Eurasian J. Sci. Eng., 2023, 9(3), 67-75
https://doi.org/10.23918/eajse.v9i3p07

Published by Tishk International University
Available at: https://eajse.tiu.edu.iq/submit/

RESEARCH ARTICLE Open Access

Effect of Different Irrigation Materials on Cyclic Fatigue Resistance of Nickel Titanium Rotary Files: An *In-Vitro* Study

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Article History
Received: 26.04.2023
Revised: 18.08.2023
Accepted: 23.11.2023
Published: 02.01.2024
Communicated by: Dr. Orhan Tug
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Abstract:
With the advancements been made in Nickel Titanium (NiTi) rotary files to decrease complications during root canal treatment, however, different irrigation solutions are being used during the procedure that might affect the cyclic fatigue resistance of instruments. In this study effect of irrigation solutions on NiTi was compared.
A total of 30 files were divided into three groups of sodium hypochlorite, EDTA and normal saline, each group containing 10 files. After the immersion the files were rotated inside a custom-made block until the files were fractured.
According to t-test group II (EDTA) showed maximum mean time taken until fracture and least mean time in case of Group I (sodium). however according to ANOVA test no significant difference between the experimental groups were found.
Within the limitations of this study, EDTA had the least effect while sodium had the greatest effect on cyclic fatigue of the instruments.

Keywords: *Cyclic Fatigue; Endodontics; NiTi; Irrigation Solutions; Sodium Hypochlorite; EDTA; Fracture Resistance.*

1. Introduction

Root canal therapy (RCT) has emerged as the most effective treatment modality for pulpal conditions and periapical infections. The utilization of Nickel Titanium (NiTi) instruments in the domain of root canal therapy has shown a substantial increase in recent years. One of the advantages of NiTi instruments is their enhanced flexibility, which has been found to reduce procedural errors in comparison to stainless steel files. Nevertheless, it is important to note that despite the exceptional mechanical properties of Nickel-Titanium (NiTi) alloys, the use of rotational endodontic instruments is still associated with a significant risk of instrument separation due to their inherent limited fatigue life. The occurrence of file separation can be attributed to various reasons, with cyclic fatigue and torsional stress being the predominant causes. The cyclic fatigue phenomena can be elucidated through the application of continuous tensile and compressive cycles on the rotary file within an angulated root

canal, ultimately leading to mechanical fatigue. Torsional fracture may occur when the tip of the file becomes lodged while the shaft of the file continues to rotate. The canal system exhibits a high degree of complexity, characterized by the presence of various curvatures that might lead to the spatial separation of instruments within the canal. These situations present complex challenges [1, 2, 3].

Various strategies have been established to enhance the development and production of enhanced iterations of endodontic tools. These techniques aim to improve fatigue strength, employ diverse cross-sectional designs, and utilize different alloys to enhance mechanical qualities [4]. The newly developed NiTi alloys, namely CM-wire, M-wire, and Phase-R, exhibit notable characteristics in terms of instrument performance, including enhanced fracture resistance and greater flexibility. Furthermore, the utilization of nickel titanium heat treatment technology aims to ensure that the temperature transformation phase of the metal occurs near the intracanal temperature. The instrument that has undergone thermal treatment will demonstrate martensitic behaviour and possess enhanced resistance to cycle fatigue when exposed to a simulated intracanal temperature. These beneficial qualities, resulting from the anticipated high transition temperature, make the instrument well-suited for use in complex root canal architecture. In addition to cyclic and torsional fatigue, various factors exist that can influence the resistance of endodontic instruments, including anatomical conditions such as the angles and radii of curvature within the root canal, the numerical designation of the instrument, the torque applied, the proficiency of the operator, the frequency of sterilization cycles, and the type of irrigation employed during treatment. These factors have the potential to impact the cyclic fatigue resistance of NiTi instruments [5, 6, 7]. The primary objective of root canal treatment is to effectively eliminate bacteria present within the canal, hence achieving disinfection. The desired outcome can be attained by the utilization of both mechanical and chemical procedures. During the mechanical operation, a layer known as the smear layer is created. This layer has the potential to cover the areas of the root canal walls that have been treated with instruments, obstructing the dentinal tubules. Consequently, this hinders the disinfection process and hinders the penetration of disinfectants into the deeper regions of the dentinal tubules [8, 9]. Furthermore, irrigation solutions are employed during root canal procedures to achieve chemical disinfection of the canal, eliminating bacteria and eliminating the smear layer, which comprises both organic and inorganic substances within the canal throughout the treatment process. It is not recommended to do instrumentation on a dry canal; rather, it is advisable to instrument the canal while ensuring a substantial irrigation process is in effect. The utilization of irrigation is of utmost important in the context of root canal therapy, as it serves the purpose of effectively eliminating dentin shavings from the intracanal system. As a result, they do not condense in close proximity to the apex of the root canal. The proper functioning of instruments is hindered in dry canals due to the absence of lubrication. They have enhanced the efficacy when operating in wet canals. When canal walls are lubricated by irrigation, instruments exhibit a reduced susceptibility to breakage. When in contact with the substance, they function as a solvent for necrotic tissue, effectively removing debris, pulp tissue, and microorganisms from uneven dentinal walls. They aid in the removal of material from lateral and auxiliary channels that cannot be accessed using conventional tools. Most of these irrigations used possess germicidal properties. Over the course of time, a multitude of research have been conducted to examine the efficacy of various root canal irrigants therapies. The use of instrument debridement during instrumentation is inadequate for achieving thorough removal of pulp tissue, debris, and bacterial biofilm from the root canal, EDTA and sodium hypochlorite (NaOCl) are commonly employed as irrigants in studies evaluating the efficacy of antibacterial activity of the irrigants [10].

The utilization of Ethylenediaminetetraacetic acid (EDTA) aids in the elimination of the smear layer that are formed during instrumentation procedure, while Sodium Hypochlorite serves the purpose of

disinfecting the canal and dissolving organic tissue. The concurrent application of both irrigants enhances the efficacy of root canal disinfection. Nevertheless, the interaction between nickel titanium rotary files and irrigation materials may potentially result in corrosion and distortion, leading to a reduction in the fatigue life of the files [11,7]. This study was conducted to determine the influence of different irrigation materials on the longevity of heat-treated nickel titanium rotary files.

2. Methodology

In this study thirty experimental heat-treated rotary 2 shape Nickle Titanium files from Micro Mega, France, were used in the study as shown in (Figure,1). Those thirty samples were randomly divided into three groups, as in table 1, Group 1 (Normal Saline), Group 2 (Sodium hypochlorite 5%), Group 3 (EDTA gel) as in (Figure 2).

The size of those experimental files was maintained at a regular ISO size 25/4, and 25 mm length. A metal simulator were prepared then, the experimental files were put to the test in the metal simulated apparatus with a 5 mm radius and a 60° angle of curvature to have a resemblance of curved canal in natural tooth as shown in (figure 3) (12), group I files were immersed in normal saline for the duration of 10 minutes, group II files were immersed in sodium hypochlorite 5% (Hyposol, India) for the duration of 10 minutes, and group III files were coated with EDTA Gel (Glyde, Dentsply) for 10 minutes (Figure, 2). Following their immersion, the experimental files were thoroughly washed under running water. Later, each file was individually inserted into the Endomotor (Eighteenth, Changzhou, China), with the file stoppers at the support steel cylinder and the file tip between two shaping steel cylinders (Figure,3,4). Then, each file was allowed to rotate while in the metal apparatus with the speed of the endomotor at 400 rpm and 2.5 N/cm torque and a digital timer was started. The moment the instrument broke was then noted (in seconds). The formula below was used to calculate an estimate of a file's total number of cycles prior to breakage. until fracture = 300/60 x time until fracture, cycles carried out via experimental file (In sec.)

Table 1: study design for sample preparation

Group Number	Description	Number of Files
I	NORMAL SALINE	10
II	SODIUM HYPOCHLORITE	10
III	EDTA	10

Figure 1: 2 shape rotary system

Figure 2: group 1,2,3 immersed in normal saline, sodium hypochlorite, EDTA gel

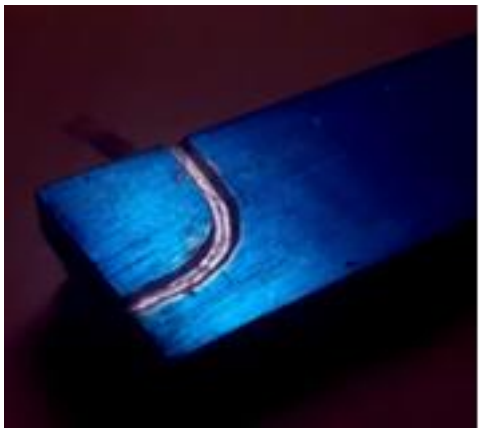

Figure 3: Metal simulated apparatus

Figure 4: file rotating inside metal apparatus

3. Results

The paired two sample t-test for means found a significant difference between group II (sodium hypochlorite) and group III (EDTA) (Table 2), while there was no significant difference between group I (normal saline) and group II (sodium hypochlorite) (Table 3) nor between group III (EDTA) and group I (Normal Saline) (Table 4).

The greatest group difference is between groups II (sodium hypochlorite) and group III (EDTA)(Table 1), and the smallest group difference is between groups I (normal saline) and II (sodium hypochlorite) (Table 3). Group III (EDTA) had the longest NiTi file survival time (277 seconds), whereas group I (Normal Saline) had the shortest (66 seconds) (Table 2).

Overall, EDTA demonstrated excellent cycle flexural fracture resistance with the longest survival time when evaluating the selected experimental irrigation type, followed by normal saline, while sodium hypochlorite demonstrated the least amount of cyclic flexural fracture resistance.

Table 2: t-test comparing sodium hypochlorite vs EDTA.

t-Test: Paired Two Sample for Means SODIUM VS EDTA		
	Variable 1	*Variable 2*
Mean	100.5	141.8
Variance	409.1666667	3378.844444
Observations	10	10
Pearson Correlation	-0.397742679	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.900313454	
P(T<=t) one-tail	0.044921524	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.089843048	
t Critical two-tail	2.262157163	

Table 3: t-test comparing sodium hypochlorite vs normal saline.

t-Test: Paired Two Sample for Means SODIUM VS SALINE		
	Variable 1	*Variable 2*
Mean	100.5	108.2
Variance	409.1666667	1255.511111
Observations	10	10
Pearson Correlation	0.482587655	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.780650466	

P(T<=t) one-tail	0.227524786	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.455049572	
t Critical two-tail	2.262157163	

Table 4: t-test comparing EDTA vs Normal Saline.

t-Test: Paired Two Sample for Means		
EDTA VS SALINE		
	Variable 1	*Variable 2*
Mean	141.8	108.2
Variance	3378.844444	1255.511111
Observations	10	10
Pearson Correlation	-0.019560994	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.547396104	
P(T<=t) one-tail	0.078086459	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.156172919	
t Critical two-tail	2.262157163	

4. Discussion

The goal of the current study was to determine how various irrigation solutions affected the cyclic fatigue resistance of rotary files. The rotational system used in this study, the 2shape (Micro Mega, France) is made of heat-treated (T-wire), which boosts its flexibility and resistance to cyclic fatigue compared with conventional wire. This system has triple helix cross section, which has a pair of main cutting edges and one secondary cutting edge, which improves the file's ability to cut effectively and clear away debris during instrumentation of the canals. Two files make up the 2Shape rotary file system: TS1 (25/.04) and TS2 (25/.06). In this study NiTi rotary file size 25 4% was used, [13].

The files were inserted into three different irrigation materials of normal saline, EDTA gel and sodium hypochlorite for ten minutes which was an average time of contact for instrumentation of a canal

according to pilot study. Later, the files were subjected to continuous rotation inside a custom-made metal block at 2.5Nm at 300 RPM which was recommended by the manufacture.

In this study among the study group, when compared to the sodium hypochlorite and normal saline groups, the EDTA group had greater cycle fatigue resistance; however, when the findings of the other groups were compared, there was no statistically significant difference.

The lubricating and chelating effects of EDTA have contributed to the EDTA group's higher cycle fatigue resistance [14]. To establish patency, EDTA is helpful in navigating sinuous, calcified channels that are small and narrow. It aids the tools in shaping the root canal by acting as a lubricant inside the canal, thus it's possible to assume that this irrigating solution could increase the file's lifespan [15].

In contrast with the results of this study in other study where cyclic fatigue resistant of NiTi files where checked, Erik CE and Ozyurek T 2019 have found that irrigation solutions had no effect on the tested files' cyclic fatigue resistance and they attributed it to the different surface treatment of files that were used in their study [17]. Which was also supported by the studies that were made by a study made by Pedulla E and his colleagues in 2018 [2].

In a different study, the effects of EDTA and NaOCl on the Edge Taper Platinum and ProTaper Gold (PTG) instruments' cyclic fatigue resistance under repeated cyclic motions in an artificial canal at 37 °C were examined. In the solutions tested, ETP demonstrated a higher cyclic fatigue resistance than PTG. NaOCl had a detrimental effect on both groups, although the fractographic appearance of the PTG and ETP instruments that were cyclically tired in EDTA was comparable to that of the instruments that were fatigued in distilled water and NaOCl, which is in consistent with the result of this study [7].

In contrast in another study, where effect of irrigation solutions on cyclic fatigue resistance of NiTi files were evaluated, it was seen that after three minutes, all instruments' resistance to fatigue was reduced by 17% EDTA, this difference in result can be attributed to that, they have used EDTA solution, while in the current study gel form of EDTA has been used [2]. Also, when the effect of irrigation solution on surface roughness of rotary files were observed the results has shown that sodium hypochlorite and EDTA both had effect on surface roughness of the files, however, the cycle fatigue resistance was unaffected by this alteration [19]. The studies demonstrated that NaOCl has negatively affected the cyclic fatigue resistance of the instruments [17].

5. Conclusion

Within the limitations of this study, among the study groups, sodium hypochlorite irrigation had the greatest effect on the cyclic fatigue resistance of Nickel Titanium rotary files, while EDTA gel had least effect.

6. Author's Contribution

We confirm that the manuscript has been read and approved by all named authors. We also confirm that each author has the same contribution to the paper. We further confirm that the order of authors listed in the manuscript has been approved by all authors.

7. Conflict of interest

There is no conflict of interest for this paper

8. Acknowledgment

Authors are also asked to write an acknowledge section for some external contributors; such as an external supervisor, reviewers, editorial team of the journal, ect. Authors are not allowed to acknowledge eachother.

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