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EFFECT OF IMMERSION IN SODIUM HYPOCHLORITE ON THE CYCLIC FATIGUE RESISTANCE OF THREE ROTARY INSTRUMENTS: AN IN VITRO STUDY

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ABSTRACT

Background: Irrigation of the root canal with irrigants like sodium hypochlorite (NaOCl) has been recommended strongly. Different concentrations of NaOCl ranging from 0.5% to 6.5% NaOCl are used owing to their antimicrobial activity and tissue dissolution activities, particularly at higher temperatures. It has been postulated that fatigue of rotary endodontic instruments can be influenced by adjoining medium and their concentration

Aim: This research was carried out with the objective of comparison between Tru Natomy, Protaper Gold and Hero Gold regarding the effect of 5.25% NaOCl and compare it with distilled water.

Methods and Materials: A total of sixty instruments were included. Three groups of instruments were included. Each group consisted of 20 files. Group A: Tru Natomy, Group B: Protaper Gold, Group C: Hero Gold. Each group of instruments were further subdivided into two subgroups (n= 10 each subgroup). Testing of the cyclic fatigue was carried out in artificial canals which were prepared inside the blocks of stainless steel. The stainless steel blocks with artificial canals were established in a receiver that was packed with experimental solutions distilled water and 5.25% NaOCl. The adjustment of temperature was done at room temperature. The rotation of the instrument was carried out inside the artificial canal as per the instructions of the manufacturer. The instrument was rotated until it got fractured. The time

taken by the instrument to fracture was recorded in seconds. The number of cycles to fracture (NCF) was analysed with the help of the equation (NCF = time to fracture x rpm/60). Surfaces at the site of fracture were examined with the help of a scanning electron microscope (EVOLS10, ZEISS) at magnification (300x and 2000x).

Results: It was noticed that there was no statistically significant change in cyclic fatigue when 5.25% sodium chloride was used as an endodontic irrigant instead of distilled water. The difference was statistically non significant ($p > 0.05$). It was observed that resistance against cyclic fatigue on treatment with different irrigation solutions was in the order of Tru Natomy> Hero Gold> Protaper Gold.

Conclusion: Cyclic fatigue in new NiTi rotary files is not affected significantly by sodium hypochlorite irrigant solution but changes are observed at the surface of NiTi rotary files on being treated with with 5.25% sodium hypochlorite irrigant solution and the Tru Natomy rotary endodontic instrument has the maximum resistance against cyclic fatigue in comparison with Hero Gold and Protaper Gold instruments.

Keywords: Cyclic fatigue, Tru Natomy, HeroGold, ProtaperGold, Resistance, Sodium hypochlorite

INTRODUCTION

In recent times, the use of Nickel-titanium (NiTi) alloy in the field of endodontics has increased significantly in comparison to stainless steel instruments owing to its some useful mechanical properties like shape memory and superelasticity. These NiTi alloys are used in the manufacturing of instruments used in endodontic procedures. The instruments prepared from NiTi alloys have enhanced flexibility and increased resistance against cyclic fatigue when compared to instruments prepared from stainless steel based alloys.[1] Fracture of NiTi alloys based endodontic instrument is however a common problem nowadays as it affects the outcome of endodontic treatment.[2] Cyclic fatigue is considered one of the most important factors in fracture of the endodontic instruments with subsequent failure of instrument. Cyclic fatigue usually takes place when endodontic instruments are rotated in a curved root canal. It leads to the development of tension or compression cycles in a repeated pattern. These compression cycles develop mostly in the portion of the root canal having maximum curvature. The repeated generation of tension cycles leads to the fracture of instruments.

The mechanical properties of rotary endodontic instruments prepared from NiTi alloys are based on the phase conversion from the austenite phase to the martensite phase. This phase conversion takes place with the application of stress and a decrease in temperature.[3] To improve the fracture resistance of NiTi alloy based rotary instruments several improvements have been made in the process of manufacturing. These improvements included different thermal treatments and changes in the internal geometry of instruments. Several NiTi alloy based rotary endodontic instruments have been introduced.[4]

ProTaper Gold NiTi rotary files (Dentsply Sirona, New Delhi, India) have been manufactured based on the geometrical features of ProTaper Universal endodontic instruments.(Dentply Siron, New Delhi, India). However, the metallurgic properties of ProTaper Gold instruments are superior owing to the advanced heat treatment based process of manufacturing. As a result, the resistance against cyclic fatigue and flexibility is greater in ProTaper Gold as compared with Protaper Universal instruments. [5,6]

Most recently TruNatomy rotary NiTi files (Coltene, Newyork, USA) have been introduced. These files use heat treated NiTi alloys to form T –wire file and are prepared specially to provide fast and better outcomes of the endodontic treatment. The complete system has been prepared to make the endodontic procedures quite simple with one endodontic file especially for flaring of the coronal portion, one endodontic file especially for the establishment of patency and maintaining glide path smooth, one endodontic file, especially for effective shaping and preparation of the root canal and one endodontic file for smooth cleaning and shaping. [7]

Hero Shaper rotary endodontic files (Dentsply Sirona, New Delhi, India) are another nickel titanium-based rotary file. According to manufacturers, these files have changeable helical angulation and modified pitch that enhances as the taper enhances in the endodontic instrument. This modified structure prevents the twisting of the endodontic instrument.

Irrigation of the root canal with irrigants like sodium hypochlorite (NaOCl) has been recommended strongly. [8] Different concentrations of NaOCl like 0.5% NaOCl and 6.5% NaOCl are used owing to their antimicrobial activity and tissue dissolution activities, particularly at higher temperatures. It has been postulated that fatigue of rotary endodontic instruments can be influenced by adjoining medium and their concentration. [9] The impact of 5.25% sodium hypochlorite on the cyclic fatigue of these heat-treated Nickel-titanium alloys has not been studied till now. [10] Therefore this research was carried out with the objective of comparison between Tru Natomy, ProtaperGold and Hero Gold regarding the effect of 5.25% NaOCl on the resistance against cyclic fatigue and comparing these results with that of results obtained on treatment of NiTi rotary files with distilled water . The proposed null hypothesis was that 5.25% NaOCl have no impact on the resistance against cyclic fatigue in these rotary endodontic files and there is no difference in resistance against cyclic fatigue in different recent NiTi instruments.

Methods and Materials

Sample size calculation

Information from the earlier study [Alfawaz H et al. Journal of Endodontics. 2018; 44(10): 1563-156 shown the expected pooled standard deviation of push-out bond strength as 253.10 and a mean difference of 300.7. Utilising the given formula (http://powerandsamplesize.com/ HyLown Consulting LLC • Atlanta, GA), a total sample size of 60 was calculated with 10 teeth in each group. The sample size was calculated for an alpha error of 5% and statistical power at 95%.

$$n = \frac{2\,\sigma 2\,(Z1-\alpha/2\tau + Z1-\beta)2}{(\mu A - \mu B)2}$$

where

μA is the mean of group A = 962.9

μB is the mean of group B = 662.3

σ is pooled standard deviation = 253.10

τ is the number of pairwise comparisons to be made = 3

α is Type I error = 0.05

β is Type II error, meaning 1−β is power (95% power) = 0.05

Substituting these values from the previous study, the sample size determined was n =20. Hence, there will be n/2 = 10 samples in each group.

Methodology

It was an in vitro observational study. Clearance was obtained from the institutional review board. A total of sixty instruments were included in study. Three groups of instruments were included. Each group consisted of 20 files. Group A: TruNatomy, Group B: Protaper Gold, Group C: Hero Gold. Each group of instruments were further subdivided into two subgroups (n=10 each subgroup). Length of each instrument was kept at 25 mm. The instruments were evaluated before the study for any deformities and defects at high magnification. However, no instruments were excluded after the evaluation. Testing of the cyclic fatigue was carried out in artificial canals which were prepared inside the blocks of stainless steel. These artificial root canals were prepared with the help of LASER based micromachine. The dimension of the artificial canals was kept following the width of the file examined. It was greater than the width of the instrument by 0.1mm. The curvature angle of the canals was kept at 60^{o}, the radius of curvature was kept at 5mm, and the location of the centre of curvature was 5mm distance from the tip of the instrument. Glass was used to cover the artificial canal to avoid slippage of the instrument and to verify the timing of the fracture of the instrument.

The stainless steel blocks with artificial canals were established in a receiver that was packed with experimental solutions distilled water and 5.25% NaOCl. The adjustment of temperature was done at 25 degrees centigrade. To create fixed and reproducible positioning of every experimental instrument inside the artificial canal, the handpiece of the rotary endodontic motor was fixed at a device. The insertion of the endodontic instrument in the artificial canal was carried out so that 19 mm of the instrument from the tip was inside the artificial canal. The rotation of the instrument was carried out inside the artificial canal as per the instructions of the manufacturer (300 rpm speed/ 3 Nmm torque for Protaper Gold, 350 rpm speed/3 Nmm torque for TruNatomy files, and 400rpm speed/1.2Nmm torque for Hero Gold). The instrument was rotated until it got fractured. The time taken by the instrument to fracture was recorded in seconds. The number of cycles to fracture(NCF) was analysed with the help of the following equation. To provided lubrication, a unique high flowing synthetic oil was used for reduction of friction.

NCF = time to fracture x rpm/60.

All the experimental procedures were carried out by the same clinician. The artificial canal was changed on the appearance of any indication of corrosion which may appear due to corrosive activity of NaOCl. The length of the fractured fragment was measured with the help of an electronic digital calliper. Two instruments that got fractured were selected from each group. They were washed in an ultrasonic bath with absolute alcohol and surfaces at the site of fracture were examined with the help of a scanning electron microscope (EVOLS10, ZEISS) at magnification (300x and 2000x).

Statistical Analysis

The data collected were statistically evaluated with help of Mann Whitney and Krushal-Wallis tests. SPSS software version 22 (IBM, USA) was used for carrying out all statistical analyses. P value at ≤0.05 was adjusted as statistically significant.

Results

It was kept in mind during analysis that as the NCF increased, cyclic fatigue decreased and vice versa. When there was an analysis of cyclic fatigue in the TruNatomy group then it was observed that cyclic fatigue changed when irrigant was changed from distilled water to sodium hypochlorite solution. However the difference was non-significant statistically (p>0.05). **(Table 1)**

On carrying out such analysis in Protaper Gold and Hero Gold it was noticed again that there was a statistically non-significant increase in cyclic fatigue when sodium chloride was used as an endodontic irrigant instead of distilled water. The difference was statistically non significant. (p>0.05). **(Table 1)**.

On carrying out a comparison among the three groups of instruments, it was observed that resistance against cyclic fatigue on treatment with different irrigation solutions was in the order of Tru Natomy> Hero Gold> ProtaperGold (p< 0.05). (**Table 1**).

Table 1: Comparison of cyclic fatigue

Groups	Protaper Gold	Hero Gold	Tru Natomy	p-value	PTG vs HG	PTG vs GE	HG vs GE
DW	505.00 ± 48.13	657.99 ± 52.40	1153.83 ± 122.39	0.001*	0.001*	0.001*	0.001*
NaOCl	494.50 ± 47.69	652.66 ± 58.66	1053.50 ± 134.81	0.001*	0.001*	0.001*	0.001*
Difference	10.50	5.33	100.33	--	--	--	--
p-value	0.791 (NS)	0.820 (NS)	0.095 (NS)	--	--	--	--

* indicates significant difference at p≤0.05; NS: Non-significant difference

PTG: Protaper Gold, HG: Hero Gold, GE: Tru Natomy

DISCUSSION

One of the most common reasons for the fracture of NiTi instruments is cyclic fatigue. [11] Therefore it is important clinically that the impact of different irrigants like 5.25% sodium hypochlorite and distilled water is analysed on the resistance against cyclic fatigue in rotary nickel-titanium alloys. [12] In this research, we have compared the effect of 5.25% sodium hypochlorite on the resistance against cyclic fatigue in three different rotary endodontic nickel titanium-based instruments namely Tru Natomy, Protaper Gold and Hero Gold.The findings were compared with the findings obtained on treatment of these instruments with distilled water. No study has been conducted in past to compare these files.

It was observed in our study that there was a decrease in cyclic fatigue of the instruments when sodium hypochlorite was used in place of distilled water. However the difference was non significant statistically. The resistance against the cyclic fatigue was maximum in the Tru Natomy file and minimum in the ProtaperGold instruments. . The null hypothesis that there is

no effect of application of 5.25% sodium hypochloride on the resistance against cyclic fatigue of rotary NiTi in comparison with distilled water was thus not rejected. However, the null hypothesis that there is no difference in resistance against cyclic fatigue in different recent NiTi instruments was rejected.

Huang et al conducted a similar study to evaluate the effect of different concentrations of sodium hypochlorite at different temperatures and found the results which were not similar to the findings of our present study.[12] They concluded that sodium hypochloride cause decrease in the resistance against fracture in nickel titanium alloys based rotary instruments. However, the file systems used in that study were different from our study. Cheung GS et al carried out a study to evaluate the effect of sodium hypochlorite on the cyclic fatigue of nickel-titanium alloys and found that sodium hypochlorite harms the resistance against cyclic fatigue in these nickel-titanium alloys. These results are in contrast to the findings of the current study. [13]

Previous studies carried out by Peters OA et al , Chai et al, and Pedulla E et al show that there is no impact of different concentrations of sodium hypochlorite on the resistance against cyclic fatigue in the rotary nickel-titanium alloys instruments. [14-16] However in our study there was no such impact of sodium hypochlorite on the resistance against cyclic fatigue. The variations in the results of these studies can be due to the differences in the method applied. In these studies the instruments being examined were immersed in sodium hypochlorite solutions for longer duration ranging from one to two hours and at temperature as higher as 60 degree centigrates. These conditions didn't represent the actual clinical conditions. On the other hand to get closer to clinical conditions, this study involved dynamic immersion in 5.25% NaOCl solution for 5 minutes at room temperature only, only of the working part (16 mm) of 25, .06 endodontic NiTi rotary files of three different varieties according to the speed and torque, as prescribed by the manufacturer. It was decided to select 5 minutes as the contact time of the instrument with the solution to stay within the realistic timeframe for clinical practice.[17-20]Hence unlike these previous studies, the influence of sodium hypochlorite on the resistance against cyclic fatigue in different nickel titanium alloys in our study was statistically non significant although changes were noticed at the surfaces of instruments being examined.

In our study dimensions of the artificial canals prepared were according to the dimensions of the group of instruments being analysed. The width of the artificial canal was kept 0.1 mm greater than that of the instruments to be examined. The curvature angle of the canals was kept at 60^{o}, the radius of curvature was kept at 5mm, and the location of the centre of curvature was 5mm distance from the tip of the instrument.This helped in reducing any minor changes in the positioning of the instruments that could have affected the values of the number of cycles to fracture. We used 5.25% sodium hypochlorite in our study because it is recommended clinically that the root canal should be kept wet with such active endodontic irrigants. [21-23]

It has been found that sodium hypochlorite can remove nickel from the surface of the instrument causing micropitting that can harm the properties of the nickel-titanium rotary files. When nickel-titanium files are exposed to sodium hypochlorite then there is a development of zones of corrosion causing a reduction in the resistance against cyclic fatigue in nickel-titanium alloys instruments. On increasing the concentration of sodium hypochlorite, chloride concentration increases causing a more negative impact on the nickel-titanium alloys. [24-29]

In our study, the TruNatomy NiTi file showed maximum resistance against the cyclic fatigue followed by Protaper Gold, Hero Gold and Edge file X3 file. TruNatomy files are the most

recent rotary nickel-titanium alloy based instruments having well annealed and heat-treated alloys. These files use heat treated NiTi alloys to form T –wire file. The cross-section and design of the Tru Natomy file provide better resistance against cyclic fatigue. Resistance against cyclic fatigue was greater in HeroGold instruments in comparison to ProtaperGold instruments but it was lesser than the Tru Natomy instruments. These files, according to the manufacturers, contain adjustable helical angulation and adjusted pitch that advances as the taper in the endodontic instrument progresses. This redesigned construction prevents the endodontic instrument from twisting.

There were some limitations of this study. The study was carried out in mechanically designed artificial canals instead of a natural root canal. Cyclic fatigue can be affected by the debris produced during biomechanical preparation in the natural root canal. This aspect of debris was not addressed in this study. There can be a difference in the frictional resistance to instruments in natural canals as compared to the artificial canals.

Conclusion

The findings of this study help us to conclude that resistance against cyclic fatigue in new NiTi rotary files is not affected significantly by sodium hypochlorite irrigant solution but changes are observed at the surface of NiTi rotary files on being treated with with 5.25% sodium hypochlorite irrigant solution and the Tru Natomy rotary endodontic instrument has the maximum resistance against cyclic fatigue in comparison with Hero Gold and Protaper Gold.

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