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Cyclic Fatigue Resistance of Four Ni Ti Instrument After Immersion in Sodium Hypochlorite in Static Mode

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Abstract: *The purpose of this study was to assess the resistance to cyclic fatigue of four nickel-titanium(NiTi) files after the immersion in sodium hypochlorite(NaOCl) solution in static condition.*
Methods*: A total of 60 new Twisted Files, Hyflex files, Heroshaper files, Protaper files were tested. Fifteen files of the same brand were randomly assigned to four groups (n = 15) and submitted to the static immersion protocol in 5.25 % NaOCl at 37°C. Resistance to cyclic fatigue was determined by counting the numbers of cycles to failure in a 60 °curve with a 5-mm radius. Data were analysed by two-way analyses of variance.*
Results: *Resistance to cyclic fatigue of the same NiTifile was not significantly affected by immersion in NaOCl (P > .05).*
Conclusion*: Static immersion in NaOCl for 5 minutes did not reduce the cyclic fatigue resistance of NiTi significantly. However, the type of instrument influences cyclic fatigue resistance. In our study, Twisted Files were more resistant followed by Hyflex,Heroshaper and Protaper*.

I. Introduction

Over the years, the revolutionary development of incorporating nickel-titanium (NiTi) into endodontic files has greatly transformed the methods of root canal instrumentation. They help minimize the undesirable complications often encountered during instrumentation in fine and curved canal. Files made from this alloy are biologically acceptable, highly flexible, and considerably stronger in fatigue resistance than stainless steel (SS) files.

Despite its increased strength and flexibility, separation is still a concern with NiTi instruments, and they have been reported to undergo unexpected fractures. Although some mechanical tests have been performed on NiTi and stainless steel endodontic instruments, appropriate fatigue tests have not been developed for proper endodontic instrument testing . The American Dental Association (ADA) Specification No. 28 is conducted in a static mode. All NiTi engine-driven rotary systems require the instruments to be activated at a predetermined rpm before insertion into the canal. ADA Specification No. 28 does not consider canal geometry as well as the fatigue and breakage of rotary instruments operating in flexed conditions during the preparation of curved canals.

The phenomenon of repeated cyclic metal fatigue caused by canal curvatures may be the most crucial factor in instrument separation. When NiTi rotary instruments are loaded in a cyclic mode, complete fracture may occur after sufficient cycles with load variations. It has been suggested that cyclic fatigue has accounted for 50% to 90% of mechanical failures. However, few scientific data have been published regarding the life span of NiTi rotary instruments while operating in the mode of pecking motion or in a static condition, and while being activated at different rotational speeds.

Efforts are ongoing to identify factors that impact NiTi rotary fracture resistance (eg, file sequence, torque-limiting motors, cross-sectional file design, and file surface treatments as electropolishing and magneto-electropolishing processes). One additional factor potentially limiting the resistance to fatigue and torsional fracture is corrosion that may occur in the presence of NaOCl solution. Sodium hypochlorite (NaOCl) is the most common irrigant used in root canal treatment.

NiTi instruments come into contact with NaOCl during disinfection or when the solution is present in the pulp chamber and root canal during instrumentation and for this reason the time course and extent of corrosive action of NaOCl on NiTi surfaces are currently unclear. The corrosion patterns, involving selective removal of nickel from the surface, can create micro pitting. It is supposed that these microstructuraldefect scan lead to areas of stress collection and crack formation, weakening the structure of the instrument.
Therefore, the purpose of this study was to assess the resistance to cyclic fatigue of four nickel-titanium(Ni Ti) files after the immersion in sodium hypochlorite(NaOCl) solution in static condition.

II. Material and Method

A total of 60 new Twisted Files, Hyflex files, Heroshaper files, Protaper files were tested. Fifteen files of the same brand were randomly assigned to four groups (n = 15) and submitted to the static immersion

protocol in 5.25 % NaOCl at 37°C.The fatigue test was conducted in a custom made device which allowed a reproducible simulation of rotary instrumentation within a curved canal. It provided the instrument with a suitable simulated root canal of 16mm length with a 60 °angle of curvature and a 5-mm radius of curvature. The centre of the curvature was 6 mm from the tip of the instrument, and the curved segment of the canal was approximately 6 mm in length.Files were statically immersed in freshly prepared 5.25% Sodium Hypochlorite solution for 5 minutes. Immediately after removal from immersion, all files were rinsed with distilled water to neutralize the effect of 5.25% Sodium Hypochlorite, dried, and stored in glass vials. The instruments were then subjected to cyclic fatigue test using a custom made jig.The instrument was rotated at 300 rpm by using an electric motor (X-smart; DentsplyMaillefer). The instrument tip was aligned to a specific mark (to allow for repositioning to the same location), and then the file was set to rotate, synchronized with timing by a stopwatch.
The instrument was allowed to rotate freely until fracture. Timing was stopped as fracture was detected visually. The time was then converted into number of revolutions to failure. For each instrument, the time in seconds from the start of the test until the moment of breakage was recorded with a stopwatch to an accuracy of 0.1 seconds, and the number of cycles to failure (NCF) were calculated to the nearest full number multiplying the seconds by 5 (number of cycles for second using 300 rpm). All the readings were recorded and subjected for Statistical Evaluation.

III. Observation

Comparison of cyclic fatigue resistance of four NiTIi instrument immersed in sodium hypochlorite in static mode

Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
I	15	466.66	115.66	29.86	402.61	530.71	62.00	586.00
II	15	518.13	24.23	6.25	504.71	531.55	480.00	570.00
III	15	836.93	17.02	4.25	827.86	846.01	812.00	867.00
IV	15	860.00	23.91	6.39	846.19	873.80	827.00	902.00
Total	60	670.05	189.76	24.49	621.02	719.07	62.00	902.00

One way ANOVA

Source of variation	Sum of Squares	df	Mean Square	F	p-value
Between Groups	1917408.84	3	639136.28	172.65	0.0001 S,p<0.05
Within Groups	207300.00	56	3701.78		
Total	2124708.85	59			

Multiple Comparison: Scheffe Test

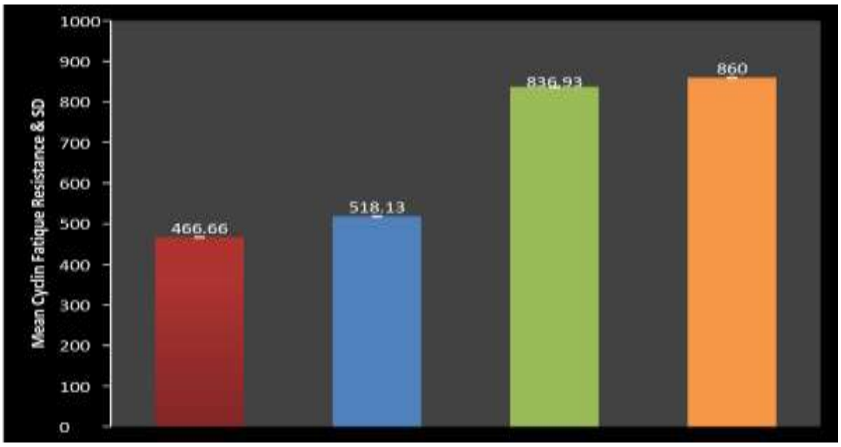
Groups		Mean Difference (I-J)	Std. Error	P-VALUE	95% Confidence Interval	
					Lower Bound	Upper Bound
I	II	51.46	22.21	0.106,**NS**	7.36	110.29
	III	370.27	21.86	0.0001,**S**	312.37	428.17
	IV	393.33	22.60	0.0001,**S**	333.46	453.20
II	III	318.80	21.86	0.0001,**S**	260.90	376.70
	IV	341.86	22.60	0.0001,**S**	281.99	401.73
III	IV	23.06	22.26	0.729,**NS**	35.89	82.02

- NS-Not Significant,p>0.05
- S-Significant,p<0.05

IV. Result

By using Scheffe Multiple Comparison test statistically significant difference was found among group I and III (p=0.0001), I and IV (p=0.0001), II and III (p=0.0001) and II and IV (p=0.0001) and no significant difference was found between subgroups I and II (p=0.053) and subgroups III and IV (p=0.695).

By using one way ANOVA statistically significant variation was found in cyclic fatigue resistance among four groups(F=350.77, p-value=0.0001).



By using multiple comparison Scheffe test statistically significant difference was found between group I versus group II(p=0.0001), group I versus group III(p=0.0001), group I versus group IV(p=0.0001), group II versus III(p=0.0001) and group II versus group IV(p=0.0001) and no significant difference was found between group III and group IV(p=0.106).

V. Discussion

This study aimed to assess the resistance to cyclic fatigue of four NiTifiles after immersion in NaOCl solution in static mode. Many studies have considered the effects of NaOCl on NiTi alloys. Pedulla et al immersed ProTaper rotary instruments in5% NaOCl solution at 50°C for 5 minutes and found corrosion effects afflicting the cyclic fatigue fracture resistance, especially when the instrument was completely immersed in solution, because of galvanic corrosion phenomena caused by the different composition of the working part and the shaft of ProTaper file. Peters et al investigated the effect of immersion in 5.25% NaOCl for 1 or 2 hours at temperatures of 21°C and 60°C on torque and fatigue resistance of 25.04 ProFile and RaCefiles and found that NiTi rotary files exhibit reduced resistance to cyclic fatigue after contact with heated NaOCl, so they should be considered single-use instruments.

Possible explanations for these conflictingfindings are the different test and immersion protocols used. Immersion varied substantially (between 5minutes and 48 hours) provided that the instrument was totally and statically immersed in the solution. These conditions, which mimic those used during cleaning procedures of the instruments involving NaOCl as a disinfectant agent, are very unlikely in clinical practice when the shaft is completely lodged within the head of the endodontic hand piece and the endodontic file rotates during root canal therapy. However, the clinicians should consider that the use of heating NaOCl (50 C or 60 C) or its use as a disinfectant agent of NiTifiles as well as the onset of galvanic corrosion during endodontic therapy (the presence of NaOCl solution in pulp chambers of teeth with restorations of different metal such as amalgam restorations, gold crowns, and so on) trigger corrosion processes and might further reduce the cyclic fatigue resistance of file.

In these experimental conditions, static immersion in NaOCl for 5 minutes did not reduce significantly the cyclic fatigue resistance of NiTifiles. These findings may be because of the type of analysis. The cyclic fatigue device generates the maximum stress at the center of the simulated curve (about 6 mm from the tip), so if a corrosive zone was present at that level, the instrument could break early. However, if the corrosive attack hits the instrument in a different area from that of maximum stress generated by the testing device, the resistance to cyclic fatigue of the instrument will probably not be reduced.

Under the conditions of this in vitro study, statistically significant differences were found between the four different NiTifiles tested; Twisted Files were more resistant to cyclic fatigue than Hyflex, Heroshaper and Protaper. These differences are probably because of the different type of alloy and production processes used for these instruments. Moreover, it has been shown that the different cross-section and cutting flutes design of the four NiTi instruments used in this study do not influence the fatigue resistance of files that are of the same size.

VI. Conclusion

Under these experimental conditions, static in NaOCl for 5 minutes did not reduce significantly the cyclic fatigue resistance of NiTifiles. However the type of instrument influenced cyclic fatigue resistance.

VII. Limitation

Corrosive effect of different concentrations of sodium hypochlorite on Ni Ti files was not taken into consideration.Custom made jig that allowed a reproducible simulation of rotary instrumentation within a curved canal may differ from actual clinical condition.

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