Cyclic Fatigue resistance of Edge File X7 Endodontic System

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Abstract

Aim of the study: this study aimed to evaluate the effect of different taper (4% and 6%) on the cyclic fatigue resistance of Edge file X7 system using three types of canal curvature 45°,60° and 90°.

Materials and Methods: In this research, sixty **(60)** NITI rotary files were utilized these files were split into two groups (n = 30 for each group), group one Edge File X7 taper 4%, group two Edge File X7 taper 6. Then, Each group was split up into three smaller groups, each with n = 10 instruments. each subgroup was tested in 45°, 60° and 90° canal curvature respectively in a stainless-steel metal block containing artificial canal with a radius of curvature of 3mm and diameter of 1.5 mm. Each file was rotated in a continuous rotation motion 300 rpm and 3N.cm torque until it fractured. The time it took to separate the files were noted. Each file's number of cycles to fracture (NCF) was computed. One-way ANOVA was used to statistically examine the data.

Results: At 45º canal curvature there is no statistical difference between Edge file X7 taper 4% and Edge file X7 taper 6% (**$p > 0.01$**). Regarding canal curvature of 60º there is statistical difference between Edge file X7 taper 4% and Edge file X7 taper 6% (**$p < 0.01$**). For canal curvature of 90 º there is statistical difference between Edge file X7 taper 4% and Edge file X7 taper 6% (**$p < 0.01$**).

Conclusion: This study concluded that the Edge File X7 system resists cyclic fatigue better when the canal curvature decreased. To limit the possibility of separation, it is **advised** that these files be used just once

Keywords: Cyclic fatigue resistance, Endodontic, Edge file X7, Root canal system.

1. Introduction

Shape and sanitize the root canal system appropriately are the main objectives of endodontic treatment while retaining the original design and avoiding iatrogenic occurrences. Manual root canal preparation has traditionally been done with burs, reamers, and files. Most hand preparation procedures, including as ledging, zipping, apical blocking, and canal transit, are time intensive and prone to iatrogenic mistakes. NITI rotary devices have lately gained popularity [1].

Root canal instrumentation makes it easier to: (i) mechanically remove vital and/or necrotic tissue and microbial biofilms; (ii) irrigate the region as effectively as possible for chemical cleaning and sanitation; (iii) place a filling within the thoroughly cleansed and formed root canal area [2], therefore any endodontic therapy can be successful if the Microorganisms have been completely removed from the root canal system [3].

This process can be carried out automatically, manually, or by combining both. Although the creation of numerous instruments with different sequences, apical diameters, and tapers has resulted from the advent of motorized equipment (rotary and reciprocating), which has made shaping simpler [4].

Endodontics underwent a conceptual shift with the introduction of systems employing nickel titanium tools, which had a significant impact on how the root canal system was prepared. Only the amount of files to be used and the fact that they are actuated by a micromotor distinguish this type of apparatus from conventional manual endodontics' indications. With the aid of these instruments, the therapy can be delivered more quickly and effectively. There are more options available with the "endodontic motor," including the use of different methods or kinds of files and tapers, two-way clockwise and counterclockwise instrumentation, and operating length selection [5].

There is an incredible selection of rotary devices for endodontic therapy. There has been an ongoing search for speedier, safer, and more potent therapeutic tools. Each technology was launched with advantages, which are seen in their almost flawless root canal preparation. Manufacturers frequently provide new devices or adjustments in order to increase the effectiveness and lessen the restrictions of these current systems[6].

During root canal treatment, the intracanal fracture of nickel-titanium (NITI) rotary files remains one of the key problems. Numerous authors have shown that there are two primary reasons why rotary NITI files fail: cyclic flexural fatigue and torsion failure [7].

The instrument's continuous tension and compression load on the area of greatest root canal curvature produces cyclic failure. 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. Other factors, including the degree of spin, cross-sectional design, metallurgical characteristics, and thermomechanical processes, can be taken into account when creating files [8].

Several thermally treated NITI alloys have been developed by manufacturers to improve the resistance to cyclic fatigue [9].. 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 [10].

It was found that the cross-sectional shape and other factors were linked to the resistance to fatigue, such as manufacturing type and quality, dimensions, taper, and heat treatment [11]. The cross-sectional design is one of the factors that have been connected to the fracture of NITI alloy of endodontic rotary files [12].

By reducing the tension placed on the device, mechanical motion also significantly improves cyclic fatigue resistance. To improve instrument performance manufacturers are used to developing some strategies like changing the rotation kinematics during root canal preparation [13].

2. Materials and Methods

This study involved 60 new instruments from Edge File X7 system (0.25 tip size, 0.04 taper and 0.25 tip size, 0.06 taper) (Edge Endo; Albuquerque, New Mexico, United States) divided by two groups each group consists of 30 instruments in each group three types of canal curvature used 10 instruments for each canal curvature were tested figure 1.

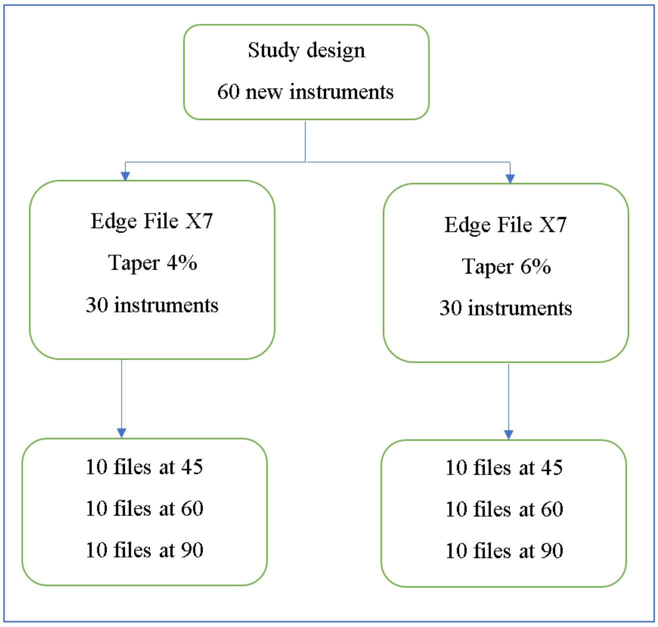

Figure 1: Samples Grouping

2.1 Canal curvature drawing criteria

Pruett's approach from 1997 uses two factors to define the geometry of any root canal curvature: angle of curvature (a1) and radius of curvature (r1) [14] (Figure 2). These measurements are defined by a straight line traced along the canal's coronal section's long axis. The lengthy stem of the canal's apical portion is traced by a second line. Each of these lines has a spot (point a) where the canal's curvature begins and ends. (point b). A circle with tangents at each of locations a and b represents the curved section of the canal there [15].

The angle of curvature is determined by drawing a circle around these two spots and measuring the angle that the circle's arcs generate (a and b). The radius of this circle is equal to the radius of curvature [15].

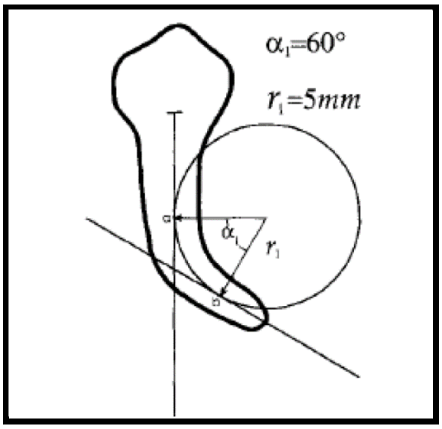

Figure 2: Pruett method [15].

2.2 Preparation of artificial canals.

The artificial canals are prepared on a stainless-steel metal block with dimensions 50mm x 30mm x 5mm by computer numerically controlled milling machine (CNC machine, Taiwan) with three types of canal curvature: 45°, 60° and 90° (as shown in Figure 3 A and B), to investigate how canal curvature affects the cyclic fatigue resistance of the instruments.

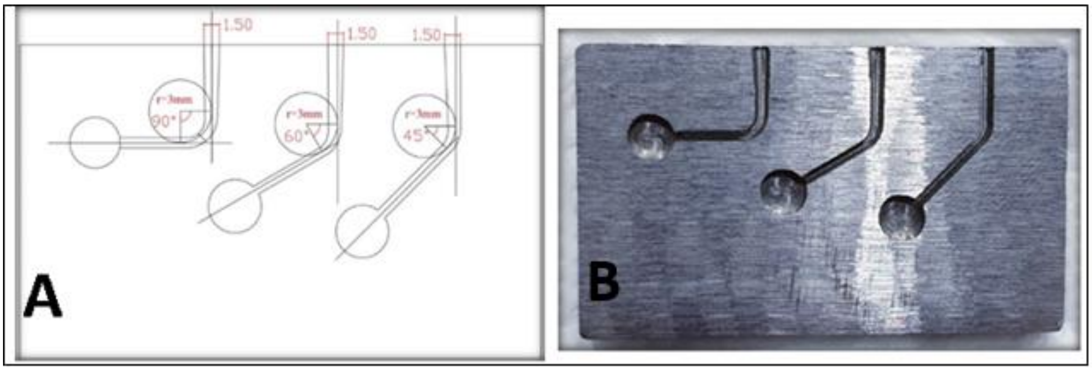

Figure 3: **A**. Schematic drawing of types of canal curvature drawn by AutoCAD 2006 program according to the method proposed by [15]. **B**. Artificial canals.

2.3 Cyclic Fatigue Resistance Test

For this study, a total of 60 new instruments were chosen, thirty instrument from Edge File X7 (25/.04) and thirty instrument from Edge File X7 (25/.06). Ten instruments (n=10) from each group were tested in 45°, 60° and 90° canal respectively. The cyclic fatigue test was carried out in a custom-made device consisting of an endo-motor handpiece attached to a table vice vertically (as shown in Figure 4). and stainless-steel metal block containing artificial canal with a radius of curvature of 3mm, a diameter of 1.5 mm [16]. It simulates a root canal with three curvatures of 45°, 60° and 90° angle.

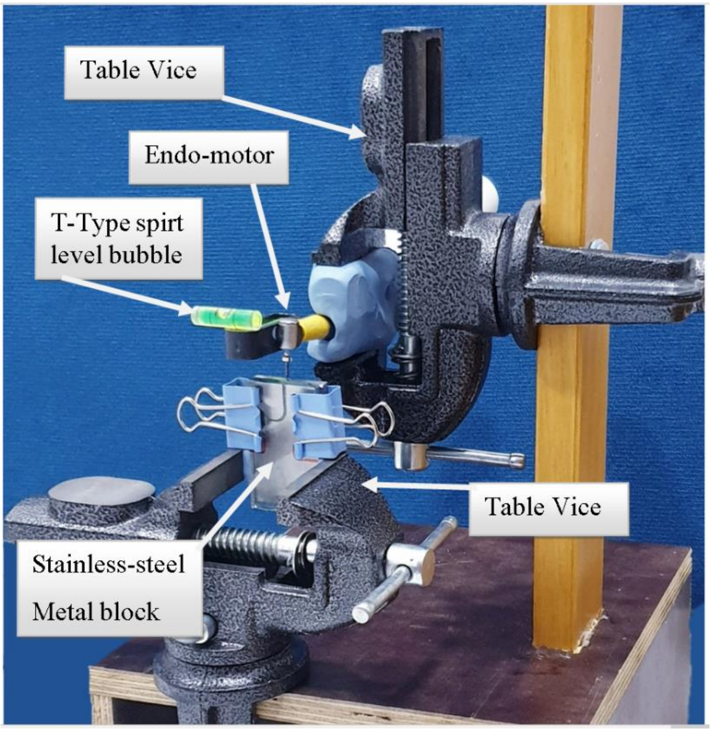

Figure 4: Custom made device for Cyclic fatigue test.

Capar, Ertas [16] used 45° and 60° angles, while Azim, Tarrosh [17] used a 90° angle. 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 the of the instrument was 5 mm away from the curve according to [17].

In order to standardize the instrument penetration depth and a red line was painted for all canals as shown in figure 5, this red line will keep the tip of the file at the same distance from the canal curvature for all canals and prevent the over penetration of the files inside the canals so this will affect the results of the test.

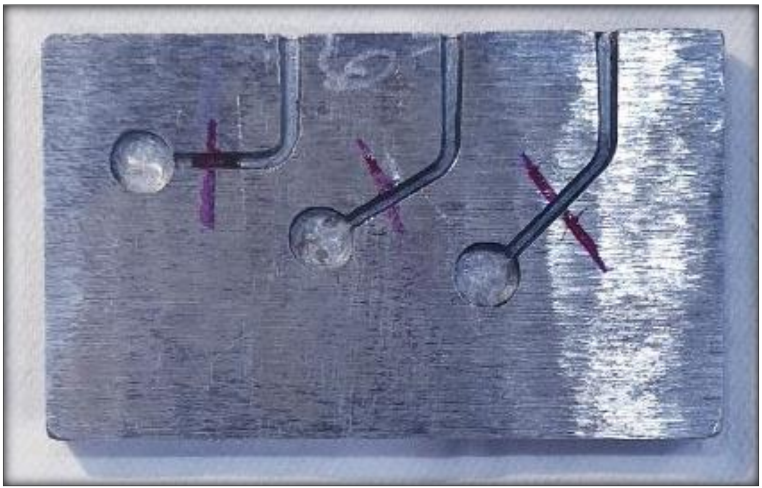

Figure 5: Cyclic fatigue test of Edge file X7 25/0.04 in 90°

Figure 5: Stainless steel artificial canals.

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 to any unwanted direction and deliver the rotation of the file inside the canal without pressure (Figure 6). as did **Altaay and Shukri [18]** when they connect it with the metal block.

Figure 7: T-type spirit level bubble.

A glass screen was placed over the artificial canal to keep the instruments from sliding out, allow for easy removal of the fragmented instrument, and prevent the loss of the broken pieces [19].

2.4 Counting the Number of Cycles to Fracture

Instruments moved easily and pressure-free in accordance with the manufacturer's specified speed and torque as Edge system X7 used at 300rpm and 3N.cm[20]. Using an electric endomotor E-Connect until a fracture occurred, at which point the time to fracture was recorded in seconds and video recording was established. A synthetic oil (WD-40 Company, Milton Keynes, UK) was utilized as lubricant to lessen friction as the file made contact with the artificial canal walls [21]. The number of cycles to fracture (NCF) was calculated using the method shown below: = revolutions per minute (rpm) × time to fracture (s)/60, according to [22]

3. Results

3.1 Statistical Analysis

The data of the number of cycles to fracture (NCF) for all groups were analyzed with the aid of SPSS 26 (IBM-SPSS Inc., Chicago, IL, USA). A one-way analysis of variance(ANOVA) was then used to assess the results to see whether there were any significant differences between the each canal curvature.

3.2 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 (Shapiro-wilk test) to determine if the data were normally distributed, as shown in table 1. This test revealed that the data are normally distributed. For all of the files, the shapiro wilk test value is bigger than the alpha value ($p > 0.05$).

Table (1): Shapiro-wilk test for all instruments.

Tests of Normality				
		Shapiro-Wilk		
Canal curvature	system	Statistic	df	Sig.
45º	Edge File X7 taper 4%	0.933	10	0.476
	Edge File X7 taper 6%	0.897	10	0.201
60º	Edge File X7 taper 4%	0.894	10	0.190
	Edge File X7 taper 6%	0.964	10	0.826
90º	Edge File X7 taper 4%	0.873	10	0.108
	Edge File X7 taper 6%	0.958	10	0.759

***p* > 0.05 normally distributed**

3.3 Comparison among NCF of all Instruments at each canal curvature.

As stated in the table below, a one-way ANOVA test was done for groups that revealed a significant difference between groups table (2). As shown by the sig. value it is less than 0.01 and that means there is significant differences between subjects at level of 1%.

Table (2): ANOVA test for all groups.

Canal curvature		Sum of Squares	df	Mean Square	F	Sig.
45 º	Between Groups	2.43E8	3	8.127E7	27.36	0.00
	Within Groups	1.06E8	36	2970195.34		
	Total	3.50E8	39			
60 º	Between Groups	1.88E8	3	6.277E7	132.46	0.00
	Within Groups	1.70E7	36	473875.55		
	Total	2.05E8	39			
90 º	Between Groups	8840686.87	3	2946895.62	175.19	0.00
	Within Groups	605547.50	36	16820.76		
	Total	9446234.37	39			

***p* < 0.01 significant**

3.4 Mean and St. Deviation of NCF for each group at each canal curvature.

In the table (3), shows the mean and Std. Deviation of NCF for each group it is obvious that each statistical mean at one column of canal curvature take the same letter of other mean of the same column that means there is no statistical difference between them, if the statistical mean at one column took different letter that means there is statistical difference between them.

Table (3): Mean and Std. Deviation of NCF for each group.

systems		45 º	60 º	90 º
Edge file X7 Taper 4%	Mean	6220.00 a	5682.00 a	1228.00 a
	N	10	10	10
	Std. Deviation	2815.32	1301.39	248.09
Edge file X7 Taper 6%	Mean	6317.50 a	2142.00 b	406.50 b
	N	10	10	10
	Std. Deviation	1920.44	403.82	73.41
Total	Mean	12537.50	7824.00	1634.50
	N	20	20	20
	Std. Deviation	4735.76	1705.21	321.50

Regarding the canal curvature of 45º there is no statistical difference between Edge file X7 taper 4% and Edge file X7 taper 6% so they took the same letter (a).

For the canal curvature of 60º there is statistical difference between Edge file X7 taper 4% and Edge file X7 taper 6% so they took the different letters (a and b).

At canal curvature of 90 º there is statistical difference between Edge file X7 taper 4% and Edge file X7 taper 6% so they took the different letters (a and b). figure 8.

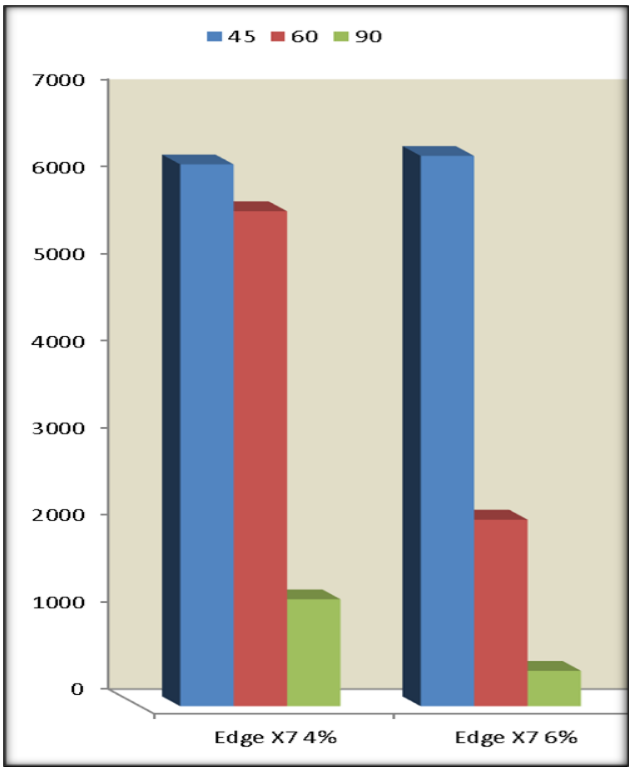

Figure 8: Bar chart (NCF) at each canal curvature.

4. DISCUSSION

Since it has been demonstrated that the majority of files that break while being used in clinical settings break primarily due to their cyclic fatigue, manufacturers constantly work to increase the cyclic fatigue resistance of NITI rotary files by changing the metallurgy, design, and kinematics of the files [23, 24].

The radius appears to have a greater influence on cyclic fatigue resistance. When a NITI instrument tip becomes locked in a root canal with a severe curvature, it seems to break faster than when the canal is straight [25].

Some NITI instrument systems have been updated using new alloys or designs that have undergone thermal treatment to increase their torsional and cyclic fatigue resistance [26]. The testing of rotary NITI instrument cyclic fatigue has not yet been standardized [27]. many different tests Various types of devices have been used, such as the 3-point bending technique, instrument operation against an angled surface, testing in a curved metal replicated canal, or a grooved block [28].

This study employed an artificial canals with a 45°, 60° and 90° curvature angle and a 3.5-mm curvature radius with 1.5mm diameter [16], 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[29-33].

4.1 Stainless steel artificial canals

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, The depth of the artificial canals were machined to 2 mm in order to accommodate the varying diameters and tapers of all files and enable them to easily rotate inside the canals [34].

To see how the file moved through the channel and when the instrument fractured, the glass top cover on the stainless-steel testing block was removed. Additionally, it assisted in preserving the oil inside the canal for a longer length of time, stopping the file from straying outside the canal's confines and preventing the loss of the broken pieces [19]. According to Azim, Tarrosh [17] all instruments were used inside the artificial canal until the tip of the instrument was 5 mm away from the curve and red line was painted at all canals.

Static and dynamic stainless-steel blocks are the two kinds that are available. In a dynamic model, pressure is spread vertically along the file spine during insertion and withdrawal. In contrast, in a static model, stress will be localized on a single section of the file [35]. Although a dynamic model could simulate clinical circumstances, it was difficult to regulate the pecking action exactly in practice [36]. Dynamic fatigue tests use more pulsations in the instruments during endodontic therapy, and the only additional information a dynamic model can provide is the amount of time an instrument spends operating in a canal while under the conditions being studied; however, because the parameters being examined in these dynamic models are very different from those that would be present in a clinical scenario, their results cannot be directly applied to clinical practice [37]. As a result, a static model was utilized in this study.

4.2. T-Type spirt level bubble

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 titling to any unwanted direction and deliver the rotation of the file inside the canal without pressure, as did Altaay and Shukri [18] when they connected it with the metal block.

4.3 Discussion on factors affecting cyclic fatigue

4.3.1 Cross-Sectional Design

Cross-sectional design and core mass have already been shown to have an impact on cycle fatigue resistance, and it appears that greater cyclic fatigue resistance is associated with a reduced metal volume. (core mass) [38, 39].

Uygun, Kol [40] evaluated the cyclic fatigue resistance of Pro Taper Gold, Pro Taper Next, and Pro Taper Universal's at 5mm and 8mm from the instrument tip. The cyclic fatigue resistance of all instruments is higher at 5 mm from the tip than at 8 mm from the tip. These findings showed that Ni-Ti instruments' cycle fatigue resistance increased with decreasing instrument cross sections.

The cross-sectional form, the centricity of the cross-section, the taper, and the tone all have an impact on the bending moments of an instrument [41]. Zhang, Cheung [42] demonstrated that the cross-sectional design had a greater influence on the stresses created by various load trajectories than did the instrument's taper or size. Generally speaking, an instrument's flat design (slender rectangle; S-shape) appears to favor enhanced cycle fatigue resistance [43].

4.3.2 Rotational Speed

It appears that rotational speed significantly affects cyclic fatigue because it tends to reduce the time to fracture [44]. the effect of frictional heat production and a potential phase transition dependent on the Austinite finished-temperature [45]. Other study confirmed that the cycle fatigue was unaffected by speed [46]. The constant lubricant (WD-40 Company, Milton Keynes, UK) replenishment used in the current study and rotational speed 300 rpm, however, make this feature appear to be insignificant. As the oil lubricant used to reduce the friction between the instrument and the metal canal according to [21].

4.3.3 Alloy

The impact of the NITI alloy on the cyclic fatigue resistance of endodontic rotary files has also been investigated in the past. According to the majority of experts, the martensitic phase of the NITI alloy is the crystalline structure that is most resistant to cyclic fatigue [47]. To enhance the microstructure and change behavior of NITI alloys, endodontic tools are thermo mechanically treated [48].

4.3.4 Taper

The metallurgical characteristics and heat processes of the NITI alloy had an effect on the elasticity and cyclic fatigue resistance of NITI endodontic files. [49, 50]. Gambarini, Gerosa [51] discovered that 25.04 NITI endodontic rotary files had much greater cyclic fatigue resistance in comparison between 20.06 and 25.06. These results confirm those of the present study and highlight the significance of the taper above the apical width.

The following statement sums up these results: Increases in the instrument's mass due to increases in the taper and/or apical width had a detrimental effect on the instrument's resilience to cycle wear; this reduced the instrument's flexibility and led to extra root canal dentine removal, apical transport, root perforations, and fractures [52, 53]. Faus-Llácer, Kharrat [54] showed that increasing the apical diameter and taper of NITI endodontic rotary files reduced their cyclic fatigue resistance.

4.3.5 Angle of curvature and radius of curvature

Regarding how the angle of canal curvature affected NCF, Edge file X7 system tools significantly decreased NCF as the angle of canal curvature grew. Greater compressive and tensile loads were placed on the instruments as canal curvature grew, which led to earlier failure [55]**.** This result was consistent with other studies [56, 57]. In order to calculate the NCF under various load conditions, 45°, 60°, and 90° degrees of curvature were used in this study.

According to previous research [58], The fatigue life of Ni-Ti rotary tools is significantly impacted by the radius of curve. 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.

Alcalde, Duarte [59] discovered that in comparison to the 25.08 Ni Ti endodontic reciprocating files and the 25.07 Ni Ti endodontic reciprocating files, the 25.06 NITI endodontic reciprocating files demonstrated superior cycle wear resistance and angular rotation before breaking. Angle 90° demonstrated lower cyclic fatigue resistance than angle 60° and 45° in all examined file systems.

It appears that the current generation of heat-treated NITI files has higher metallurgical qualities, which may be due to the "WireFire^{TM}" technology utilized and its unique design [60]. 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 [18].

The Edge File X7 includes a parabolic cross-section and changeable helix angle, which are said to give enough strength while remaining flexible to boost cyclic fatigue resistance [61]. According to Zhang, Cheung [62], the cross-sectional design of the instrument had a greater influence on the development of stress than its size or taper.

5. Limitations

Even with careful design, this study had certain limitations. This study, like other in vitro studies, cannot fully imitate a clinical setting. Second, just one type of radius of curvature has been employed, whereas in everyday practice, the canal curvature and radius of curvature vary among canals. Third, this study utilized a static cyclic fatigue test in which the picking motion in the dynamic test is absent. Fourth, this study was carried out at room temperature, which is different from oral conditions. Fifth this study was carried out on stainless steel artificial canals instead of natural teeth and this cannot simulate the daily clinical situations.

6. Conclusion

Within the bounds of this research the Edge file X7 system is found to be more resistant to cyclic fatigue at 45° canal curvature, followed by 60° and 90° canal curvature, regarding the taper used 4% is better than 6%.

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