Original Article

Effect Of Torsional Preloading Of Heat-Treated Files On The Cyclic Fatigue Resistance In Simulated 90° Root Canal Curvature

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Abstract

AIM: To check the effect of torsional preloading of heat-treated files on the cyclic fatigue resistance in simulated 90° canal curvature.

METHODOLOGY: Eight Hyflex EDM, size 20.04, 25mm and eight Hyflex CM, size 20.04, 25 mm were selected for the study. Four subgroups of eight new files from each brand were created. Three groups were subjected to various numbers of rotary (1, 5 and 10) cycles and autoclave sterilisation cycles in a 45°-curve-simulated acrylic canal. A single group was designated as the control group and was not gone through any rotational cycles or autoclave sterilisation. Then, cyclic fatigue was conducted to the preloaded files using a specially created experimental setup. The fixed shaping block was manufactured of concave, tempered steel with a radius of curvature of 5 mm and a constant degree of curvature of 90°. In a metal block with a simulated 90° bend, NiTi files were tested until they fractured. The number of cycles to failure (NCF) for each instrument was then calculated. To compare the cyclic fatigue of various rotary files, a statistical analysis using the one-way ANOVA test and the post hoc Tukey's test was conducted.

RESULTS: In cyclic fatigue fracture test, Hyflex EDM showed higher flexibility with highest value of 16.4±1.35 s compared to Hyflex CM with the value of 13.1±1.45 s.

CONCLUSIONS: EDM (HyFlex EDM) wire technology showed better cyclic fatigue resistance than CM wire (Hyflex CM)

KEYWORDS: Cyclic fatigue, Heat Treatment, NiTi Alloy, Hyflex EDM, Hyflex CM

INTRODUCTION

In recent years, endodontic instruments have been made using nickel titanium alloy (Nitinol). Comparing nitinol alloys to stainless steel alloys, the former has higher strength and a lower elastic modulus. Because Nitinol wires exhibit super-elastic behaviour, they recover their original shape after deformation upon unloading.[1]

The mechanical characteristics of NiTi endodontic instruments have been enhanced by thermomechanical production techniques. Using this method, the NiTi alloy's transition temperatures can be changed with the goal of influencing its microstructure and, as a result, the mechanical performance of the instruments. [2] These specific thermal treatments' ultimate goal is to produce high-quality instruments with improved resistance to cyclic flexural strain and flexibility fatigue.[3,4] On the other hand, the NiTi alloy's machining properties are highly complex due to its high toughness and distinctive super elastic behaviour.

Utilizing alloys like controlled memory (CM),M-Wire and manufacturing processes like electrical discharge machining has improved the mechanical properties and microstructure of NiTi alloys (EDM). [5] De Arruda Santos et al. developed CM alloys in 2013 to alter the temperature at which austenite transforms into martensite and produce a stable martensitic microstructure at body temperature.[6] HyFlex CM and HyFlex EDM files (Coltene, Whaledent AG, Altstätten, Switzerland) are both made from CM wire however they are produced in different ways. While HyFlex EDM files are created utilising EDM technology, HyFlex CM files are created in conventional way (i.e., by grinding the CM alloy). [5] As a result, a particular kind of manufacturing technique known as an electric discharge machine (EDM) was developed. Sparks caused by high-energy, high-frequency electric discharges compel a substance to melt and evaporate locally between a metal workpiece and an electrode, resulting in a finished product with the appropriate geometry. Using this technique, NiTi instruments with precise cutting edges, built-in abrasive properties, variable shifting profiles, and significant flexibility can be created.[7]

NiTi rotary files could abruptly fracture inside the root canals despite these advantages. New production methods and alloys have been used by the file manufacturers to produce files with improved mechanical properties, which have been demonstrated to boost NiTi file efficiency and reduce fracture rate in root canals. [8]

Before reusing old files or using new ones, NiTi files are sterilised, usually by autoclave at temperature exceeding 100 °C. Some planned packages of chosen files may be preferred by a clinician, and not all prearranged files are used in a single session. In this scenario, unused, fresh NiTi files could go through numerous autoclave cycles. [9] There have been reports of increased NiTi wire corrosion at high temperatures. For financial reasons, NiTi rotary files are frequently reused in clinical practice. To avoid patient cross-contamination, regular autoclave sterilisation is required. Additionally, many professionals employ pre-made sets of NiTi files. Some of these rotary files might not be utilised in a single procedure, in which case they must be sterilised in an autoclave before being used again. The heat utilised during sterilisation procedures may impact the mechanical properties of NiTi files since thermal methods are used in their manufacturing. According to earlier studies, autoclave sterilisation enhanced the surface roughness of NiTi rotary files, which in turn had an impact on their mechanical characteristics. [10]

MATERIALS AND METHODS

In this study, eight HyFlex CM (20.04, 25mm) and eight HyFlex EDM (20.04, 25 mm) rotary files were used. There were two files in each of the four subgroups of the files. Out of which one group was designated as the control group and was not gone through any rotational cycles or autoclave sterilisation. The other three groups had three autoclave sterilisation cycles as well as three rotary cycles (1, 5, and 10). In 45^{o} simulated acrylic channels, NiTi files underwent rotating cycles in between sterilising sessions. (Figure 1).

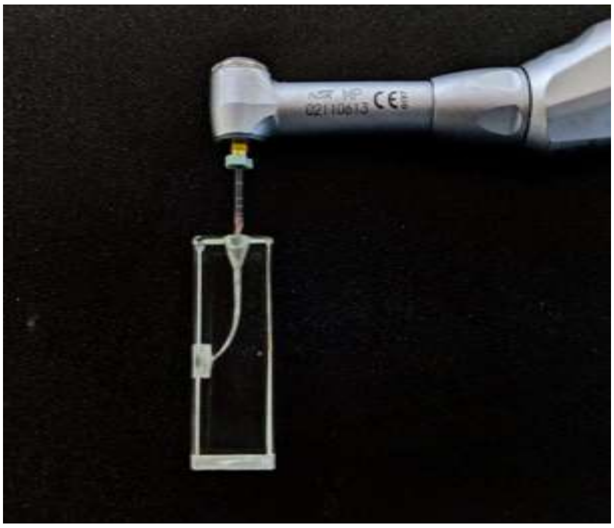


Figure 1: NiTi files subjected to rotary cycles in simulated acrylic canals of 45o

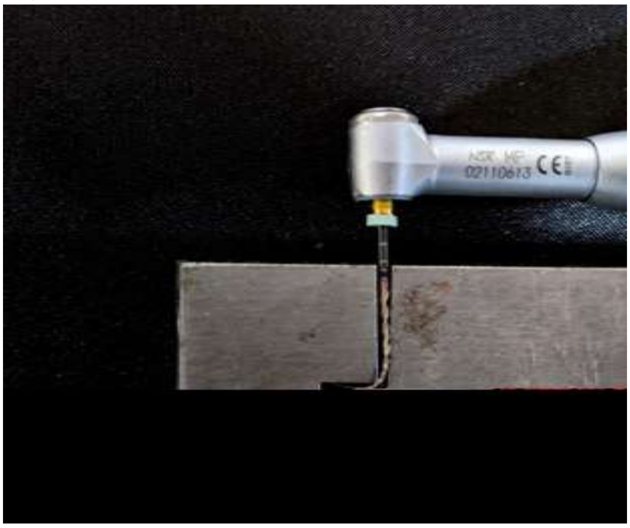


Figure 2: Preloaded files subjected to cyclic fatigue within simulated 90o curvature canal in a stainless-steel metal block

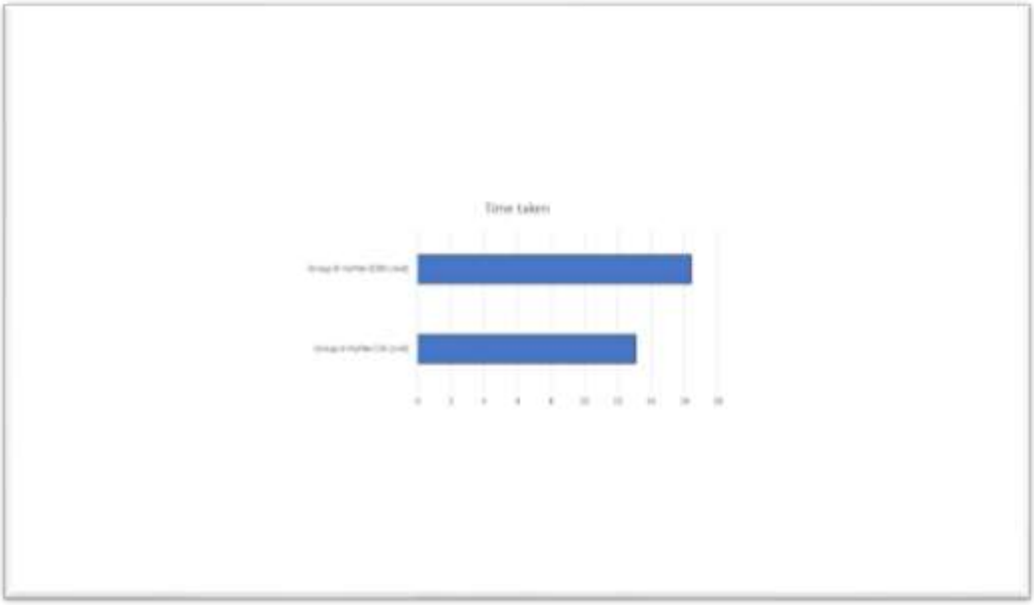
Each NiTi rotary file was connected to a glass base using a rapidly drying cyanoacrylate adhesive before undergoing numerous autoclave cycles. Each cycle took place for 20 minutes at 134 °C and 30 psi of pressure, followed by a 15-minute drying interval. The preloaded files were then subjected to cyclic fatigue utilising a specifically constructed testing apparatus. In a metal block with a simulated 90° curvature, NiTi files were tested until they fractured. The fixed shaping block had a radius of curvature of 5 mm and a constant degree of curvature of 90° and was made of concave, tempered steel. The instruments were used up until a fracture developed, and the time to fracture was captured in high-definition video and measured in seconds.

Then, using the following formula, the number of cycles to failure (NCF) was calculated for each instrument: NCF File fracture time in seconds multiplied by endomotor speed (rpm). Following the calculation of mean data for each group, statistical analysis was performed using one way ANOVA and post hoc Tukey's test.

STATISTICAL ANALYSIS

The data were analysed using one way- ANOVA and post hoc-Tukey's test using SPSS 21.0 software (IBM-SPSS Inc, Chicago, IL). The statistical significance level was set at $p < 0.001$.

RESULT



Graph 1: Time to Fracture in Seconds

Table 1: **Time taken to fracture in seconds** (*=welch test)

	Group A-Hyflex CM (n=8)	Group B-HyFlex EDM (n=8)	ONE WAY ANOVA		POSTHOC TUKEY TEST
			F* value	P VALUE	Group A-Hyflex CM vs Group B-HyFlex EDM difference (p value)
Time taken	13.1±1.45	16.4±1.35	243.488	**<0.001**	-3.3 (<0.001)

According to one-way ANOVA test: Comparison of Time taken between the two groups, it can be observed that Group B-HyFlex EDM has the highest value of cyclic fatigue 16.4±1.35 compared to Group A – Hyflex CM with the value of 13.1±1.45. This difference is statistically significant with $p < 0.001$. (Table 1) (Graph 1) According to Post hoc Tukey's test, both Hyflex EDM and Hyflex CM had significant difference with each other.

DISCUSSION

The literature on endodontics has been quite interested in the cyclic fatigue resistance of NiTi rotary instruments. As a result of the buildup of fatigue and torsional stress, the effects of metal fatigue, torsional fracture, or NiTi rotary instrument fracture are yet unknown. [12] Material fatigue seems to be a significant factor for rotational instrument separation during clinical use. Peng and co. [13] categorised most of the studied fractured instrument as flexural failure, indicating that the main mechanism for material failure is fatigue failure. According to a related study by Cheung et al. [14], the huge most (93% of the time) of the instruments looked to have failed as a result of flexural exhaustion. Following are some possible explanations for this 14: first, fatigue-crack growth rates reported to be substantially higher in NiTi alloys than in other metals of comparable strength. [15] Consequently, when a microcrack starts, it can spread rapidly and result in catastrophic collapse.

Human teeth were typically employed in earlier studies that compared the cyclic fatigue resistance of files after simulating clinical use. [16,17] The present study used artificial acrylic canals to guarantee greater standardisation because teeth with varying hardness values and anatomical variations may be subject to varied forces.

In this study, an extreme canal curvature of 90° was used because curved canals were found in 59 percent of the teeth, with posterior teeth having a higher frequency than anterior teeth. The apical third section (53.9 percent) had the most root canal curvature, followed by the cervical (33.3 percent) and middle (12.8 percent) third sections. [18]

In cyclic fatigue fracture test, Hyflex EDM showed higher flexibility with highest value of 16.4±1.35 s compared to Hyflex CM with the value of 13.1±1.45 s which coincided with prior studies. [7, 9, 18] CM wire, which is used in EDM, is made primarily of martensite and is hence more flexible. Additionally, the EDM manufacturing technique

produced no machining groove and instead had a characteristic crater-like surface, which helped to prevent crack propagation. The higher cyclic fatigue resistance of Hyflex EDM files may also be due to the electro discharge machining method utilised during production. The manufactured alloy of the file is not the only factor influencing the instruments' resilience to cyclic fatigue. The lifespan of the cyclic fatigue, the cross-section type, area, and usage speed may have an impact on the file.
There were certain limitations is the present study as it was performed in a simulated canal in a stainless-steel block and the oral cavity temperature was not considered in the study. Additionally, more research is required to determine the impact of irrigating solutions on the cycle fatigue resistance of heat-treated NiTi instruments.

CONCLUSION

Within the constraints of the investigation, it can be concluded that EDM wire (HyFlex EDM) demonstrated higher cyclic fatigue resistance than CM wire NiTi files (Hyflex CM). Acknowledgement: None

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