Frontiers in Dentistry

Effect of Cryotherapy on Fracture Resistance of Neoniti Rotary Instruments

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Article Info

Article type:
Original Article

Article History:
Received: 28 May 2022
Accepted: 20 Jan 2022
Published: 05 Aug 2023

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ABSTRACT

Objectives: Nickel-titanium (NiTi) rotary files were introduced to optimize root canal instrumentation in endodontic treatment. However, despite the numerous advantages of NiTi instruments, they may unexpectedly break during clinical use, resulting in obstruction of the root canal system. This investigation aimed to assess the effect of cryotherapy on fracture resistance of Neoniti rotary files.

Materials and Methods: This in vitro, study was conducted on 20 Neoniti rotary files with #35 tip size and 6% taper in two groups with and without cryogenic treatment (N=10). For cryogenic treatment, the files were immersed in liquid nitrogen at -196°C for 24 hours. Next, the Neoniti files in both groups were subjected to cyclic fatigue testing in a hand-piece operating at 500 rpm with 20 N/cm torque. The files were rotated until fracture and the fracture time as well as the number of cycles to fracture were recorded for each file. The two groups were compared by independent t-test at 0.05 level of significance.

Results: The number of cycles to fracture was 235700±50649.22 in the control and 280600±22979.21 in the cryotherapy group. The mean fracture time was 471.40±101.29 and 561.20±45.958 seconds in the control and cryotherapy groups, respectively. Significant differences in both variables were noted between the two groups ($P<0.05$).

Conclusion: Based on our findings, utilizing cryogenic treatment may enhance the fracture resistance of rotary instruments, making it a beneficial practice for dental clinicians to adopt. By using cryogenically treated rotary instruments, clinicians can potentially reduce the risk of file fracture during dental procedures.

Keywords: Cryotherapy; Materials Testing; Root Canal Preparation

➢ **Cite this article as:** Zadfatah F, Galledar S, Pourasgar Sh, Fathiazar A. Effect of cryotherapy on fracture resistance of Neoniti rotary instruments. *Front Dent*. 2023:20:28.

INTRODUCTION

Root canal preparation is among the most important steps in endodontic treatment. It is performed aiming to debride the root canal and create an optimal space for efficient root canal obturation [1]. Root canal instrumenta-tion can be performed manually or by using rotary instruments. Manual instrumentation is often time-consuming, and may cause procedural errors such as ledge formation or root canal transportation in narrow and curved canals. Use of nickel-titanium (NiTi) files with high flexibility can effectively decrease procedural errors in narrow and curved canals [2].

Unlike stainless-steel files, the super-elastic property of NiTi alloy allows the NiTi files to return to their original shape after deforma-tion. Deformations up to 10% are completely reversible in NiTi files; whereas files made of conventional alloys show a maximum reversible deformation rate of 1%. Moreover, the wear and deformation of NiTi files are lower than those of stainless steel files, and they also appear to have excellent anti-corrosive properties. Therefore, NiTi endodontic files are more flexible, are better adapted to the root canal curvature, and show higher fracture resistance [3]. The super-elastic property of NiTi rotary files allows conical shaping of the root canal system, and prevents the occurrence of procedural errors [1,4,5]. However, flexure and torsion of the file in the process of root canal shaping can lead to fracture of NiTi rotary files [6].

The recently-introduced Neoniti rotary system is manufactured by electric discharge machining (EDM) technology, which has been suggested to overcome fatigue fracture of the files. The manufacturer claims that this technology along with optimal cryogenic procedures are responsible for improved properties of Neoniti files [7]. Neoniti is a NiTi rotary file system. According to the manufacturer, the smart non-homogenous square- and rectangular-shaped cross-sectional design of the blades is responsible for high cutting efficiency and safety of the files, and decreased frequency of file fracture in curved canals. The EDM manufacturing technology has conferred high fracture resistance to Neoniti files [8].

Several surface treatments have been proposed and employed to enhance the cutting efficiency and wear resistance of NiTi instruments, including ion implantation, thermal nitridation, cryogenic treatment, and electro-polishing [9,10]. Among different techniques, cryogenic treatment which is defined as exposure of instruments to very low temperatures can affect the entire thickness of metal, and not only the superficial areas [9].

Rotary files have several physical and mechanical differences with each other, and show different behaviors in curved canals [11]. The available literature regarding the effect of cryotherapy on fracture resistance of rotary files is controversial. For instance, George et al [12] showed that cryotherapy significantly improved the cyclic fatigue resistance of NiTi rotary endodontic files; which was in contrast to the findings of Yazdizadeh et al [13] and Vinothkumar et al [14] demonstrated that cryogenic treatment had no significant effect on cyclic fatigue of rotary files. Considering the existing controversy in this regard, further investigations on this topic seem imperative.

Rotary file manufacturers constantly attempt to improve the mechanical properties of endodontic instruments to minimize the occurrence of procedural errors and especially instrument fracture. Nonetheless, fracture of rotary files in the root canal system, especially in curved canals, still remains a problem [15]. Thus, this study aimed to assess the effect of cryotherapy on fracture resistance of Neoniti rotary files by comparing the frequency of cycles to fracture and fracture time between the control files and those subjected to cryogenic treatment.

MATERIALS AND METHODS

A total of 20 Neoniti A1 rotary files (Neolix, Châtres-la-Forêt, France) with #25 tip size and 6% taper were included in this in-vitro study. All files had the same manufacturing date. According to an investigation by Sabet et al [16] the mean time and standard deviation of the mean time to fracture of rotary files was assumed to be 167.4±42 and 189.1±28, respectively. Using G-Power V3 software, the number of samples in each group was calculated as 10 (alpha=0.05, 95% power).

The files were coded and randomly divided into control- and cryogenic- groups. The controls received no pretreatment, while the files in the cryogenic group were immersed in liquid nitrogen at -196°C for 24 hours, after which they were removed and allowed to gradually warm-up to room temperature. All files in both groups were placed in a handpiece equipped with a torque-control rotary motor (VDW Silver, Munich, Germany) operating at 500rpm with 1.5N/cm torque. The instruments were rotated until fracture occurred and the time to fracture was recorded with a chronometer. Additionally, the number of cycles to fracture was calculated using the following formula [16]:

Number of cycles to failure = frequency of rotations per minute (rpm) × fracture time

Data were analyzed and the mean, median, and standard deviation values were reported descriptively. Independent t-test was applied to compare the frequency of cycles to fracture and fracture time between the control and cryogenic treatment groups. $P<0.05$ was considered statistically significant.
The protocol for this study was approved by the ethics committee of our university (IR.ARUMS.REC.1399.506).

RESULTS

Descriptive data of fracture time and number of cycles to fracture are shown in Table 1.
The Kolmogorov-Smirnov test showed normal distribution of data. Independent t-test revealed a significant difference in the number of cycles to fracture between the two groups, such that the number of cycles to fracture was significantly higher in the cryotherapy group (P=0.025). Also, independent t-test showed that the mean fracture time was significantly longer in the cryotherapy group (P=0.020).

DISCUSSION

Different rotary files are significantly different in terms of physical and mechanical properties. Thus, they have distinct behaviors in curved canals. The manufacturers of rotary files have attempted to improve the mechanical properties of these instruments to prevent procedural errors and fractures. Nonetheless, fracture of rotary files still remains a problem in severely curved canals [11]. Different methods have been proposed to improve the cutting efficiency and wear resistance of nickel-titanium instruments such as ion implantation, cryotherapy, and electro-polishing [9].
Cryogenic treatment can affect the entire thickness of metal, and not only the superficial areas, which is an advantage. Deep cryogenic treatment is a one-step permanent procedure to improve physical and mechanical properties of different alloys. In this process, sub-zero temperatures are used to stabilize dimensions, modify and merge particles, and confer higher wear resistance to areas at risk of wear and scratching. It improves the efficiency and prolongs the survival time of metals, and decreases loss of time [17]. One reason for enhanced fracture resistance of rotary files that have undergone cryogenic treatment is complete transformation of the austenitic phase to the martensitic phase, which can release the internal stress of the alloy, and increase its wear resistance. The lower the cryotherapy temperature, the better the plastic formation. When phase transformation is completed, fracture resistance of the file increases [12].
According to the results obtained in the present study, cryogenic treatment significantly increased fracture time as well as the frequency of cycles to fracture in Neoniti A1 rotary files. Our findings are in line with those of previous studies on fracture time and frequency of cycles to fracture Ujjwal et al [18] in their systematic review concluded that cryotherapy increases the fracture resistance of NiTi rotary files. The same results were reported by George et al [12]. They evaluated 20 K3, RaCe, and Hero-Shaper rotary files with #25 tip size and 6% taper and demonstrated that cryotherapy significantly increased the fracture resistance of the files compared with controls [12].
Gavini et al [10] conducted an experiment on

Table 1. Mean and standard deviation (SD) of fracture time and number of cycles to fracture of Neoniti files in the two study groups (N=10)

	Group	Mean	SD	Minimum	Maximum
Fracture time (seconds)	With cryotherapy	561.2	45.95	469	634
	Without cryotherapy	471.4	101.29	350	605
Number of cycles to fracture	With cryotherapy	280600	22979.18	234500	317000
	Without cryotherapy	235700	50649.22	175000	302500

K3 size #25, taper 0.04 files. These files had undergone nitrogen ion implantation and the results showed more fracture resistance than the control group. The results reported by these studies corroborate our findings.

In contrast to our observations, Sabet et al [16] found no significant difference between untreated and cryogenically-treated files when evaluating 20 HyFlex files with #25 tip size and 6% taper. Also, Yazdizadeh et al [13] did not observe a significant difference in fracture resistance between cryogenically-treated and untreated RaCe and Mtwo files used in a simulated root canal with 45-degree curvature. The results reported by Vinothkumar et al [14] were also different from that obtained in the present study. Variations in findings may be due to several factors such as different rotary file types, physical properties, manufacturing technology, and rotation speed.

Our study suggests that cryogenic treatment has a marked impact on the frequency of cycles to fracture and fracture time of files, resulting in significant improvements compared to untreated instruments. These findings indicate that cryogenic treatment holds great potential in enhancing the physical and mechanical properties of Neoniti rotary files.

CONCLUSION

Within the limitations of this in vitro study, our findings demonstrate the efficacy of cryogenic treatment in reducing failures associated with the use of Neoniti rotary files for root canal therapy.

CONFLICT OF INTEREST STATEMENT

None declared.

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