IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 19, Issue 4 Ser.7 (April. 2020), PP 60-63
www.iosrjournals.org

Comparative Evaluation of Cyclic Fatigue Resistance of Heat Treated Nickel Titanium Rotary Systems Used In Root Canals with 30^0,60^0 And 90^0 Angles of Curvature

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Abstract:
Aim: *To compare cyclic fatigue resistance of Protaper Gold and Hyflex EDM Nickel Titanium rotary endodontic files used in root canals with 30^0,60^0 and 90^0 angulations and 2mm radius of curvature*
Materials and Methods*: 39 new NiTi instruments from each group were subjected to cyclic fatigue tests in simulated root canals with 30, 60 and 90 degrees curvatures (n=13) in each sub group. Custom made jig was made and the instruments were rotated according to manufactures recommendations. The time taken to fracture was recorded and numbers of cycles to fracture were calculated. All data was subjected to statistical analysis using Mann Whitney U test. For repeated measures Friedman test was used.SEM analysis was done to evaluate type of fracture.*
Results*: Hyflex EDM showed a significant increase in cyclic fatigue p<0.05) than Protaper Gold.*
Conclusion: *Hyflex EDM files had significantly higher cyclic fatigue resistance than Protaper Gold files.*
Key Word*: Cyclic fatigue resistance Protaper Gold, Hyflex EDM*

Date of Submission: 08-04-2020 Date of Acceptance: 23-04-2020

I. Introduction

The foundation of successful endodontic treatment depends primarily on complete debridement of microorganisms and pathologic debris for which efficient chemo mechanical instrumentation is crucial. The advent of nickel titanium files has contributed to quicker and predictable root canal treatment outcomes.[1]

Super elastic nature of nickel titanium files aids in cleaning and shaping of curved root canals as they flex more than stainless steel before exceeding their elastic limit. They not only enable efficient mechanical preparation of root canals but also diminish the probability of iatrogenic errors such as transportation or perforation.[2]

However clinicians are concerned about their breakage as majority of teeth have curved canals in multiple planes. Removal of broken instruments may not always be possible altering the outcome of root canal treatment.[3]

Fractures of files occur either due to torsional failure or flexural fatigue failure.[4]

In a curved root canal, at the point of maximum flexure, flexural fatigue occurs when repeated tension/compression cycles accumulate resulting in fracture.[5]Cheng et al has reported that 93 % instruments seem to have failed because of flexural fatigue.[6]

Several methods have been incorporated in manufacturing process to reduce the incidence of separation of NiTi instruments. These methods include surface treatment such as thermal nitridation, ion implantation[7]plasma immersion and electro polishing that finishes the surfaces and prevents crack propagation. Others include modification of cross section and taper.[8]

ProTaper Gold files (PTG) (DENTSPLY Tulsa Dental Specialties, Tulsa, OK) are files that have changing helical angle, convex triangular cross section, higher austenite finish temperature and 2 stage transformation [A-R-M] enabling them to have better cyclic fatigue resistance and improved flexibility.[9]

Hyflex EDM is manufactured using electric discharge machining from controlled memory wire. They have different cross sections along the cutting surface varying from triangular to trapezoidal to quadrangular from handle to tip. These files are suitable for shaping severely curved canals as the spark machined surface remains unaffected after multiple uses confirming high wear resistance. At room temperature it is reported to have a mixture of martensitic and austenite phase with martensitic phase more predominant. This enables it to be less stiff and more flexible.[10]

The aim of this study was to analyse cyclic fatigue resistance of Hyflex EDM and Protaper Gold rotary endodontic files used in root canals with curvatures 30^0,60^0 and 90^0.

II. Material and Methods

Samples were grouped as follows
Group 1: Hyflex EDM (25/.08) (n=39)
Group 2: Protaper Gold (F2 25/.08) (n=39)
Sub group: 30 degree (n=13), 45 degree (n=13), 60degree (n=13)
Each file was examined for defects before the test with digital operative microscope. A custom made cyclic fatigue testing device was fabricated. It consisted of a metal frame on which artificial canals were milled at angulations of 30° ,60° and 90° and radius of curvature of 2mm.Centre of curvature was approximately 5 mm from the tip of instrument ,the curved segment of canal was 5mm in length. The depth of the canal was machined to a depth of 0.2 mm allowing instrument to rotate freely. A tempered glass was used to cover the canals to prevent instrument from slipping out and also for visualization of instruments. Synthetic oil was used for lubrication to reduce friction. Files were run with 16:1 reduction hand piece X-Smart (Dentsply) at 300 rpm for Protaper Gold and 500 rpm for Hyflex EDM. The hand piece was supported by a mobile plastic support which helped in 3 dimensional alignment and positioning of the instrument to the same depth.[10]
The length of the fractured tip was measured using a digital micro calliper.
The time to fracture was visually recorded with help of digital stop watch.
The number of cycles to fracture was calculated using the formula

Number of cycles of fracture = time to fracture x no: of rotations.

SEM ANALYSIS
A scanning electron microscope (SEM) (JEOL, JXA840A, JEOL Ltd., Tokyo, Japan) was used to characterize the topographic features of the fracture surfaces of broken files.

Statistical analysis
Data was analysed using SPSS version 23.0.To find statistical difference between samples of independent groups Mann Whitney test was used. For repeated measures (30, 60&90 degrees) Friedman test was used. The level $P < 0.05$ was considered as significant.

III. Result

The mean and standard deviation of Hyflex EDM (group I) and Protaper Gold (group II) at 30, 60 and 90 degrees is represented in the table 1.

Hyflex EDM instruments demonstrated a significantly higher cyclic resistance (p = 0.000) than Protaper Gold at 30, 60 and 90 degree angulations.Hyflex EDM instruments demonstrated a significantly higher cyclic resistance (p = 0.000) than Protaper Gold at 30, 60 and 90 degree angulations.

Table no 1:Cyclic fatigue resistance between EDM & PTG

Degrees	Group	Mean	SD	P value
30^0	Group I Group II	1601.77 718.54	272.131 204.027	0.000
60^0	Group I Group II	1083.23 533.38	254.318 123.810	0.000
90^0	Group I Group II	946.15 322.92	271.586 87.818	0.000

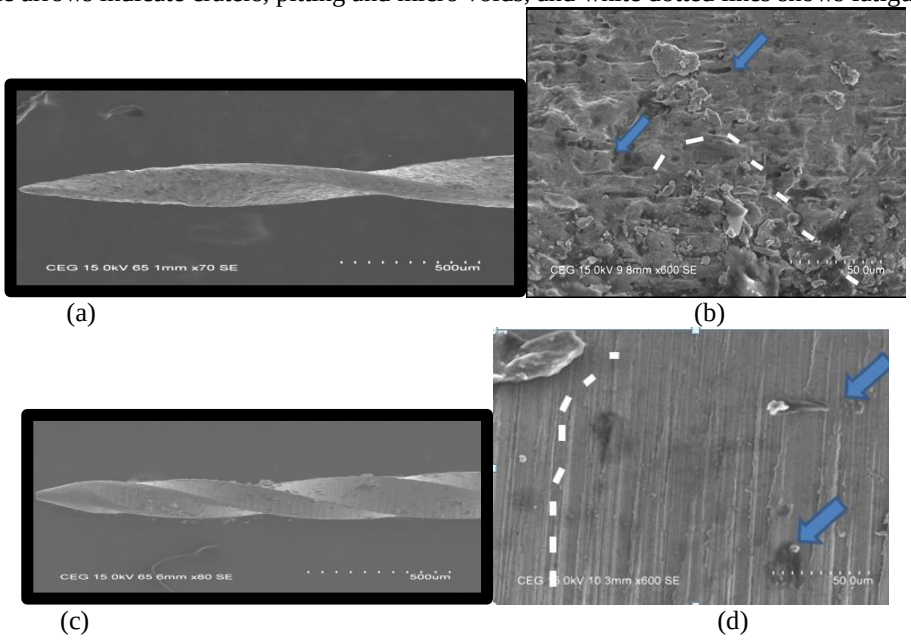
Table II: Cyclic resistance offered by EDM and PTG compared across different angulations

Degrees	Group	Mean	SD	Pvalue
30^0	Group I Group II	1601.77 718.54	272.131 204.027	0.000
60^0	Group I Group II	1083.23 533.38	254.318 123.810	0.000
90^0	Group I Group II	946.15 322.92	271.586 87.818	0.000

The cyclic resistance for EDM between 30 and 60 degree angulations was found to be significant (p value=.002). As per the observations, the cyclic resistance decreased with increased angulations in general. But a comparison between the resistance offered at 60 and 90 degrees for EDM, was insignificant with p value = .345; the resistance offered at both the angulations did not show much variation.

Likewise for PTG, the results showed almost similar observations. At 90 degrees the resistance offered was much less compared at 60 and 30 degree angulations and was found to be statistically significant (p=.002,.001 respectively)

SEM ANALYSIS: Left column (250 × magnification), right column (1500 × magnification) of HEDM (a,b) and PTG (c,d). The arrows indicate craters, pitting and micro voids, and white dotted lines shows fatigue striations



(a) (b)

(c) (d)

IV. Discussion

The major concern throughout canal shaping procedures is the risk of file fracture which can occur due to cyclic fatigue or torsional failure. When an instrument rotates freely in a curved canal it is subjected to alternating cycles of tension and compression which can result in micro cracks leading to fracture at the point of maximum flexure. This structural breakdown of metal is called cyclic fatigue. Its occurs unexpectedly without any signs of permanent deformation.[11]Torsional failure occurs when the file binds in the canal while the shank continues to rotate.[12]Failure due to cyclic fatigue occurs more frequently than torsional.[13]Thermal treatment can optimize microstructure, transformation behaviour and improve mechanical properties.[9]

Kaval et al. found that HyflexEDM instruments had the highest cyclic fatigue resistance, compared to PTG and ProtaperUniversal instruments.[14]Gündoğar et al. reported that among heat treated NiTi files including OneShape, Reciproc Blue, and WaveOne Gold, HEDM instruments had better cyclic fatigue resistance.[15]

Our findings were in concurrence with the above mentioned studies. Previous studies have proven the superiority of HEDM instrument but fracture resistance at 90° and radius of curvature at 2mm has not been evaluated. This study compared the cyclic fatigue resistance of two heat treated systems at different angulations and radius of curvature.

The apparatus used to test cyclic fatigue was an artificial stainless- steel simulated canals with a 30°, 60° and 90° angulation and a 2- mm radius of curvature. Evaluation at different angulations done in this study showed that an increase in angle of curvature increased the risk of file fracture even with fewer rotations.Studies have shown that the average canal curvature of mandibular molars fall between 20- 30^0 hence 30° was selected.[16]Although higher angle of curvature is rare, 90° angulations was included as it is important to evaluate fracture resistance in critical conditions.

Intensity of stress subjected to an endodontic file is determined by radius of curvature.[17]Abrupt curvatures are commonly found at apical third of root canal which increases the risk of file fracture and apical transportation.

[18]In this study radius of curvature was set at 2mm indicative of abrupt curvatures. Natural teeth were not considered as standardization is difficult due to morphological variations.[19]

Synthetic oil was used as lubricant during testing to avoid increase in temperature due to internal friction. Studies have proved that an increase in temperature can affect cyclic fatigue.[20]
Nguyen et al found that a temperature elevation did not exceed 3 degree when tested with synthetic oil.[21]

Cyclic fatigue resistance can vary with size of the instruments. For standardization instrument size25 were selected for both brands.[18]The fractured NiTi files were subjected to the SEM imaging to analyse the

pattern of fracture. Both files exhibited features of fatigue failure characterized by dimpled overload zone with micro voids.

Surface fracture of Protaper Gold showed one or two crack initiation areas with rapid zone of fracture, surface pitting and micro voids.

Hyflex EDM disclosed multiple sites of crack origin indicating stress getting split between all the cracks decreasing strain localization and slow propagation of fracture.

In this study cyclic fatigue resistance of Hyflex EDM was found to be more than Protaper gold. This may be due to superior manufacturing process by electrical discharge machining.[4]

V. Conclusion

Hyflex EDM showed significantly higher cyclic fatigue resistance than Protaper Gold even at high angular deflections making it suitable to be used in severely curved canals.

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Acknowledgements

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

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