The effect of sterilization cycle on cyclic fatigue resistance of rotary files (in vitro study)

Mohammed Hamoudi Alsunboli [1] Seemaa abdulameer kadhem[2], Ahmed Saad[3]

[1]*Al-Bayan University /College Of Dentistry/Iraq*
Email: m.hamoudi@albayan.edu.iq
[2]*Al-Bayan University /College Of Dentistry/Iraq*
Email: simaa.a@albayan.edu.iq
[3]*Al-Bayan University /College Of Dentistry/Iraq*
Email: ahmed.saad@albayan.edu.iq.

***Correspondence author:** Mohammed Hamoudi Alsunboli m.hamoudi@albayan.edu.iq

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Abstract

Background

Files' cutting efficiency, cyclic fatigue resistance, surface roughness, and accumulation of dentinal debris on them, among other characteristics, can all be affected by the repetitive autoclaving and sterilization. Cutting efficiency, also referred to as an instrument's ability to extract dentine from a canal, is one of its qualities.

Aim of study:

The study's objective is to ascertain how autoclave sterilization affects the cycle fatigue resistance (CFR) of two various rotary nickel-titanium (NiTi) systems.

Methods:

The Edge File and Fanta File rotary endodontic instrument groups were chosen. Each group (n = 42) was split into 3 subgroups (n = 14 each), Based on the amount of autoclaving cycles (0, 1, 2 cycles). The tools went through an autoclave without being used.

Results:

The result appeared different significant between the two group and sub group with the different cycle of sterilization that used with it with the length of fractures and time that recorded in each group.

Conclusion:

cyclic of sterilization appeared to have considerably varied cycle fatigue resistance for various lengths of fractures and durations, according to the comparison between the two evaluated instruments.

Keywords:

sterilization cycle; rotary files; fatigue resistance

The repeated autoclaving and sterilization of files can have an impact on their cutting effectiveness, cyclic fatigue resistance, surface roughness, and buildup of dentinal debris on them, among other properties. One of an instrument's characteristics, known as the capacity to remove dentine from a canal, is cutting efficiency. many variables, like the angle of incidence between the tool and the root. Cross-sectional design, rake and helical angles, metal hardness, thermal treatments, and tool action all have an impact on how well endodontic files cut.

The most crucial phase of root canal therapy (RCT) is chemomechanical cleaning and shaping [1]. Nickel-titanium (NiTi) rotary endodontic files speed up and improve predictability during this crucial stage, but there is a small chance of tool separation, a condition that has been widely covered in the endodontic literature [2].

Modern NiTi instruments have remarkable qualities, but they are still susceptible to splitting due to cyclic or flexural fatigue [3]. Repetitive bending of the instruments in curved channels is thought to result in cyclic fatigue, which in turn causes deformation and tension within the instruments and fracture as a result of complete cycles of strain and compression[4].

Thermomechanical processing was created by manufacturers by changing the transformation temps of NiTi alloys to increase fatigue resistance and prevent instrument fracture [5]. The mechanical and physical characteristics of NiTi alloy were improved after it underwent thermal processing [6].

When NiTi rotary files may be used frequently in clinical practice environments, cross-contamination must be avoided [7] by repeatedly autoclaving the instruments. An autoclave is the most effective sterilization method for endodontic tools, according to a thorough review and meta-analysis study from 2020 [8].

Numerous studies that looked into the impact of autoclave cleaning on the physical characteristics of NiTi rotary files produced conflicting findings. According to some studies, repetitive sterilization damages files and causes fractures [9]. While other studies claimed that repeatedly heating and cooling NiTi files did not result in their collapse [10]

Plotino et al. [11] demonstrated that only one file (K3XF) out of the four examined groups, where their properties were unaffected, experienced a significant rise in cyclic fatigue resistance as a result of repeated sterilization. HyFlex CM and K3XF's cyclic fatigue life was also found to be longer than that of the other three evaluated groups, according to Zhao et al. [7].

Recent research [8] revealed that most NiTi endodontic files' physical and mechanical characteristics were unaffected by heated autoclave sterilization. Studies have reportedly produced a variety of outcomes using various NiTi endodontic rotary files, which is inconsistent. The market is flooded with heat-treated NiTi endodontic files that have a wide range of metallurgical characteristics. In order to improve fatigue resistance, cutting efficiency, flexibility, and canal centering capability, Dentsply Tulsa in Tulsa, Oklahoma, the United States, created the Vortex Blue NiTi rotary instrument [12].

It has been asserted that the cycle fatigue resistance of Vortex Blue is significantly lower when compared to comparable-sized NiTi files made of M-wire [13]. For the Edge- File X7 instruments (Edge Endo; Albuquerque, New Mexico, USA), a method known as "FireWireTM" is used to create NiTi files with a constant taper, which may improve flexibility and resilience to fatigue and lessen the shape memory effect to which NiTi instruments are susceptible. [14] According to a recent research [15], VB files are less resistant to fatigue than Edge File instruments are. The TRU Shape (TS) file, manufactured by DENTSPLY Tulsa Dental Specialties in Tulsa, Oklahoma, is an innovative heat-treated NiTi file with an S-curve and a (0.06) taper in the apical (2) mm. The TS file is new to the industry and has not been thoroughly researched [16].

Material and method

The Edge File (0.25/0.6) and Fanta File (0.25/0.6) groups of rotary endodontic instruments, respectively, were chosen as the two different kinds of NiTi rotary endodontic heat-treated instruments. There were a total of 3 subcategories (n = 14) for each group (n = 42).

Subgroup1= treated with non-sterilization
Subgroup2 = treated with one cycle
Subgroup3 = treated with two cycle

The cyclic fatigue test cannot be reliably carried out with natural teeth due to the wide range of canal shapes found in real teeth.

This research was carried out in canals that were specifically designed for the purpose and made of tapered stainless steel. These artificial canals have a coronal portion that is 1.5 mm wide at the beginning and progressively narrows to 1 mm at the end, with a regular (60o) curvature angle and a (5) mm radius of curvature. (17).

The same 25 millimeters was the length of each file. A total of 42 files, or twenty-four instruments of each category, were gathered. Sterilized (S) and non-sterilized (NS) tools were separated into three subgroups of each group (n = 14 each). The sterilized instruments underwent various autoclave sterilization cycles, each lasting for a varying amount of time at a temperature of 134°C. (time included 2 sec. for sterilization to 11 sec. for drying).

A methodology that was earlier described was used for testing. (11). The device was essentially a mobile metal support that was linked to its mainframe. This metal support held the hand part of the artificial canals and the metal block in position. Each tool underwent testing in a fictitious root canal with a 5 mm radius and a 60° angle of curvature. The length of the curved portion of the canal was approximately 5 mm, with the middle of the curve situated 5 mm from the file's tip.

The dentistry handpiece was fixed on a wooden block, which made it simple to move while positioning each file to the same depth for standardization and ensuring three-dimensional alignment inside the artificial canal. The researcher can see the files while they are operating and when a fracture has occurred because the artificial canal is covered with a transparent metal sheet, preventing the files from falling out. As a result, the files could be seen through the window made of clear plastic, making the fracture visible. (14).

In the past, a stainless steel block was fastened to a wooden block to avoid movement and keep the two objects in an almost constant relationship. To reduce friction and heat generation, glycerin was completely stuffed inside the artificial canal before each file was made to the precise dimension (19 mm) inside a canal.(19) Using a cordless endodontic handpiece with an eighth endo-motor, the files were triggered inside the canals.

For more precise work and to reduce human error, video recording has been done concurrently (19). The (NCF) for each file is described by this equation.
"Number of cycles to failure NCF = Speed RPM X Time (T) to fracture in minute".

The SAS (2018) program was used to analyze the NCF data in order to identify the effects of different variables on the research parameters. In order to analyze means in this study meaningfully, the least significant difference (LSD) test (ANOVA) was employed.

Statistical Analysis:

The Statistical Analysis System-SAS (2018) application was used to determine the effects of various factors on the study parameters. In order to evaluate the means in this research meaningfully, the least significant difference (LSD) test was used. (ANOVA).

Results

Descriptive statistics of TtF for the each file are summarized in Table (1, 2 and 3).

Table 1: Effect of type of File and cycle of sterilization in Length of File

Sterilization	Mean ± SE of Length of File		LSD	P-value
	Edge file	Fanta file		
Before	25.00 ±0.00 A a	25.00 ±0.00 A a	0.00 NS	1.00
After one cycle	25.00 ±0.00 A a	25.00 ±0.00 A a	0.00 NS	1.00
After two cycle	25.00 ±0.00 A a	25.00 ±0.00 A a	0.00 NS	1.00
LSD	0.00 NS	0.00 NS	---	
P-value	1.00	1.00		

Means with different big letters in the same column and small letters in the same row are significantly different , NS: Non-Significant.

Table 2: Effect of type of File and cycle of sterilization in Length of Fracture

Sterilization	Mean ± SE of Length of Fracture		LSD	P-value
	Edge file	Fanta file		
Before	3.03 ±0.16 C b	3.65 ±0.16 A a	0.485 *	0.0138
After one cycle	4.71 ±0.12 A a	3.41 ±0.09 A b	0.331 **	0.0001
After two cycle	3.70 ±0.12 B a	3.27 ±0.16 A b	0.412 *	0.0397
LSD	0.401 **	0.415 NS	---	
P-value	0.0001	0.183		

Means with different big letters in the same column and small letters in the same row are significantly different , * (P⩽0.05), ** (P⩽0.01).

Table 3: Effect of type of File and cycle of sterilization in Time

Sterilization	Mean ± SE of Time (sec.)		LSD	P-value
	Edge file	Fanta file		
Before	8.83 ±0.31 A a	4.51 ±0.15 A b	0.717 **	0.0001
After one cycle	5.61 ±0.28 B a	3.71 ±0.22 B b	0.741 **	0.0001
After two cycle	5.42 ±0.08 B a	3.63 ±0.25 B b	0.545 **	0.0001
LSD	0.715 **	0.607 **	---	
P-value	0.0001	0.0095		

Means with different big letters in the same column and small letters in the same row are significantly different , ** (P⩽0.01).

In the table (1), we notice no significant differences between the two type of files and before and after the number of cycle of sterilization in length of file, while in table (2) appeared high significant differences in the effect of cycle of sterilization on the edge file in length of fracture and after one cycle of sterilization on both types of file, while appeared a significant differences in effect of sterilization before the sterilization and two cycle of sterilization on both types of files when appeared no significant differences in one cycle of sterilization on both type of files, while in table (3) there are a high significant differences of types of file and before and after the sterilization (one and two cycle) in time

Note:- Averages that carry different letters in table (1,2 and 3) are significantly different, and averages that carry similar letters do not differ significantly. The highest average takes the letter a and so on downwards. If you find an average that takes two letters like ab, this is no different neither from the average that carries a nor from the average that carries b. as appeared in figure (1 and 2)

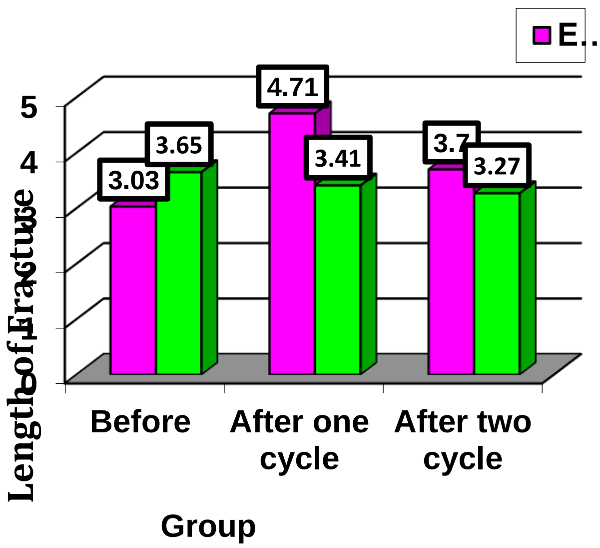

Figure 1. Effect of type of File and cycle of sterilization in Length of Fracture

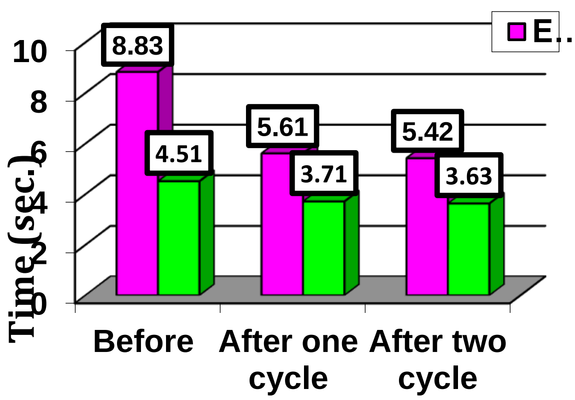

Figure 2. Effect of type of File and cycle of sterilization in Time

Discussion

Rotating files are autoclaved in order to remove microbial contamination and improve the likelihood that root canal treatment will be successful.[20] Many doctors opt for having predetermined groups of specific files. These documents might not all be utilized in the course of the therapy, though. Therefore, several autoclaving cycles are performed on the rotating files that have not been used. Most studies that have been made public in the media have looked at how frequently autoclaving rotating NiTi file systems affects them[21].

The autoclaving process hardly ever alters the physical characteristics of stainless steel tools. According to Silvaggio and Hicks' study, there is no increased risk of file breakage when autoclaving rotary NiTi files.[22] Rotating NiTi files have different CFRs for a number of causes, including variations in the manufacturing process, operational elements, file design, properties, canal curvature, and the method of fatigue failure testing. To increase the lifespan of NiTi instruments, the following techniques can be used: (i) thermal processes prior to machining; (ii) suitable machining conditions for the NiTi alloy, and (iii) electro-polishing. (23]

Aminsobhani M et al. claim that the Neolix Neoniti files' Austenite start temps were set up so that the austenite phase was present at the mouth temperature. The R- phase transition can be seen in neoniti.[24] The austenite-finish temperatures of the neoniti, providing the instruments greater flexibility when used in a clinical setting, were higher than a person's body temperature, causing the material to undergo a phase change from martensite to austenite. [25] When kept at room temperature, the majority of EdgeFile and Neoendo data are in the austenite phase.

The most frequent reason for NiTi failure during root canal preparation is cyclic fatigue-induced breakage. The quantity of metal mass in the file cross-section and cyclic fatigue have previously been shown to be inversely correlated [26], so it has been proposed that the thermal and surface treatment used during the production of the NiTi alloy enhances fatigue resistance.

These files are frequently used for economic reasons, and because of this, they undergo autoclave sterilization throughout their working lifetimes. This study's objective was to assess the impacts of autoclave sterilization on two files with similar designs and taper angles but different NiTi alloy treatments in terms of their resilience to cyclic fatigue.

Regardless of the quantity of autoclaving cycles, the heat-treated Race Evo file fared better in terms of cyclic fatigue resistance than the traditional electropolished Race file. This is consistent with the overwhelming majority of studies that demonstrate that thermomechanically altering the microstructure of the NiTi alloy improves its performance, particularly in terms of cyclic fatigue resistance [27]. In water that has been heated to 35 °C, a metal canal block is immersed.

In the second study, autoclave sterilization had no effect on Race Evo or Race files' ability to withstand cyclic wear. It seems that the autoclave sterilization temperatures to which the files are subjected might not be sufficiently high to cause the NiTi alloy to undergo significant microstructural changes that would adversely affect its resilience to fatigue. This conclusion was confirmed by earlier studies [28] that showed autoclave sterilization had no negative effects on the cyclic fatigue resistance of conventional or heat-treated NiTi files. Actually, After five autoclaving cycles, Viana et al. [29] and Champa et al. [28] both found that Reciproc files had more cyclic fatigue resilience. However, Hilfer et al. [30] discovered that the cyclic fatigue resistance of a size 25/0.06 Twisted File had diminished. In addition to having a significant 90-degree curve, the simulated metal canal in their study also had a significant taper in the file.

In order to standardize the experimental conditions, files were tried in a canal grooved inside of a metal block that was not rocked back and forth. Even though it does not accurately reflect clinical situations or the extensive distribution of stresses associated with rhythmic movement, In earlier studies, this static model was favored for assessing cyclic fatigue [31]. Having said that, different clinical settings may be possible that different clinical settings will yield different results from the ones found in this research.

It has been demonstrated that the surface quality of the file is crucial because corrosion and fractures can cause an instrument to break [32]. According to Praisarnti et al. [33], electropolishing improved the resilience to fatigue failure, particularly when corrosive sodium hypochlorite was present. However, unlike heat-treatment, it has no impact on the fundamental mechanical characteristics of the metal itself.

Fractured surfaces are often found to have a variety of textures on SEM, which represent the various loads and failure types. Typically, areas of crack initiation and linear striations parallel to the direction of the tensile stress characterize flexural fatigue failure, whereas plastic deformation and dimpling patterns indicate torsional fracture [34]. Race Evo files displayed unique striations that appeared to be the progression of flexural fatigue from an initial point to dimpling, a sign of ductile failure [35]. On the broken surfaces of both kinds of files, ductile and microvoid coalescence failure characteristics could be seen [36].

The experimental setting was standardized by testing files in a metal block canal without any back-and-forth movement. In previous studies [8,9,13,14], it remained the standard static model for evaluating cyclic fatigue. It does not, however, correctly reflect clinical situations or the rhythmic movement-related stressors that are distributed widely. However, it's possible that various clinical environments won't produce the same results as these studies.

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Fractured surfaces typically show a variety of textures through SEM, which represent the various loads and failure types. Flexural fatigue failures are typically indicated by straight striations parallel to the path of the tensile stress and regions of fracture initiation, whereas plastic deformation and dimpling patterns indicate torsional fractures [34]. Indicative of ductile failure, Race Evo files showed distinctive flexural fatigue-related striations spreading from an initiation point and then dimpling [35]. The fractured surfaces of both kinds of files displayed characteristics indicative of ductile and microvoid coalescence failure [36].

Conclusion

When the two instruments under test were compared, it became clear that their cycle fatigue resistance for various lengths of fractures and timesframes appeared to be significantly different. However, more investigation is necessary to completely comprehend the various factors that can affect an instrument's cyclic fatigue resistance, fracture modes, and novel apparatus designs that share more characteristics with root dentine. Therefore, additional research is needed to support the findings of the current study with various sterilization cycles.

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