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Cyclic Fatigue Resistance of Three Different Rotary Ni-Ti Instruments

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Abstract:

Introduction: The aim of this study was to evaluate and compare the resistance to cyclic fatigue of new and sterilized three rotary NiTi files in mild and sever curvature canals. **Material and methods:** Size 25/.06 of Mpro, 2Shape and Revo s instruments were tested inside two artificial canals of (60˚ curvature, 3 mm radius) and (45˚ curvature,5 mm radius) while immersed in distilled water at 37°C ± 0.5°C ,before and after sterilization, the number of cycles to failure (NCF) was calculated, and the fracture surface was examined by using a scanning electron microscope. The data of NCF were analyzed by using three way analysis of variance and Tukey post hoc tests. The level of significance was set at $P < .05$ Results: The Mpro instrument had a significantly higher NCF compared with the other instruments in severe and mild curvature canals ($P < .05$). also the 2Shape had a significantly higher NCF compared with the Revo-s in severe and mild curvature canals ($P < .05$). the non sterile Mpro had significantly higher NCF compared with the sterile Mpro, while the non sterile 2Shape had significantly lower NCF compared with the sterile 2Shape, however there was no statistically significant difference between sterile and non sterile Revo-s. Conclusion: The fatigue resistance of Mpro was greater than that of other instruments. Mpro and 2Shape instruments displayed superior cyclic fatigue resistance than Revo-s, curvature severity inversely affect cyclic fatigue resistance of NiTi instruments, while sterilization has an increasing effect on fatigue resistance of Mpro, a decreasing effect on fatigue resistance of 2Shape. However for Revo-s, autoclaving had no significant effect.

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Introduction:

Root canal cleaning and shaping are important phases in endodontic therapy However, As a NiTi file bends around a curved canal during , it is subjected to stresses along any part of the file that is bent toward the inside of the curve, the file is subjected to compressive stress. On the outside of the curve, the file is subjected to tensile stress.

As the file rotates, every bent segment of the file experiences a cycle of both compressive and tensile stress, the continuous cycle of compressive and tensile stresses leads to microfractures in the metal matrix of the file. This phenomenon is known as cyclic fatigue. The mechanical performance of NiTi alloys is extremely sensitive to their microstructures and associated thermomechanical treatment history. Therefore, one of many promising solutions to improve fatigue resistance of rotary instruments is to optimize the microstructure of NiTi alloys through novel thermomechanical processing or new manufacturing technologies. CM-Wire and recently T-wire have been developed through a proprietary thermomechanical processing procedure and claimed by their manufacturers that they had better cyclic fatigue resistance in comparison with those made of conventional superelastic NiTi alloy. It has been suggested that NiTi shape memory and super elastic properties are strongly dependent on the thermomechanical processing history of the manufactured product, and consequently it has been reported that the additional heat treatment of NiTi instruments during autoclave sterilization might increase their flexibility. In other studies a similar relationship has been observed between the sterilization procedures and different types of NiTi rotary instruments whose performance and physical properties were affected, negatively or positively, by the sterilization process.

Material and methods :

three NiTi instruments, Mpro, 2Shape and Revo-s, size 25/.06 (n = 32/system), were used for this study. Each group was then divided into 2 subgroups (n = 16), unsterilized instruments and sterilized instruments. The sterilized instruments were subjected to 5 cycles of autoclave sterilization1,2, each subgroup was further divided into two subdivisions (n=8) according to the curvature they are rotating in, A custom-made stainless steel block with 2 curvatures was used ; a severe curvature of 60˚curvature, 3 mm radius and mild curvature of 45˚ curvature,5 mm radius was used for testing the cyclic fatigue testing as illustrated in previous studies.1,3,4the instruments were rotated (Endo-Mate DT, NSK)****, according to manufacturer's recommended speed and torque for each system and tested while immersed in distilled water at 37°C ± o.5°C.5 The time to fracture was recorded and stopped as soon as a fracture of the instrument was visually detected. The number of cycles to failure (NCF) for each curvature was calculated. Surface topography images of 5 random specimens of fractured instruments were analyzed by using a scanning electron microscope(SEM).

Results :

The data of NCF for different instruments are presented in Table (1). The severely curved canal revealed statistically lower NCF value than the mild curvature canal ($P < .05$), in both curvatures M pro instrument had a significantly higher NCF compared with the other groups ($P < .05$). the 2Shape instrument had a significantly higher NCF compared with the Revo-s instrument, the lowest NCF values were registered for Revo-s instrument in both curvatures ($P < .05$). Testing protocol did not show any significant difference between Revo-s with autoclaving and Revo-s without autoclaving, however it showed significant difference between Mpro With autoclaving and Mpro without autoclaving, also it showed

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significant difference between 2Shape with autoclaving and 2Shape with autoclaving , Mpro without autoclaving had lower fatigue resistance than Mpro With autoclaving, while 2Shape without autoclaving had higher fatigue resistance than 2Shape with autoclaving.

Surface topography images of fracture surfaces of random samples are presented in Figure 1, Figure 2 and figure 3. In all samples, the fracture planes showed areas of elevations at the peripheries with fibrous central areas. Black dimplings were also evident and areas of crack propagation, all criteria suggestive the ductile fracture pattern of cyclic fatigue failure.

Table 1: Mean (±SD) of NCF of different file types regarding sterilization and canal curvature

Type of file	Sterilization	Canal 1 (sever curvature)	Canal 2 (mild curvature)
Revo-s	Sterile	7228.81(±885.21) ^{Bc}	23101.31(±606.84) ^{Ac}
	Non sterile	9264.5(±1399868) ^{Bbc}	23280.25(±1066.72)^{Ac}
2Shape	Sterile	15346.63(±1583.03)^{Ba}	25437.56(±945.96) ^{Ab}
	Non sterile	11263(±3063.61)^{Bb}	23341.06(±1192.69)^{Ac}
Mpro	Sterile	6487.5(±2033.7)^{Bc}	Did not break ^{Aa}
	Non sterile	16396.88(±2455.9)^{Ba}	Did not break^{Aa}
Same small letters within columns indicate no statistically significant difference. Same capital letters within rows indicate no statistically significant difference.			

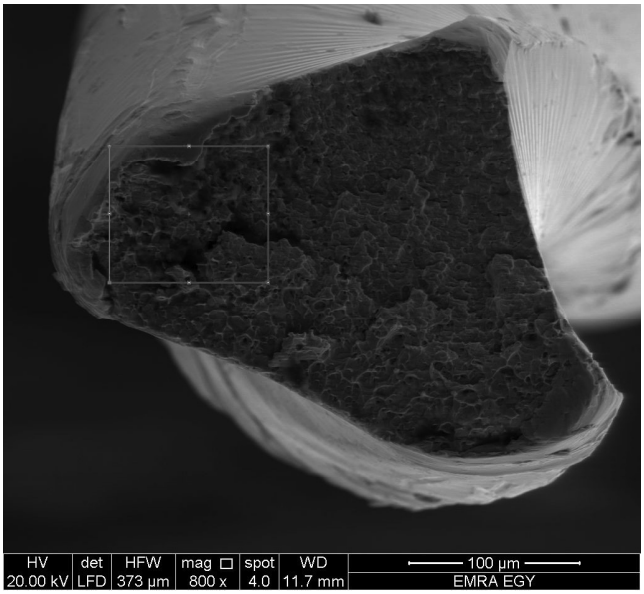

Figure 1: SEM photomicrograph of a fractured surface of 2Shape file in top view (x 800) showing areas of cracks and central fibrous appearance

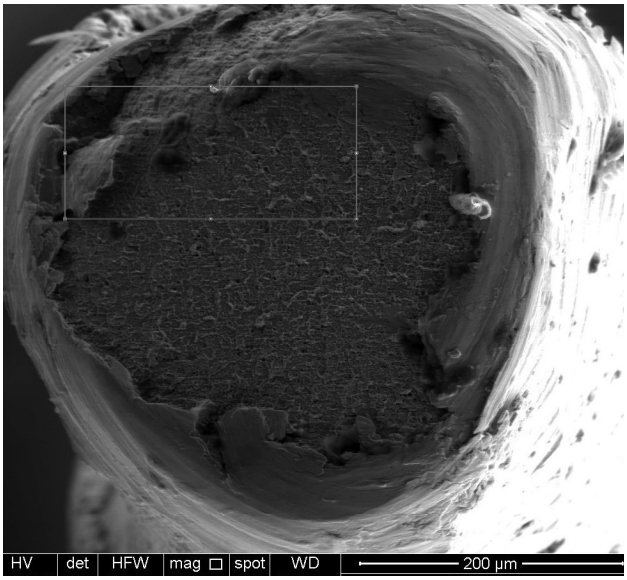

Figure 2: SEM photomicrograph of a fractured surface of Mpro file in top view (x 800) showing central fibrous appearance and areas of elevation.

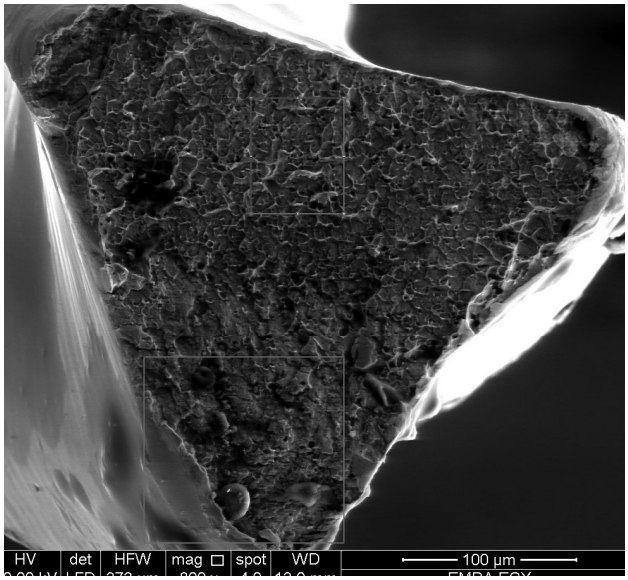

Figure 3: SEM photomicrograph of a fractured surface of Revo-s file in top view (x 800) showing central fibrous appearance, areas of elevations at the periphery and dimples.

Discussion :

File separation during endodontic treatment is a serious problem that could affect tooth survival. Many studies have found cyclic fatigue to be the leading cause for file fractures[6]discarded from this endodontic clinic over 17 months, was analyzed. The incidences of instrument separation were 7% for ProFile and 14% for ProTaper ($p < 0.05$. This led both files manufacturers and researchers to study cyclic fatigue and try to introduce files with enhanced fatigue resistance. Heat treatment of NiTi files has been proven to be successful technique to remarkably improve fatigue resistance of files. Multiple files have been market as heat treat NiTi files, e.g.: M-wire, Twisted File, CM-wire, ProTaper Gold and recently T-Wire. Heat treated file are produced by proprietary technology not disclosed by the manufacturers. Effect of autoclaving on endodontic instruments has got increasing attention. This is because some reports has shown autoclaving to act as a heat treatment capable of reverting some of the plastic deformation files have endured during endodontic treatment[7]post-preparation and post-sterilization standardized images of each instrument were recorded. Assessment of instrument deformation and their subsequent shape recovery was carried out visually and by comparing the digitised images. Data analysis was carried out using chi-square tests. RESULTS: None of the 400 instruments fractured. Visual assessment of instruments post-preparation revealed that 30.5% had unwound and 0.5% had reverse winding. Following sterilization 8.5% remained unwound and 0.5% remained with reverse winding. When assessing instrument shape using digital images, 35.25% were unwound post-preparation, which reduced to 11% post-sterilization. Nine size 25, 0.08 instruments deformed, but none fully regained their original shape after sterilization; however, other sizes of deformed instruments did regain their shape ($P < 0.001$[,8]. Other studies have found autoclaving to significantly enhance cyclic fatigue resistance of heat treated NiTi files[3,9].

In previous studies; effect of autoclaving was carried out by two scenarios, multiple sterilizations of unused instruments that undergo different defined number of autoclaving cycles2,10 ,and repeated sterilization of files after being challenged by stepwise increased amount of cyclic stress (fatigue)11,2 , in the current study, the first scenario was used, and

instruments was tested at body temperature to mimic the clinical condition so as to get dependable data 4,12 ,

Through glass container containing water of temperature adjusted to body temperature(35-37.5) by thermostat and measured by thermometer[4,5,13].

The device used in the present study, was designed aiming to eliminate the human factor for evaluation of file position in the artificial canal.

In the current study, two artificial canals were used; the 1st canal was of curvature angle 60° and radius 3mm representing the severe curvature[3,4,5] ,the 2nd canal was of curvature 45° and radius 3 mm representing the mild curvature[1,11]. severely curved canal reveals a challenging anatomy compared with mild curved canal. In the present study, the instruments tested in the sever curvature canal showed lower NCF compared with the mild curvature. This finding is in agreement with previous studies. [14,15]

In the present study, at both curvature canals Mpro performed obviously the best followed by 2Shape, then Revo-s ,regardless if testing protocol is taken into account or not, this is similar to the results of other studies that found files made of CM wire have significantly higher cyclic fatigue resistance than files made conventional NiTi alloy.[3,16] The newly developed 2Shape instruments revealed enhanced fatigue resistance in both curvatures compared with Revo-s ,2Shape instruments are manufactured from T-Wire heat-treated alloy that might improve the fatigue resistance. It has been postulated that thermal processing raised the austenitic transformation temperature of NiTi alloy[18]manufacturers have introduced new alloys and developed new manufacturing processes for the fabrication of NiTi files. This study aimed to examine the phase transformation behavior and microstructure of NiTi instruments from a novel controlled memory NiTi wire (CM wire and enhanced the arrangement of crystal structure, which accordingly improved the performance of instrument[19] . this was similar to the study of Elnaghy AM and Elsaka SE [20]which is the only article that could be found comparing the cyclic fatigue resistance of 2Shape files to conventional NiTi files. In both curvatures Revo -s had the least mean NCF, this similar to previous studies tested the cyclic fatigue resistance of conventional NiTi alloy [21]Orange, CA,[22,23] The results of the current study also found that autoclaving does not affect fatigue resistance of Revo-s files which is similar to other studies [24,3,9]. However, autoclaving did reduce the fatigue resistance of 2Shape files. Also it was found that autoclaving did increase the fatigue resistance of Mpro files, which is similar result to other studies performed on CM wire alloy.[3,21Orange, CA]

Fractographic (top view) SEM analysis of 5 randomly selected rotary endodontic files under different powers revealed the typical cyclic fatigue picture.

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