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Impact of sodium hypochlorite irrigant on fatigue resistance of different nickel-titanium instruments

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Abstract---Aim: The purpose of this study was to investigate the resistant of three NiTi files, ProTaper (PTN), Hyflex EDM and 2Shape (TS) to cyclic fatigue after being immersed in a 2.5 percent NaOCl irrigant solution in different times (1&5 minutes) at 37°C. Materials and Methods: Seventy-two heat treated files used in this study, divided into three main groups (n=24) according to their metallurgy group-1: PTN, group-2: Hyflex EDM and group-3: TS files each group then subdivided into three subgroups, subgroup-1 immersed in 2.5 percent NaOCl for 1minute at 37°C subgroup-2 immersed in 2.5 percent NaOCl for 5 minutes at 37°C and subgroup-3 did not undergo any immersion as a control group. All files were put through cyclic fatigue testing in a digital water bath at 37°C to imitate body temperature in a stainless-steel artificial canal. The time to fracture was recorded in minutes, then by multiplying the time to fracture by the rotations per minute, the number of cycles to fracture (NCF) was calculated. The data were checked for normality before running a one-way ANOVA with a post hoc test. Results: Hyflex EDM files significantly more resistant to fracture ($p < 0.05$) than the PTN and TS files in all groups. PTN files showed a significant decrease in cycle fatigue resistance in groups immersed in NaOCl for 1&5 minutes ($p<0.05$) than the control group. Conclusion: Hyflex EDM files were more resistant to cyclic fatigue than PTN and TS files in different time of immersion. PTN resistance to cyclic fatigue was considerably lowered by immersion in 2.5 percent NaOCl for 1&5 minutes.

Keywords---Endodontics, NiTi instruments, heat-treated files, Cyclic Fatigue, Sodium hypochlorite.

Introduction

Root canal therapy aims to disinfect the root canal system to a high quality with chemomechanical instrumentation before filling the canal to avoid reinfection. To transfer irrigants to the apical area of the canal and execute their bactericidal impact as well as dissolve organic contaminant, canal preparation requires a continuous and gradually tapering form. Over the last two decades, rotary files made of NiTi have become increasingly popular for this purpose [1]. Despite the introduction of NiTi file systems to reduce the risk of endodontic procedural errors [2]. There is growing concern about the likelihood of instrument failure within the root canals [3]. Which occurs unexpectedly due to cyclic fatigue [4] and often not preceded by signs of damage resulting from permanent deformation [5].

The main cause of instrument failures during clinical use was noticed to be cyclic fatigue. The kinematics, alloy, and metallurgical qualities of the instrument are all thought to play a role in fracture of instruments [6]. Due to differences in chemical composition, the reaction of the instruments to cyclic fatigue or interaction with corrosive chemicals could be influenced by various types of alloys and manufacturing processes utilized for NiTi rotary systems [7].

Nickel- Titanium rotary instruments are routinely subjected to thermomechanical treatment in order to optimize their microstructure and transformation behaviour, which has a substantial impact on NiTi instrument performance [8]. Heat treatment is utilized to create a favourable phase transition point between the martensite and austenite phases in NiTi instruments to improve fatigue resistance [9]. M-wire was introduced in 2007as a heat-treated wire, that have a superelastisity and more resistance to fatigue in comparing to standerd NiTi. It featured better superelasticity to stress and improved fatigue resistance [10]. ProTaper Next (PTN) is a heat-treated made from M-wire alloy (Dentsply Sirona in Ballaigues, Switzerland).

Patented treatments have recently been used in the development of new HyFlex EDM files (Coltene/Whaledent). The fact that these files are made using an electro discharge machining (EDM) process is their most distinguishing feature [11].

2Shape (TS) instruments produced by Micro_Mega, (Besancon, France) using unique heat treatment (T-Wire technology) which improves the instrument flexibility and cycle fatigue resistance [12].

Root canal irrigants that act as lubricants and antibacterial agents are required for appropriate root canal cleaning [13]. The antibacterial efficiency of NaOCl promotes the breakdown of vital and necrotic tissues [14]. NaOCl solutions, on the other hand, are corrosive to metals and may have an adverse effect on the mechanical qualities of NiTi instruments when they come together with them during endodontic treatments [1]. Physicians should be aware that the resistance of NiTi files to cyclic fatigue may be diminished as a result of interaction with

NaOCl, increasing the likelihood of instrument damage during the root canal therapy [15].

While several studies have investigated the corrosive impact of NaOCl on traditional NiTi endodontic instruments, few research have been conducted on the impact of NaOCl on NiTi files that have been treated. So, the purpose of this experiment is to estimate the fatigue resistance of three NiTi files made from different metallurgy after immersion in NaOCl for (1 and 5 minutes).

Materials and Methods

This study used three NiTi rotary files, Hyflex EDM, TS and PTN as main groups, with an equal statistical distribution (n =24). All of the files tested had a tip size of ISO 25 and a 25mm length and were inspected for faults or deformities using an operational microscope under x20 magnification prior to the experiment. Each main group then subdivided into three subgroups of eight according to the time of immersion in NaOCl or no immersion as a control group.

All files in the first and second subgroups were immersed for 1 and 5 minutes, res pectively in NaOCl 2.5 percent at 37°C to a depth of 16mm. The control group con sisted of new files that had not been immersed in solution.

Group 1: Twenty-Four PTN NiTi rotary instrument (X2, 0.06 taper, 0.25 tip size).**1A:** Eight PTN undergo immersion in 2.5 NaOCl for 1 min. **1B:** Eight PTN undergo immersion in 2.5 NaOCl for 5 min. **1C:** Eight PTN control files with no immersion.

Group 2: Twenty-Four Hyflex EDM NiTi rotary instrument (Varible taper, 0.25 tip size).**2A:** Eight Hyflex EDM files undergo immersion in 2.5 NaOCl for 1 min.**2B:** Eight Hyflex EDM files undergo immersion in 2.5 NaOCl for 5 min.**2C:** Eight Hyflex EDM control files with no immersion.

Group 3: Twenty-Four 2Shape NiTi rotary instrument (TS2, 0.06 taper, 0.25 tip size). **3A:** Eight 2Shape files undergo immersion in 2.5 NaOCl for 1 min.**3B:** Eight 2Shape files undergo immersion in 2.5 NaOCl for 5 min.**3C:** Eight 2Shape control files with no immersion.

A digital water bath machine was used to regulate the temperature. In this study, a testing tool (Figure -1) was made of a stainless-steel block attached to the base of the digital water bath. The steel block was machined according to Larsen et al [16]. and Haikel et al [2] guidelines, and it had a simulated root canal with a single curvature of 60° and a radius of 5mm that was engraved into the block to a depth of 1. 5mm. A removable glass plate was placed on the steel block to aid in seeing the file in motion, securing the file in the canal, and allowing for easy retrieval of the broken file fragments.

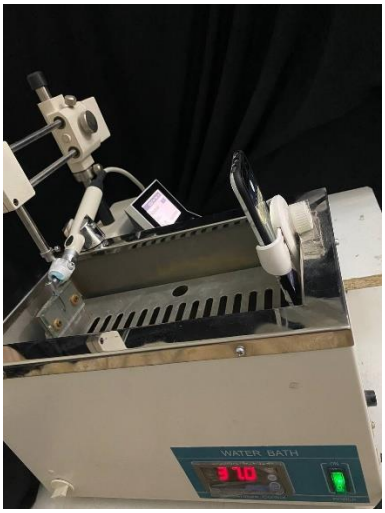

Figure 1: Cyclic fatigue testing device

The test was carried out in a continuous clockwise rotation at the recommended speed for each system by the manufacturer, PTN (speed 300 rpm, torque 2.0 Ncm), Hyflex EDM (speed 500 rpm, torque 2.5 Ncm) and TS (speed 300 rpm, torque 2.0 Ncm). The process recorded by video from the starting of rotation until the separation of instrument. Following that, for each file, Multiplying the time to fracture (minutes) by the number of rotations or cycles per minute revealed the total number of cycles to fracture (NCF). The NCF of the files passed the Shapiro–Wilk test, indicating that the data was normally distributed. The significance of difference among groups was compared using a one-way ANOVA, Post hoc test. For all tests, the level of confidence was set at p 0.05. The SPSS version 25 data processing program was used to examine all of the data.

Statistical analysis

The Shapiro-Wilk test was used to verify the normality of the data distribution; then, the data were analysed using one-way ANOVA, the post hoc Tukey's test using IBM SPSS (SPSS, Chicago, IL, USA) Statistics at a significance level of 0.05.

Results

Regardless of immersion procedure, the files of the Hyflex EDM group had higher NCF than the files of the PTN and TS groups, while the TS group had the lowest N CF of all immersion groups (Fig -2).

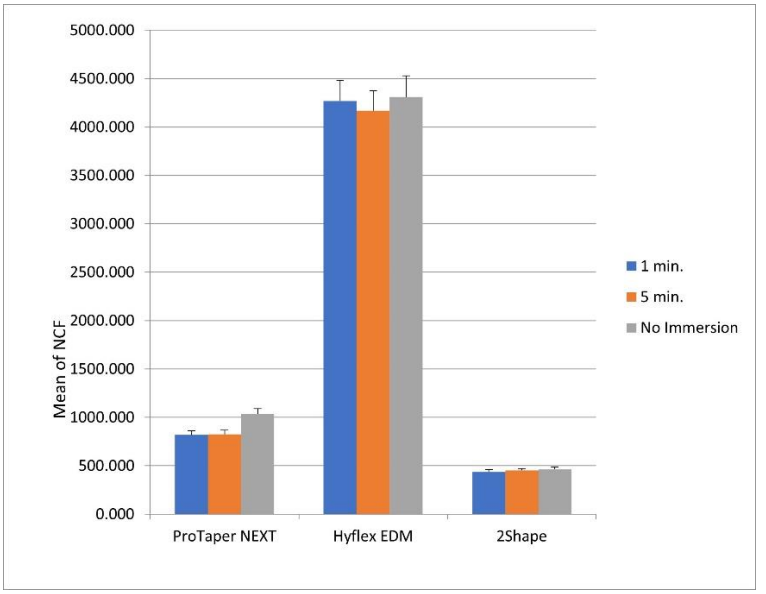

Figure 2: Bar chart for NCF for all groups

ANOVA test revealed no statistically significant differences in NCF between the sin gle groupof Hyflex EDM and TS groups after immersion in NaOCl, while the difference was statistically significant in the PTN group ($p<0.05$). (Table - 1). Post hoc tests revealed that the NCF of the PTN immersed for 1& 5min in NaOCl group was considerably lower than that of the PTN-control group (Table-2). In varying immersion times, there was no significant difference in fracture length between groups.

Table -1 Descriptive statistics of NCF among immersion by groups

Groups		Mean	±SD	Minimum	Maximum	P value
Protaper NEXT	1min	818.2500	89.86776	726.00	951.00	
	5min	823.7500	64.79363	740.00	910.00	
	No Immersion	1036.2500	99.56154	935.00	1200.00	**0.000**
Hyflex EDM	1min	4269.3750	103.28316	4150.00	4500.00	
	5min	4168.7500	158.31140	3795.00	4265.00	
	No Immersion	4311.8750	155.49317	4140.00	4600.00	0.140 ^
2Shape	1min	436.8750	47.72971	355.00	500.00	
	5min	450.0000	53.25143	390.00	550.00	
	No Immersion	463.7500	66.42665	385.00	560.00	0.641 ^

not significant $p>0.05$.

Table-2 Multiple Comparisons of NCF among immersion by groups using Tukey post hoc.

Groups	(I) Immersion	(J) Immersion	Mean Difference (I-J)	P value
Protaper NEXT	1min	5min	-5.50000	0.991 ^
		No Immersion	-218.00000	**0.000 ***
	5min	No Immersion	-212.50000	**0.000 ***

not significant p>0.05.

Discussion

One of the most prevalent complications during root canal preparation is the fracture of the revolving NiTi tool [17]. The producers aimed to enhance the resistance of NiTi rotary files to cyclic fatigue by changing their design, kinematics and metallurgy, as well as the heat treatments they use [18].

The current study compared the fatigue resistance of three NiTi files, PTN, Hyflex EDM and TS after 1 and 5minutes immersion in 2.5 NaOCl at body temperature, The importance of performing the immersion and the testing at body temperature was to replicate the clinical situation and so acquire reliable statistics [19].

The cyclic resistance of the Hyflex EDM was statistically higher than that of the ot her NiTi files examined in this study, regardless of the immersion period. One possible explanation for the study findings is that the metallurgical traits and qualities of the NiTi files differed between the instruments evaluated. The electro-discharge machining method utilized to create the EDM files promotes the formation of martensite and quantities of R-phase, which gives the instrument more softness, ductility, flexibility, and fatigue resistance [20].

The PTN file, on the other hand, contains the M- Wire, which could explain why the NCF of hyflex EDM and PTN files are higher than in the TS file, which is constructed with a proprietary T -Wire alloy developed and implemented solely by Micro Mega. The patented M-wire alloy has an austenitic structure, this has been connected to increased hardness and decreased ductility [21], which could explain why PTN files perform inferior to the EDM files.

According to this investigation, Hyflex EDM and TS files were more resistant to NaOCl than PTN files under the same testing conditions. According to this research, heat treatment does not always make a file more susceptible to NaOCl corrosion. A disparity in the instrument's sensitivity to corrosion by NaOCl could be due to a variety of manufacturing conditions, such as file surface treatment after carving (e.g. Hyflex EDM electrical discharge machining). Moreover CM-wire exhibit a lower weight percent of Nickel (52% wt.%) when compared to others. The less content of Ni may reduce the corrosion effect of NaOCl, since Ni dissolve more easily than Titanium [26]

The resistance to cyclic fatigue of the EDM and TS was not significantly reduced by 1 minute or 5 minutes static immersion in NaOCl in this experiment. but immersion in NaOCl in the same protocol significantly reduced the fatigue resistance of PTN files agreed with the Previous studies reported that NaOCl had a negative impact on the cyclic fatigue resistance of ProTaper NiTi files [22,19].

In a study published in 2019, Ertuğrul [23] compared the resistances to cyclic fatigue of three different NiTi files (PTN, One Shape, One Curve) in 2.5 percent NaOCl solution and distilled water at intracanal temperature. He agreed that PTN files in distilled water had much greater NCF than 2.5 percent NaOCl,

Cai et al., 2017 [24] found that a 5.25 percent NaOCl solution had no influence on the cyclic fatigue resistances of EDM and M3 (United Dental, Shanghai, China) files, while a 17 percent EDTA solution had a negative effect, which is in agreement with our findings. But did not agree with Palma et al., 2019 [25] who found that immersing PTN, Hyflex CM, and Hyflex EDM in a 3 percent NaOCl solution for 1 or 5 minutes reduced their resistance to cycle fatigue, with the CM wire-made versions showing greater relevance. This may be attributed to different concentration of NaOCl (3%) or due different testing conditions (dynamic immersion, 45° angle curvature).

These results could be due to the sort of analysis used. The maximum stress generated by the cyclic fatigue device is in the middle of the simulated curve, therefore if a zone corrosive attack exists at that level, the instrument may fracture prematurely. If the corrosive attack occurs in another place than the maximum stress generated by the testing equipment, the instrument's cyclic fatigue resistance is unlikely to be lowered [1].

Conclusion

Within the constraints of this investigation, it can be concluded that under the test conditions, The NCF for the Hyflex EDM files was statically higher than the NCF for PTN and 2Shape files in all immersion groups. The NCF for the 2Shape files was the lowest among all immersion groups. The 2.5 percent NaOCl solution had no noticeable effect on the cyclic fatigue resistant of the Hyflex EDM or 2Shape files. The resistance of the PTN files to cyclic fatigue was significantly decrease after immersion in 2.5% NaOCl for 1 and 5 minutes. Length of fractured fragment was not affected by different instrument used.

Caution is needed in extrapolating the results of this in vitro study to clinical conditions because it is difficult to compare the effect of a single factor on the cyclic fatigue resistance of the tested files, as they were produced using different heat-treatment procedures and had various geometric characteristics and designs.

Highlights

- Cyclic fatigue is one of the major causes of endodontic failure.
- Hyflex EDM is statically more resistant to cyclic fatigue than PTN and TS.

- PTN was affected by immersion in NaOCl solution.

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