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Cyclic Fatigue Resistance of Edge File X7 and 2Shape Endodontic Systems: in vitro study.

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Abstract

Objectives: In order to test the resistance of rotary instruments to cyclic fatigue fracture and its importance in root canal preparationthe purpose of this study was to see how different tapers (4% and 6%) affected the cyclic fatigue resistance of the Edge File X7 and 2Shape endodontic systems at 45° and 60°canal curvature.

Methods: Eighty NiTi files from two different systems (N= 40 each) were used; Group 1: Edge File X7, Group 2: 2Shape. each group was subdivided into four subgroups (N= 10 for each subgroup). The files were evaluated for cyclic fatigue resistance using a modified custom-made static model with 45°and 60° angles having a radius of 3mm and a diameter of 1.5 mm. Each file was rotated in a continuous rotation motion at 300 rpm with 1.2 N.cm torque for TS1, 300 rpm with 2.5 N.cm torque for TS2, and Edge file X7 was used at 300 rpm and 3 N.cm. Until it fractured. The time it took to separate the files was noted. Each file's number of cycles to failure was computed. A Kolmogorov-Smirnova normality test was done for all groups, and a two-way ANOVA was used to statistically examine the data.

Results: The ranking of the groups from the highest to the lowest NCF was as follows: EdgeFile 4% 45 degrees (6594.00), EdgeFile 6% 45 degrees (6317.90), EdgeFile 4% 60 degrees (5682.00), EdgeFile 6% 60 degrees (2142.00), 2Shape 4% 45 degrees (2517.00), 2Shape 4% 60 degrees (535.90), 2Shape 6% 45 degrees (474.50), and 2Shape 6% 60 degrees (213.00).

Conclusions: Edge File X7 showed better results than the 2Shape system. EdgeFile X7 4% at 45 degrees showed the highest NCF. The 2Shape system 6% at 60 degree that showed lowest NCF. As the canal curvature increased the NCF decreased. Taper 4% is better than taper 6%.

Keywords: EdgeFile X7; 2Shape; Cyclic fatigue resistance; Endodontic; Canal curvature.

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INTRODUCTION

The primary goals of endodontic therapy are to properly prepare and clean root canal apparatus while retaining the original design and avoiding iatrogenic occurrences. Manual root canal preparation has traditionally been done with reamers, and files. Most hand preparation procedures, including ledging, zipping, apical blocking, and canal transit, are time-intensive and prone to iatrogenic mistakes. NiTi rotary devices have lately gained popularity[1].

NiTi endodontic rotary instruments may fracture as a result of severe torsion or cyclic fatigue [2]. Cyclic failure is brought on by the instrument's continuous tension and compression load on the area of greatest root canal curvature. Torsional failure happens when the instrument shank continues to rotate while the file tip binds into the canal, increasing the torque and exceeding the metal's plastic limit. During the production of files, supplementary components like the degree of rotation, cross-sectional layout, metallurgical characteristics, and thermomechanical techniques are all variables that can be considered [3].

NiTi endodontic rotary files' cyclic fatigue resistance is influenced by a number of variables, for example: canal radius and angle of curvature [4], irrigation solutions [5], number of sterilization cycles [6] and the alloy of NiTi [7].

Several thermally treated NiTi alloys have been developed by manufacturers to improve their resistance to cyclic fatigue [8]. Furthermore, several investigations have shown that the root canal morphology has concealed curvature; this type of curvature increases the bending stresses in NiTi rotary files [9].

2Shape (Micro-Mega, Besancon, France) are rotated continuously in a sequence that has been heat treated using T-Wire technology. The

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company claims that the flexibility of the instruments promotes user comfort and makes it easier to negotiate great curves with the instruments, which recover their original shape after each usage. The asymmetrical cross-section of the file, which has two primary and one secondary cutting edge, provides greater cleaning of the root canal walls; these edges increase the cutting efficiency of the file and improve debris removal [10].

EdgeFile X7 instruments are produced using a proprietary process known as FireWire, which combines heat treatment and cryogenic applications to create a unique crystalline matrix of the heat-treated FireWire alloy, increasing the file's flexibility and fracture resistance while reducing the shape memory effect inherent in NITI instruments. The file's cross-section is triangular, and the helix angle is changeable [11].

The purpose of this study was to see how different tapers (4% and 6%) affected the cyclic fatigue resistance of the Edge File X7 and 2Shape endodontic systems at 45° and 60°canal curvature.

MATERIALS AND METHODS

This study involved 80 new instruments: 40 instruments from the 2Shape system (20 instruments for TS1 4% and 20 instruments for TS2 6%) (TS; Micro-Mega, Besancon, France) and 40 instruments from Edge File X7 (Edge Endo; Albuquerque, New Mexico, United States) (20 instruments for 4% and 20 instruments for 6%).

Sample grouping

The systems used in this study are divided into eight groups as follow:

Group 1: Edge 4% 45 degrees.

Group 2: Edge 4% 60 degrees.

Group 3: Edge 6% 45 degrees.

Group 4: Edge 6% 60 degrees.

Group 5: 2Shape 4% 45 degrees.

Group 6: 2Shape 4% 60 degrees.

Group 7: 2Shape 6% 45 degrees.

Group 8: 2Shape 6% 60 degrees.

Canal curvature drawing criteria

Pruett's approach from 1997 uses two factors to define the geometry of any root canal curvature: angle of curvature and radius of curvature [12]. To describe these measurements, first line is established along the coronal portion of the canal's long axis and second line is established along the apical portion of the canal's long axis. When the canal start to deviate there will be a beginning point position and a finishing point position for the canal curvature. A circle with tangents at positions represents the curved section of the canal at these locations. The angle of curvature is the number of degrees on the arc of the circle between these two points. The radius of this circle is equal to the radius of curvature [13].

Preparation of artificial canals.

The artificial canals are prepared on a stainless-steel metal block with dimensions of 50mm length x 30mm height x 5mm thickness by a computer numerically controlled milling machine (CNC machine, Taiwan) in Mosul city with two types of canal curvature: 45° and 60° (as shown in figure 1: A and B).

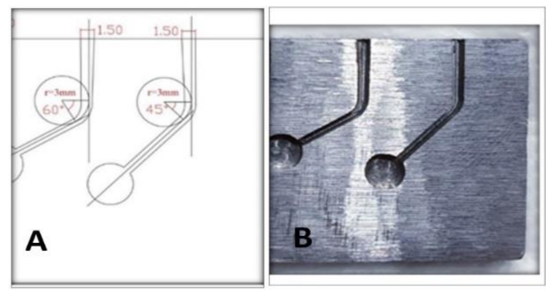

Figure 1: A. Schematic drawing of types of canal curvature drawn by AutoCAD 2006 program according to the method proposed by [13]. B. Artificial canals.

Cyclic Fatigue Resistance Test

The cyclic fatigue test was carried out in a custom-made device modified from the device that was used by [14], consisting of an endo-motor handpiece attached to a table vice vertically (as shown in figure 2) and a stainless-steel metal block containing artificial canals 45° and 60° with a radius of curvature of 3mm and a diameter of 1.5 mm [15].

The curved segment of the canal was 3.5 mm in length. The stainless-steel artificial canal was fixed to a table vice horizontally. Each instrument was introduced into the canal until the tip of the instrument was 5 mm away from the curve apically, as

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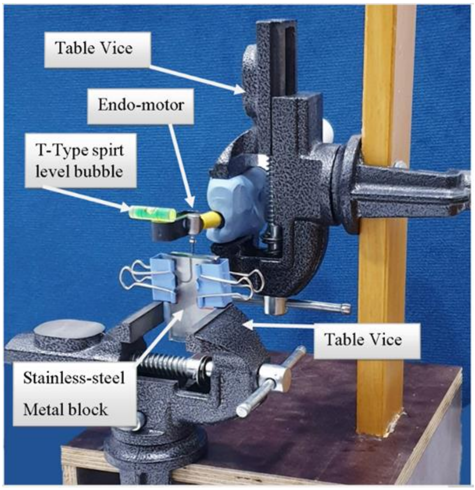

Figure 2: Custom-made device of cyclic fatigue test

stated by [16], and the limit of penetration still contained the tip of the instrument inside the simulated canals; all instruments didn't reach the artificial canal exit.

To standardize the instrument penetration depth, a red line was painted for all canals. This red line will keep the tip of the file at the same distance from the canal curvature apically for all canals and prevent over-penetration of the files inside the canals, so this will affect the results of the test.

A T-type spirit level bubble was glued to the head of the handpiece by Fix All 808 universal fast adhesive glue in order to ensure the centralization of the file inside the artificial canal, prevent titling in any unwanted direction, and deliver the rotation of the file inside the canal without pressure.

To stop the instruments from slipping out of the artificial canal, see the instrument when it breaks, remove the broken instrument with ease, and prevent the loss of the shattered pieces, the artificial canal was protected with a glass plate [17].

Counting the Number of cycles to failure.

Instruments rotated freely without pressure as stated by speed and torque that was modified as said by [18] for 2Shape TS1 used at 300 rpm and 1.2 N.cm, for 2Shape TS2 used at 300 rpm and 2.5 N.cm as stated by [19] and for Edge file X7 used at 300 rpm and 3 N.cm as used by [20]. Using an electric endo-motor E-Connect (Changzhou Sifary Medical, China) until a fracture occurred, at which point the time to fracture was recorded in seconds and video recording was established. synthetic oil (WD-40 Company, Milton Keynes, UK) was utilized as a lubricant to lessen friction as the file made contact with the artificial canal walls [21]. Number of cycles to failure (NCF) was calculated using the method below: NCF = revolutions per minute (rpm) × time to fracture (s)/60, as stated by [22].

Statistical Analysis

The obtained data were analyzed with SPSS version 26 (IBM-SPSS Inc., Chicago, IL, USA). The normal distribution of the variables was tested using the Kolmogorov-Smirnov test. A one-way analysis of variance test was used. Data are given as the mean and (± standard deviation). A P value less than 0.05 was considered statistically significant.

RESULTS

Test of Normality of all Instruments

At the start of the statistical analysis, the NCF results for all instruments were assessed using the generally used normality test (Kolmogorov-Smirnova) to determine if the data were normally distributed. As shown in the table below, this test revealed that the data were normally distributed. For all of the files, the Kolmogorov-Smirnova test value is bigger than the alpha value ($p > 0.05$) as showed by Table (1).

Mean Values and (± Standard Deviation) of Number of cycles to failure for all group using two-way ANOVA test.

The report of two-way ANOVA test shows the interaction between the effect of canal curvature and two taper used, this report distinguishes between the eight group of the study. Regarding the means that took different letters, this indicates they are statistically different from each other. The results for the number of cycles to failure for each group are presented in Table 2. There were statistically significant differences among the groups ($P < 0.01$).

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Table (1). Kolmogorov-Smirnova test of Normality (n= 80)

systems	Statistic	df	Sig.
Group 1: Edge 4% 45 degrees	0.153	10	0.200
Group 2: Edge 4% 60 degrees	0.239	10	0.112
Group 3: Edge 6% 45 degrees	0.143	10	0.220
Group 4: Edge 6% 60 degrees	0.134	10	0.200
Group 5: 2Shape 4% 45 degrees	0.185	10	0.210
Group 6: 2Shape 4% 60 degrees	0.214	10	0.185
Group 7: 2Shape 6% 45 degrees	0.131	10	0.195
Group 8: 2Shape 6% 60 degrees	0.264	10	0.059

$p > 0.05$ normally distributed

The ranking of the groups from the highest to the lowest NCF was as follows: EdgeFile 4% 45 degrees (6594.00), EdgeFile 6% 45 degrees (6317.90), EdgeFile 4% 60 degrees (5682.00), EdgeFile 6% 60 degrees (2142.00), 2Shape 4% 45 degrees (2517.00), 2Shape 4% 60 degrees (535.90), 2Shape 6% 45 degrees (474.50), and 2Shape 6% 60 degrees (213.00). In both artificial canals, the smaller file taper resulted in significantly higher cyclic fatigue resistance when compared with that of the larger file taper ($P < 0.01$).

DISCUSSION

This study employed artificial canals with a 45° and 60° curvature angle and a 3.5-mm curvature radius with 1.5mm diameter [15], since most cyclic fatigue experiments are based on these parameters, to find out how the instruments' cyclic fatigue resistance is affected by canal curvature, making comparisons easier with other studies [23-26].

Instead of using extracted teeth, stainless steel artificial canals were utilized in the study to standardize the test and exclude any other potential confounders brought on by causes of file separation other than cycle fatigue [27]. The block was made of stainless steel, and the canals were milled inside to prevent canal wear from occurring after continuous usage and maintain the same trajectory for all files. Furthermore, in order to fit the various diameters and tapers of all files and allow them to freely spin inside the canals, the depth of the artificial canals was machined to 2 mm [28].

The stainless-steel testing block was covered with a glass top cover to enable visualization of the file as it worked in the canal and the moment when the instrument broke. It also helped keep the oil inside the canal for a longer period of time, preventing the file from deviating out of the canal space and preventing the loss of the broken fragments [17]. As said by Azim, Tarrosh [16] all instruments were used inside the artificial canal until the tip of the instrument was 5 mm away from the curve and a red line was marked at all canals.

T-type spirit level bubble was connected to the head of the handpiece in order to ensure the centralization of the file inside the artificial canal, prevent tilting to any unwanted direction and deliver the rotation of the file inside the canal without pressure [29].

The effect of the NITI alloy on the cyclic fatigue resistance of endodontic rotary files has also been studied previously, and most researchers believe that the martensitic phase of the NITI alloy is the crystalline structure that is most resistant to cyclic fatigue [7]. Endodontic instruments are thermo-mechanically processed to improve the

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Table (2). Mean Values (± Standard Deviation) of Number of cycles to failure for each group.

Groups	Mean (± Standard Deviation)
Group 1: EdgeFile 4% 45 degrees [a]	6594.00 ± 3.46
Group 2: EdgeFile 4% 60 degrees [c]	5682.00 ± 3.47
Group 3: EdgeFile 6% 45 degrees [b]	6317.90 ± 4.62
Group 4: EdgeFile 6% 60 degrees [e]	2142.00 ± 2.58
Group 5: 2Shape 4% 45 degrees [d]	2517.00 ± 3.46
Group 6: 2Shape 4% 60 degrees [g]	535.90 ± 7.65
Group 7: 2Shape 6% 45 degrees [h]	474.50 ± 3.48

a, c, b, e, d, g, h, j different letters means that they were statistically different.

microstructure and transformation behavior of NITI alloys [30]. In this study two different alloy used fire wire (Edge File X7) and T Wire (2Shape). The current study revealed that the fire wire (Edge File X7) is better than T Wire (2Shape), because the fire wire treated using a special thermomechanical procedure. FireWire looks to have CM-like features with the capacity to pre-curve the file and retain the bend [31]. T-Wire treatment features revealed that 2Shape files were lower resistance to cyclic fatigue and flexibility than CM wire [32]. This might be attributed to the different metallurgical properties and thermal treatments of the NITI alloy during manufacture [33].

The endodontic rotary systems of this study was chosen because it offered

an identical apical diameter but different cross-sectional designs, NITI alloy crystal structures, and taper. The flexibility and cyclic fatigue resistance of NITI endodontic files were also impacted by the metallurgical properties and thermal treatments of the NITI alloy [34].

Gambarini, Gerosa [35] discovered that 25.04 NITI endodontic rotary files had much greater cyclic fatigue resistance in comparison between 20.06 and 25.06. These findings support those of the current investigation and emphasize the importance of the taper above the apical diameter.

Increasing the mass of the instrument based on an increase in the taper and/or apical diameter negatively affected the instrument's resistance to cyclic fatigue, influencing their flexibility and causing excessive root canal dentine removal, apical transport, root perforations, and fractures [36, 37]. Increasing the apical diameter and taper of NITI endodontic rotary files reduced their cyclic fatigue resistance [47].

Regarding the influence of the angle of canal curvature, both Edge file X7 system and 2Shape system instruments had dramatically reduced NCF as the angle of canal curvature increased. As canal curvature increased, the instruments received larger compressive and tensile stresses and hence fatigued sooner [38]. The cyclic fatigue resistance of NITI instruments was evaluated using various angles of curvature at 45°, 60°, and 90° [39].

As stated by a previous research [40], the radius of curvature has a considerable impact on the fatigue life of NITI rotary instruments. That is, when the radius of curvature grows, NCF increases dramatically. The multivariate linear regression model revealed that increasing the radius of curvature from 2 to 8 mm improves cycle fatigue resistance.

The current study's findings did not support the null hypothesis since there was a difference in the number of cycles to failure between the two types of endodontic files, with EdgeFile X7 having a greater mean NCF compared to 2Shape instruments.

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This might be attributable to a variety of variables affecting rotary file cyclic fatigue resistance, including manufacturing process, metallurgy design, helix angle, cross-sectional design, and heat treatment performed to the NITI endodontic instrument [41].

According the results obtained by this study, among the eight groups the EdgeFile X7 4% at 45 degrees has the highest mean of NCF EdgeFile X7 4% at 45 degrees (6594.00) . This may be a result of a proprietary technique called FireWire used during its manufacturing process [11]. This might be explained by the peculiar matrix of the heat-treated Fire-wire alloy, which claims to deliver high instrument strength with greater flexibility[29].

Edge File X7 demonstrated great flexibility as a result of its surface electropolishing, and heat treatment [42]. The Edge File X7 includes a triangular cross-section and changeable helix angle, which are said to give enough strength while remaining flexible to boost cyclic fatigue resistance [11]. In contrast, a triple helix having two primary and one secondary cutting edges is employed in the production of 2Shape instruments with an asymmetrical cross-section [43].

Regarding to 2Shape system based on the results of the present study this system shows lower NCF and time to fracture in comparison with Edge file X7 system in all tested canals, but when compared the taper 4% with taper 6% of the 2Shape system taper 4% shows higher NCF and time to fracture at all canal curvature. It has been stated that the tiny core diameter increases the instrument's cyclic fatigue resistance [35, 44].

The 2Shape instruments showed lower NCF among the eight groups as 2Shape 6% at 60 degrees (213.00), 2Shape system that made from heat-treated T-Wire technology .The 2Shape system had the lowest NCF and time to fracture because it is subjected to a revolutionary thermomechanical treatment (T-wire technology) that, according to the manufacturer, boosts its cyclic fatigue resistance by 40% over traditional NITI alloys, when compared to conventional NITI systems, the T-wire performed better, but when compared to other thermos-mechanically treated systems, it performed similarly or lower. The current results are consistent with the higher cyclic fatigue resistance percentages suggested by the manufacturers, demonstrating that the difference in cyclic fatigue resistance is related to various thermomechanical treatments [45]. This is consistent with previous studies on the 2Shape system [43, 46, 47].

CONCLUSION

Within the limitation of this study, it is concluded that the cyclic fatigue resistance of the Edge File X7 showed better results than the 2Shape system. EdgeFile X7 4% at 45 degree showed the highest NCF. The 2Shape system 6% at 60 degree that showed lowest NCF. As the canal curvature increased the NCF decreased. Taper 4% is better than taper 6%.

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