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Comparative Evaluation of The Effect of Temperature and Sodium Hypochloride on Cyclic Fatigue Resistance of Two Ni-Ti Rotary Endodontic Files: An In-Vitro Study

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ABSTRACT

Background: To evaluate the effect of temperature of distilled water and sodium hypochlorite (NaOCl) on the cyclic fatigue resistance of two heat treated Ni-Ti rotary endodontic files in simulated clinical use.

Materials and Method: A total of 80 new 2Shape and Neoendo flex were tested. Forty files of the same brand were randomly assigned to four groups (n = 10) and submitted to the following immersion protocol – distilled water at 20°C, distilled water at 37°C, sodium hypochlorite (NaOCl) at 20°C and sodium hypochlorite at 37°C. Resistance to cyclic fatigue was calculated by counting the numbers of cycles to fracture in a simulated double curvature canal. Data were analysed by two-way analyses of variance.

Results: Resistance to cyclic fatigue of the Ni-Ti file was not significantly affected by immersion in NaOCl ($P > .05$). The comparison between 2Shape and Neoendo flex files, when immersed in the same solution, did not show significant differences ($P > .05$). However, increasing the temperature up to 37°C reduced the fatigue resistance.

Conclusions: Under the conditions of this study, immersion in sodium hypochlorite at simulated body temperature was associated with a marked decrease in the cyclic fatigue resistance of all the rotary instruments tested in simulated clinical use.

Keywords: Cyclic fatigue, endodontic files, temperature.

INTRODUCTION

Over the last two decades, Nickel Titanium (Ni-Ti) rotary files have been used in endodontics due to their shape memory, superior flexibility, canal centring ability and hence, reduced procedural errors compared to those of conventional stainless-steel instruments.[1] These properties of Ni-Ti rotary files are associated with a reversible phase transformation called a martensitic transformation or R phase, M wire technology, CM wire technology, heat treatment or electrical discharge machining (EDS) technology with or without structural design changes in the file.[2,3,4] Although endodontic instruments have been modified, unexpected intracanal separation of these rotary endodontic files continues to be a challenge for clinicians as retrieval of separated endodontic files requires

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additional chair side time, skill set and advanced armamentarium. [5] Moreover, it may have adverse prognostic effects on the treatment outcome and longevity of the tooth. Cheung et al reported that intracanal separation of the endodontic instruments may be caused predominantly by cyclic fatigue. [6] Cheung GS[7] strongly recommended examination of the fractured file under higher magnification to understand whether it is flexural fatigue or torsional stress as the mode of failure. Extensive studies have been carried out to identify preventive strategies and to understand various factors that impact the fracture resistance due to flexural fatigue of Ni-Ti rotary files, such as canal anatomy related factors- angle, taper and radius of curvature of the canal;[8] instrument related factors- metallurgy and instrument design, core bulk, size, cross-sectional configuration and diameter, flute pitch length, cutting efficiency, clearance angle, surface finish, manufacturing defects, embedded debris, surface treatments;[8,9] mechanics related factors such as sequence, number of uses, technique of instrumentation, number of cycles of autoclaving, cleaning and sterilisation protocols, torque and speed utilized during instrumentation. [8,9]

Corrosion, one of the factors which significantly influences the fracture resistance, may occur in the presence of NaOCl solution. Ni-Ti instruments may have contact with NaOCl during canal disinfection and cleaning of used files. [9] The corrosion patterns create microstructural crack formation and weakening the structure of the instrument and making it prone to fracture. [10-15] Heated sodium hypochlorite may have an influence on the cyclic fatigue resistance of the rotary endodontic files, as concluded by Peters OA. [9]

Several experimental designs have been created to test cyclic fatigue resistance of Ni-Ti instruments. Standardization of taper, cross sectional shape and size, radius and angle of curvature in extracted teeth is a challenge even though it simulates clinical conditions better.[16] Hence, artificial canal systems were created to test the cyclic fatigue resistance such as 3 rigid stainless-steel pins,[17,18] tempered steel rod and stainless-steel block assemblies,[19] and slots in steel form blocks.[20] However, these tests were all conducted at room temperature, taking care not to generate measurable heat, which is believed to potentially change Ni-Ti properties.[21] Studies included immersion in sodium hypochlorite but testing was done in ambient temperature without immersion in any chemical.[15,19] These studies have not considered the intracanal temperature during the actual canal preparation. Newer alloys are believed to have transformation temperatures much higher than those of conventional austenitic materials used in previous generations of rotary instruments and may in fact transform close to body temperature. [22,23] Therefore, the aim of this study was to test fatigue limits of the contemporary thermally treated, NiTi rotary instruments during immersion in water and sodium hypochlorite at room and body temperature.

MATERIALS AND METHOD

The study design was approved by the Institutional Ethics Committee.

A total of 80 heat treated rotary files with apical diameter of 0.25mm, taper 0.06% and length 25-mm were selected and divided into two groups according to the file system.

Group I: 2Shape (Micro-mega, Besançon, France)

Group II: Neoendo flex files (Orikam Healthcare, India)

40 specimens from each file system were randomly divided in 4 subgroups (n = 10):

Group I Water at room temperature (20°C)

Group II Water at body temperature (37°C)

Group III Sodium hypochlorite at room temperature (20°C)

Group IV Sodium hypochlorite at body temperature (37°C)

Before the experiment, instruments were inspected for defects and deformities at 10x and 30x under stereomicroscope (Labomed). None were excluded.

Cyclic fatigue testing was performed using artificial canal milled in stainless steel block using a Computer Numeric Control Machining Bench, to ensure the accuracy of the size of canal. The artificial S-shaped canal (length = 18 mm) had 2 curves: the first was a coronal curve with a 60^0 angle of curvature and a radius of 5 mm located 8 mm from the tip of the instrument, and the second was an apical curve with a 70^0 angle of curvature and a radius of 2 mm with a centre 2 mm from the tip. The stainless-steel block containing double curvature canal was then fixed with a tempered glass of epoxy resin with adhesive for visualization and a provision was also provided for removal of fractured fragment.

The block was fixed inside a water bath filled with distilled water or 5.25% NaOCl. The artificial canal was open to the solution, allowing file to be exposed to the experimental temperature. The temperature was preset at 20 °C or 37 °C. A digital thermometer was used to measure the temperature of water or NaOCl.

The cyclic fatigue testing assembly consisted of a steel platform with a rod fixed vertically that acted as a mount for the handpiece as shown in figure 1. Silicon stopper of the file placed inside the handpiece was adjusted to get standardize 18mm working length. The X smart reduction handpiece (DENTSPLY™) was activated at constant speed of 300 rpm and torque recommended by the manufacturer for the file. Simultaneously, digital chronometer was started and the test procedure was timed. The file was allowed to rotate freely inside the artificial canal. The digital chronometer was stopped as soon as a fracture was visually detected and the time to fracture (TtF) in seconds from the start of the test until the moment of breakage was recorded and registered to the nearest whole number with a chronometer to an accuracy of 0.1. Using the time data, the number of cycles to fracture (NCF) for the file was calculated using the formula: Number of cycles to fracture (NCF) = revolutions per minute (rpm)/60 * time of fracture (sec).

RESULTS

One-way analysis of variance with a t-test was used to compare the cyclic fatigue of the instruments. The mean and standard deviations of the NCFs values for 2Shape and Neoendo Flex file system subjected to different conditions (Irrigating solution and temperature) are presented in table 1. There was no statistically significant difference between the two groups of file systems considering the immersion condition as the independent variable. However, there was a significant difference between the subgroups considering the temperature. 2Shape and Neoendo Flex file system in distilled water at 20^0C had significantly higher NCF value (509.600 and 484.750 respectively) whereas, NaOCl subgroup at 37^0C showed the lowest value. Within each testing medium, the results showed that the higher the temperature, lower the NCF value as shown in Table 1.

Table 1: Number of Cycles to Fracture (NCF) of 2Shape and Neoendo flex files.

	Groups	N	Mean	Std. Deviation	Std. Error Mean	t value	p value of t test
Water at 20°C	2Shape	10	509.600	60.9612	19.2776	0.963	0.494#
	Neoendo flex	10	484.750	54.2280	17.1484		
Water at 37°C	2Shape	10	273.600	86.4551	27.3395	2.112	0.061#
	Neoendo flex	10	208.950	42.5170	13.4450		
NaOCl at 20°C	2Shape	10	482.400	82.7355	26.1632	0.953	0.426#
	Neoendo flex	10	438.200	121.0616	38.2830		
NaOCl at 37°C	2Shape	10	262.000	67.7052	21.4103	2.043	0.085#
	Neoendo flex	10	209.650	44.5309	14.0819		

Fig 1: Assembly to study cyclic fatigue resistance.

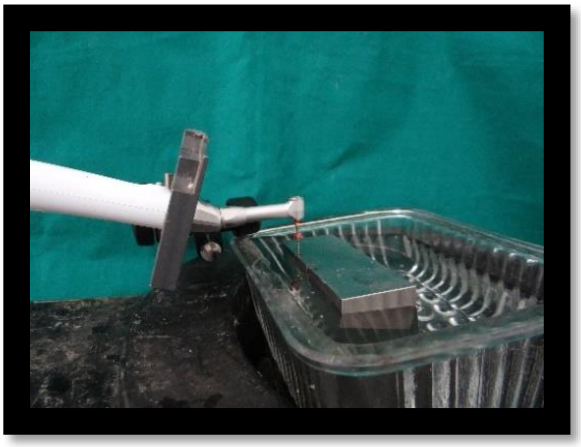


Fig 2: SEM evaluation of the fractured 2Shape.

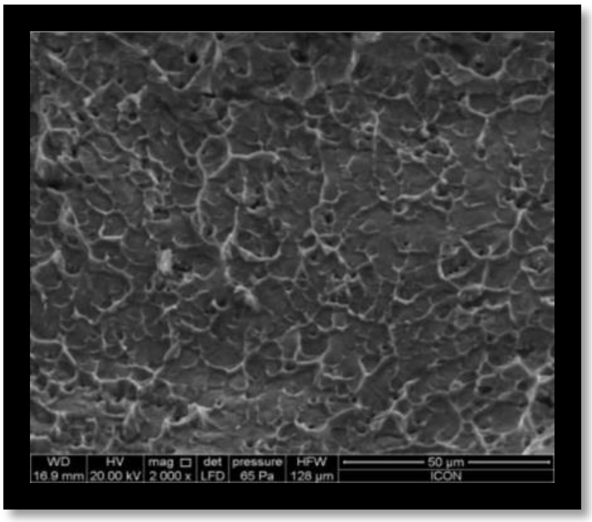
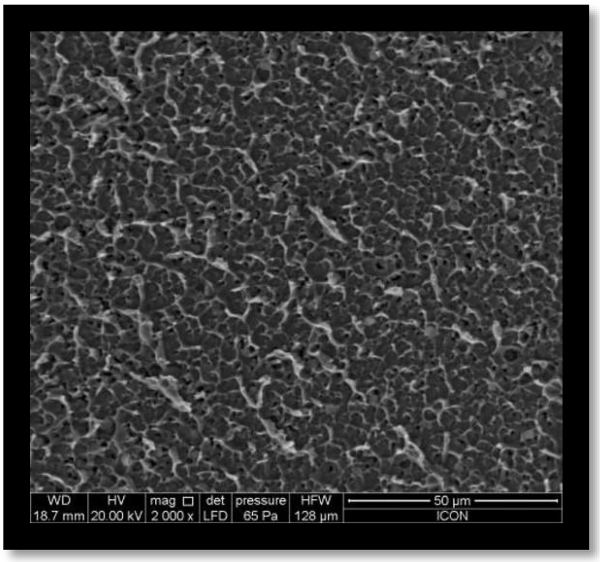


Fig 3: SEM evaluation of the fractured Neoendo Flex.



DISCUSSION

In the present study, 80 new, unused, rotary Ni-Ti files were evaluated under stereomicroscope at 10x and 30x magnification for defects and deformities such as cracks, pits, fins and none were found defective. These defects when present act as stress concentration areas in the file, making the alloy more susceptible to fatigue. For the study, same size files (0.25 apical size and 0.06 taper) of both the file systems were used as the flexural fatigue is affected by metal mass of the instrument at the point of maximum curvature. [6,24] The evaluation of the fractured fragments of both 2Shape and Neoendo Flex files under scanning Electron Microscope revealed the characteristic dimpled appearance of the cyclic fatigue fracture as shown in figure 2 and 3.

The intracanal temperature ranges from 31°C to 35°C.[16] In recent research, it has been shown that intracanal temperature significantly affects CFR when compared to testing in air and at room temperature. [25-29] Therefore, investigating the effect of intracanal temperature along with NaOCl might be more clinically relevant. Dosanjh et. al. (2017) [28] studied CFR of files at four different temperature (3°C, 22°C, 27°C and 60°C) as heated irrigant solution improves the disinfection and tissue dissolution.[30] However, it has been proven that irrigant temperature quickly equilibrate to body temperature after placement in the root canal within 30 to 60 seconds.[31] Irrespective of cooled irrigant used to reduce the periradicular inflammation or heated irrigating used to increase the efficacy of the irrigant, the irrigant reaches body temperature upon entering the canal in 240 seconds.[32, 33] Therefore, the present study used only room temperature and body temperature for investigating the cyclic fatigue resistance.

In the present study, all the tested instruments showed a marked decrease in the fatigue resistance at intracanal temperature. This is in agreement with previous studies in which increase in the temperature was found to decrease NCF values. [27, 34] In a study, rotary Ni-Ti were tested at 20°C and 37°C and found that a decrease in NCF at 37°C compared with 20°C for all the tested instrument. In another study by Hussam Alfawaz et. al. (2019)[35] the cyclic fatigue resistance of heat-treated instruments immersed in sodium hypochlorite solution under different concentrations (2.5% or 5.25%) and temperature conditions (25°C, 37°C, or 60°C) were tested and found that NaOCl irrigating solution at different concentrations and temperatures influenced the cyclic fatigue resistance of PTG instruments.

The extent that temperature affects NCF is related to the metallurgical properties of the endodontic files. In the present study, there was a significant difference between the subgroups of 2Shape and Neoendo flex file systems considering the temperature. The file Ni-Ti 2Shape endodontic file is subjected to heat treatment which causes an increase in the transformation temperature process, thereby bringing it closer to the oral temperature.[36] But as an evidence by a previous differential scanning calorimetry (DSC) test, austenite finish temperature (A_f) of 2Shape is 17°C[36]. The A_f is the possible reason for the difference in NCF value between room temperature and intracanal temperature. This suggest that 2Shape is in an austenite state at body temperature displaying a higher modulus of elasticity. Lower A_f corresponds with greater stiffness and an increased chance of fatigue failure.[37] The result of present study is in accordance with the study performed by Dara H Saeed et al. (2019),[38] in which they evaluated cyclic fatigue resistance at body temperature and 2Shape showed statistically significant reduction in fatigue life. However, a study by Uslu et al (2018)[39] compared the cyclic fatigue resistance of 2Shape, Twisted file and Endosequence Xpress (ESX) NiTi rotary files at intracanal temperature (35^{0}C). NCF values revealed that 2Shape had significantly the highest cyclic fatigue resistance followed by Twisted file and ESX. The authors believed that T wire treatment might enable the file to have a higher austenite finish temperature and softer structure at test temperature which might be the reason for higher fracture resistance of 2Shape file in the study.

As already stated, heating NaOCl increases its tissue dissolving capacity and antimicrobial activity.[30] The corrosive effects have been previously reported by Berutti[40] et al. (2006) and Peters et. al. (2007)[10], where the files exposed to NaOCl had a significantly shorter fatigue life than distilled water. This result is contradictory to present study where no significant difference in NCF between NaOCl and water has been found. Though, the result of present study is in accordance to a study by Huang et. al. (2007).[41] Tests in the previous studies were performed after the instruments were immersed in NaOCl for different time duration. However, in the present study, NaOCl was used during test and therefore simulates clinical condition. The difference in the results might be attributed to the different tested file systems and the different exposure methods to solutions, such that the exposure time of the instrument to the solution was relatively short in the present study and might not be enough for the corrosive effect of NaOCl. Plotino et al [42] (2017) studied the influence of temperature on Protaper gold and Protaper Universal. PTG gold heat treated files were not affected in their resistance to cyclic fatigue due to intracanal temperature changes. Plotino et al [6] (2009) suggested that the fit of the artificial double or single curvature of the block in cyclic fatigue testing or the relative cross sessional size and taper of the artificial canal with respect to the files and the stiffness of the files used for testing influences the path or the trajectory taken by the instrument inside the canal to rotate. As mentioned above, besides the cyclic fatigue testing devices, multiple factors influence the study outcome. These factors cause the variation in the time and number of rotations taken by the instrument to fracture in different study settings.

CONCLUSION

Within the limitation of this study, intracanal temperature had drastic effects on the cyclic fatigue life of the instruments. Also, this is an in vitro study performed on a simulated stainless-steel model. Hence, the study settings do not simulate or represent the oral conditions.

The angulation and inclination of the teeth present in the oral cavity might produce varying results in CFR. Hence, further evaluation of the clinical performance of the tested brands in vivo, and using different irrigating solutions are needed to give reliable recommendations for endodontists. Similarly, there is a need for international standard and clinically relevant test methodology to evaluate the resistance to cyclic fatigue fracture. Future studies can also consider using scanning electron microscope to analyse features of file fracture.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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