EGYPTIAN
DENTAL JOURNAL

Vol. 68, 1963:1966, April, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 2022-02-07 • Accept Date : 2022-03-26 • Available online: 2022-03-30 • DOI : 10.21608/edj.2022.120037.1970

CYCLIC FATIGUE RESISTANCE OF CM-ALLOY, T-WIRE AND CONVENTIONAL NiTi ROTARY FILES AT DIFFERENT CANAL CURVATURES

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ABSTRACT

Introduction: The aim of this study was to investigate the cyclic fatigue resistance of CM files (M3-ProGold, W3-Pro and M-Pro) and to compare it with that of the T-Wire (2Shape) and conventional NiTi (Revo-s) rotary files.

Methods: Size 25/.06 of M3 Pro Gold, W3-Pro, M-Pro, 2Shape and Revo-s files (each n = 20) were evaluated inside two artificial canals [(60 curvature, 3 mm radius) and (45 curvature, 5 mm radius)] while submerged in distilled water at 37 ± 0.5. The NCF (number of cycles to failure) was calculated. The data of NCF were analyzed using ANOVA and Tukey post hoc tests ($P \leq 0$ .05).

Results: The CM files had a significantly higher NCF than the other files in severe and moderate canal curvatures. The 2Shape had a significantly higher NCF than Revo-s in both canal curvatures. **Conclusion:** CM files have greater resistance to cyclic fatigue than T-Wire and conventional NiTi rotary files.

KEYWORDS: Cyclic Fatigue, CM-Alloy, T-Wire, Conventional NiTi

INTRODUCTION

Root canal instrumentation is an essential phase for successful endodontic treatment. Mechanical instrumentation aims to clean the root canal system, while preserving the canal curvature and maintaining the original position of the apical foramen. However, in curved root canals, there is a higher risk for ledge formation and apical transportation. Therefore, nickel-titanium (NiTi) rotary instruments were developed.

As a NiTi file enters a curve, the file is bent and is subjected to compressive stress on the inside of

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the curve. At the same time, the file is subjected to tensile stress on the outside of the curve. As the file rotates, it experiences a cycle of both compressive and tensile stresses. Such continuous cycle of stresses results in microfractures in the file metal matrix. This is known as cyclic fatigue. To improve fatigue resistance of NiTi rotary files, thermomechanical processing and new manufacturing technologies have been developed. Controlled memory (CM) alloy and T-Wire have been developed and claimed by their manufacturers to have better resistance to cyclic fatigue than conventional NiTi alloy.

To date, no sufficient data is available on mechanical properties of Chinese rotary NiTi files made of CM alloy. Therefore, the aim of this study was to investigate the cyclic fatigue resistance of CM files (M3-ProGold, W3-Pro and M-Pro) and to compare it with that of the T-Wire (2Shape) and conventional NiTi (Revo-s) rotary files.

MATERIALS AND METHODS

Size 25/.06 of 5 NiTi instruments, M3-ProGold (United Dental Group, Changzhou, China), W3-Pro (Guilin Woodpecker Medical Instrument Co., Guilin, China), M-Pro (Foshan Stardent Equipment Co., Guangdong, China), 2Shape (MicroMega, Besancon, France) and Revo-S (MicroMega, Besancon, France), were used for this study (n = 20/group). Each Group was divided into two equal subgroups (each n=10) depending on the curvature they were rotating in. Subgroup A files were rotated in custom-made stainless-steel block with severe curvature of 60 ° and 3 mm radius. Subgroup B files were rotated in custom-made stainless-steel block with moderate curvature of 45 ° and 5 mm radius [1,2,3]. Numbers of samples were chosen to be 10 for each subgroup. This was in accordance with the recommendations of ASTM International which recommends number of samples for statistical analysis of fatigue data to be from 6 to 12 [4]. The files were rotated using endodontic motor (Motopex, Guilin Woodpecker Medical Instrument Co., Guilin, China). The torque and speed of rotation were adjusted based on manufacturer's recommendations for each file. Files were rotated while submerged in distilled water at 37 ° ± 0.5 ° simulating body temperature [5]. The temperature of the water was controlled via aquastic thermostate connected to heat control (Filotronix, China) and measured via digital thermometer. The time to fracture was recorded and stopped once file fracture was visually detected. The NCF (number of cycles to failure) was calculated according to the following equation [6]:

NCF = rpm x time taken to fracture (in sec.)

Statistical analysis

Numerical data were represented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Assumption of sphericity was confirmed using Mauchly's test of sphericity. One-way ANOVA test followed by Tukey's post hoc test was used to test intergroup comparisons. One-way repeated measures ANOVA followed by multiple pairwise paired t-tests with bonferroni correction was used to test intragroup comparisons. Significance level was set at $P \leq 0.05$. Statistical analysis was performed with R statistical analysis software (R Core Team 2021, Vienna, Austria).

RESULTS

Data of NCF for different files are presented in Table (1). Regardless of the file type, the severely curved canal revealed statistically significant less NCF than the moderately curved canal. M3-ProGold, W3-Pro and M-Pro files had a statistically significant higher NCF compared with 2Shape and Revo-S files in both canal curvatures. The 2Shape files had a statistically significant higher NCF compared with the Revo-s files in both canal curvatures.

TABLE (1). NCF for different files at severe and moderate canal curvatures

Type of File	Subgroup A (Severe canal curvature)	Subgroup B (Moderate canal curvature)
M3-ProGold	17220.82 (±2577.1)^{A}	Did not break up to 10 minutes of rotation ^{B}
W3-Pro	17010.33 (±2375.2)^{A}	Did not break up to 10 minutes of rotation ^{B}
M-Pro	16590.63 (±2632.7)^{A}	Did not break up to 10 minutes of rotation ^{B}
2-shape	11550 (±3154.44)^{C}	27415.5 (±1067.49)^{D}
Revo-s	9450 (±1405.33)^{E}	24342.5 (±1278.92)^{F}

Same letters indicate no statistical significance.

DISCUSSION

The device used in the present study was designed to eliminate the human factor for evaluation of file position in the artificial canal [7,8]. The cyclic fatigue resistance was evaluated in water instead of sodium hypochlorite (NaOCl). NaOCl is the most commonly used irrigant clinically, but previous studies concluded that NaOCl did not significantly affect the cyclic fatigue resistance of NiTi files [9].

Two artificial canals were used to simulate clinical situations. The first canal was of curvature angle 60 and radius 3 mm representing the severe curvature [2,3,5,9]. The second canal was of curvature 45 and radius 5 mm representing the moderate curvature [1,10]. Regardless of the file type, files tested in the severely curved canal showed significantly less NCF than files tested in the moderately curved canal. This is in agreement with Pruett et al [11], Ounsi et al [12] and Kwak et al [13].

At both canal curvatures, files made of CM alloy (M3-ProGold, W3-Pro, M-Pro) showed higher NCF followed by 2Shape files, while Revo-s files showed lowest NCF. This is similar to the results of previous studies that found files made of CM alloy have significantly higher NCF than files made of conventional NiTi alloy or files made with different thermal treatments [2,14]. CM alloy has an enhanced arrangement of crystal structure, which improves the file flexibility and cyclic fatigue resistance [15]. CM alloy shows an increase of the proportions of the R-phase and martensite. The R-phase has the lowest shear modulus among the 3 phases of NiTi alloy [16]. Martensite has a better ability to absorb stresses and deform than austenite. This is related to the twinning phase of martensite, which is an internal movement of lattices without breaking atomic bonds when stressed [17,18]. Meanwhile, there are few studies regarding the metallurgic characterization of T-Wire heat treatment. Ozyurek et al [19] and Pedulla et al [20] showed that HyFlex CM and HyFlex EDM files, made of CM alloy, have more flexibility and higher NCF than 2Shape files. However, 2Shape files showed higher cyclic fatigue resistance in both canal curvatures than Revo-s. The 2Shape files are made of heat-treated T-Wire. This heat treatment raised the austenitic transformation temperature of NiTi alloy [17], which might have improved the fatigue resistance of the 2shape files [21]. Revo-s is made of conventional NiTi alloy, and therefore it had the least mean NCF in both curvatures [22,23,24]. The conventional NiTi file has a shape memory effect, and while the file rotates in a curvature, it tends to return to its original shape, which increases the friction between the file and canal wall [25]. On the other hand, the CM and heat-treated files have more martensite proportions at both room- and body-temperatures, have a less shape-memory, and therefore are less stressed when rotating into root canal curvature [13,26].

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