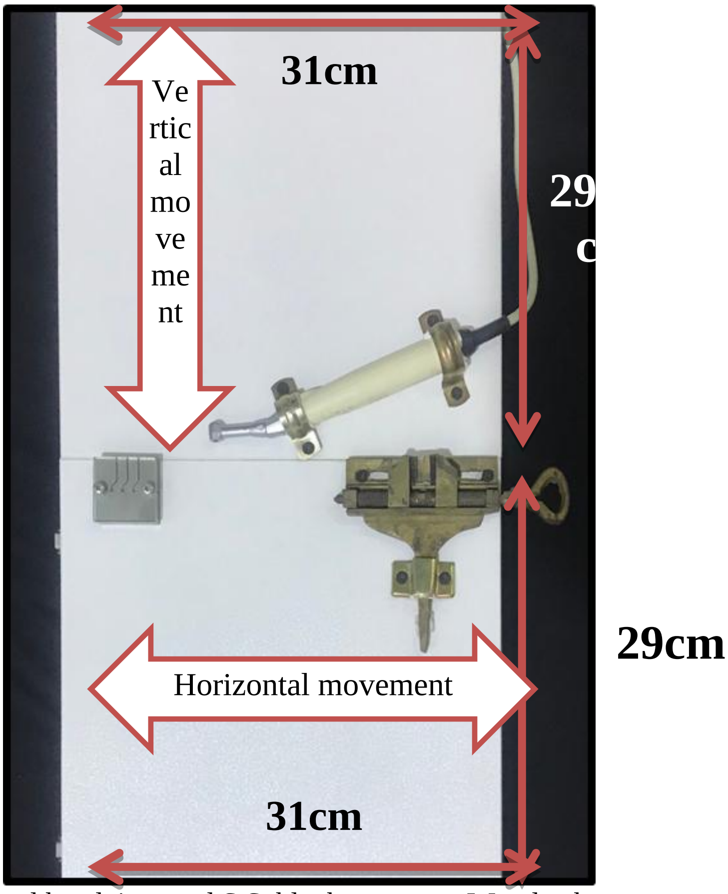

Fig. 2: Dental handpiece and S.S. block mount on Wooden base

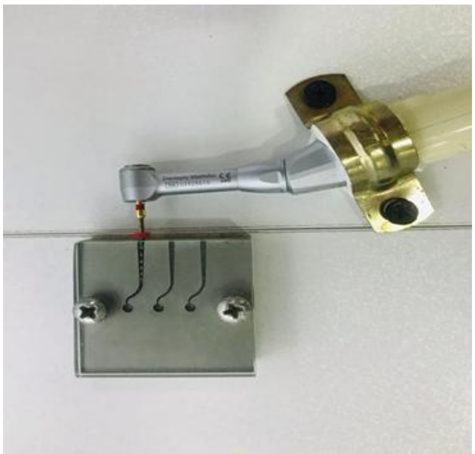

Fig. 3: File position inside the block

Table 1: Descriptive statistical analysis of the (NCF) for each group

Endodontic files	Min.	Max.	Mean	±S.D.
PTU	175.00	325	252.90	50.00
V taper Gold	350.00	495.50	427.52	44.80
AF Blue R3	600.80	974	753.59	109.09

Table 2: One-way ANOVA for NCF among groups

Score	Sum of Squares	df	Mean Square	f	P- value
Between Groups	**1291684.923**	**2**	**645842.462**	**118.069**	**0.000**
Within Groups	**147691.152**	**27**	**5470.043**		
total	**1439376.075**	**29**			

Table 3: Post hoc Tukey test between groups

(I)groups	(J)groups	Mean deference(I-J)	Std. error	P value	Upper bound	Lower bound
PTU	V taper Gold	-174.61600	33.07580	O.000	-256.6247-	-92.6073-
	AF Blue R3	-500.69000	33.07580	O.000	-582.6987-	-418.6813-
V taper Gold	AF Blue R3	-326.07400	33.07580	O.000	-408.0827-	-244.0653-

Table 4: Descriptive statistical analysis for the (fractured segment) for each file group.

Endodontic files	Min.	Max.	Mean	±S.D.
PTU	**1.50**	**3.00**	**2.1100**	**0.46056**
V taper Gold	**1.60**	**3.20**	**2.3500**	**0.49721**
AF Blue R3	**1.70**	**3.10**	**2.2600**	**0.50376**

Table 5: one-way ANOVA for fragment length among each group.

Score	Sum of Squares	df	Mean Square	f	P value
Between Groups	**.294**	**2**	**.147**	**.618**	**.546**
Within Groups	**6.418**	**27**	**.238**		
total	**6.712**	**29**			

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