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The Effect of Different Solvents for Gutta-Percha Removal on Cyclic Fatigue Resistance of Nickel-Titanium Retreatment File

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Abstract

Objectives: To evaluate the cyclic fatigue resistance of XP-Endo® Finisher R after immersion in various types of gutta-percha solvent.

Methods: A total of 48 new XP-Endo® Finisher R rotary files, 31 mm in length, were used in this study. These files were equally divided into four groups: the control group (not immersed in gutta-percha solvent) and three experimental groups (immersed in chloroform, eucalyptus oil and GuttaClear). The 16 mm working part of each file was exposed to solvents for 5 minutes. Then the cyclic fatigue testing was performed using a stainless steel artificial canal with a 0.5 mm inner diameter, a curvature angle of 60 degrees and a curvature radius of 5 mm. The time to fracture in seconds was recorded and then the number of cycles to fracture (NCF) was calculated. The length of each fracture fragment was also measured. Two fractured instruments from each group were randomly selected to examine the fracture surface under a scanning electron microscope. Data was analyzed by analysis of variance (ANOVA) and Bonferroni tests (p=0.05).

Results: There were no significant differences between the groups. However, the instruments immersed in eucalyptus oil showed the highest cyclic fatigue resistance followed by chloroform, control group and GuttaClear.

Conclusions: The immersion in different gutta-percha solvents had no effect on the cyclic fatigue resistance of XP-Endo® Finisher R retreatment files.

Keywords: cyclic fatigue, gutta-percha solvents, root canal retreatment, XP-Endo® Finisher R

Introduction

Nonsurgical root canal retreatment is indicated when the initial root canal treatment is unsuccessful.[1] The favorable outcome of root canal retreatment depends on the elimination of microorganism.[2] To achieve this goal, totally removal of previous root canal filling materials should be done, then the chemomechanical preparation of root canal system can be performed effectively.[3] Various methods have been proposed to remove root filling materials such as the use of heat, chemical solvents and mechanical removal by Nickel-Titanium (NiTi) rotary instruments.[4]

From previous reviews, in case of adequate root canal filling, the use of chemical solvents accompanied with NiTi rotary files can enhance the removal of root canal filling materials.[5] When comparing between the chemical solvents used for root canal retreatment, chloroform shows the most efficacy in soften root canal filling materials and make them easily removed.[6] Although chloroform is also known as carcinogen, the effects on health risk seem to be little when using as solvents during root canal.[7] According to the concerning of the toxicity of chloroform, natural gutta-percha solvents have been introduced such as eucalyptus oil and orange oil.[8] Gutta Clear (MDent, Bangkok, Thailand) is a new product of natural gutta-percha solvent, which is a citrus fruit oil-based solvent containing d-limonene has been introduced. The efficiency of d-limonene is equivalent to chloroform in dissolving gutta-percha.[9]

Moreover the development of gutta-percha solvents, various NiTi rotary file systems were also specifically designed for gutta-percha removal such as the ProTaper Universal retreatment system (Dentsply Maillefer, Switzerland), the R-Endo retreatment system (Micro-Mega, France), the D-Race retreatment system (FKG Dantaire, La Chaux-de-Fonds, Switzerland), the M-two retreatment system (VDW, Munich, Germany) and EdgeFile XR (EdgeEndo, USA). Nowadays, the XP-Endo® Finisher R (FKG Dantaire, La Chaux-de-Fonds, Switzerland) has been introduced. This NiTi rotary file was designed as ISO 30 in diameter with zero taper and produced under the heat-treated technology (MaxWire alloy), which claimed to resist the instrument fatigue. This rotary system can adapt to canal morphology that facilitates removal of root filling materials during retreatment procedures especially in curved root canals.[10]

Considering the advantages of using NiTi rotary in root canal retreatment, this can reduce treatment time and risk of root canal transportation.[11] However, using NiTi rotary instruments has the risk of separated due to torsional or cyclic fatigue.[12] Cyclic fatigue occurs when the instrument rotates in a curved canal and after a number of repeated cycles of tension and compression at the point of maximum flexure, the instrument fracture occurs.[13] During the retreatment process, the working part of rotary instruments come into contact for a few minutes with chemical solvents. This contact may influence the physical properties of NiTi rotary instruments. Previous study shows that chloroform had no effect on cyclic fatigue resistance of NiTi rotary retreatment files.[14] Since the literature is lacking of the effect of chloroform and the other solvents on the properties of heat-treated NiTi rotary instruments, this *in vitro* study aimed to evaluate the cyclic fatigue resistance of XP-Endo® Finisher R retreatment file after immersion in chloroform compare to the commonly used gutta-percha solvent such as eucalyptus oil and GuttaClear.

Materials and Methods

Sample size was calculated at the significance level of 0.05 and power of 0.95 using G * power, a sample size of 12 were obtained for each group.

A total of 48 new XP-Endo® Finisher R rotary files, 31 mm in length, were used in this study. These files were equally divided into four groups (twelve of each): the control group (not immersed in gutta-percha solvent) and three experimental groups (immersed in chloroform, eucalyptus oil and GuttaClear). In the immersion groups, the 16 mm working part of each file was exposed to solvents for 5 minutes in small glass tube.

The cyclic fatigue testing was performed using a specific device (Figure 1). This device comprised of a stainless steel artificial canal with a 0.5 mm inner diameter, a curvature angle of 60 degrees and a curvature radius of 5 mm. The handpiece was mounted on a holder. The speed and torque of endodontic motor (X-smart Plus; Densply Maillefer, Switzerland) were set at 1000 rpm and 1.5 N/cm as manufacturer's recommendation. The working length of artificial canal was set at 25 mm.

Each rotary file was rotated in the artificial canal until fracture occurred. The time to fracture in seconds was recorded. The number of cycles to fracture (NCF)

was calculated according to the following formula: NCF = time to fracture (in seconds) x rotational speed/60. The length of each fracture fragment was also measured using digital caliper. Two fractured instruments from each group were randomly selected to examine the fracture surface under a scanning electron microscope (SEM) (JEOL 6400; JEOL, Tokyo, Japan) at 200X magnification.

Statistical analysis

All statistical analyses were performed with SPSS 26.0 software (SPSS Inc, Chicago, IL USA). The Shapiro-Wilk test was used for normality testing. The analysis of variance (ANOVA) and Bonferroni tests were done to test the different of NCF and length of fracture between group. The level of significance was set at p=0.05.

Results

Descriptive statistics of NCF and the length of each fractured fragments of tested retreatment files are presented in Table 1.

There were no significant differences between the groups (p=0.556). However, the instruments immersed in eucalyptus oil showed the highest cyclic fatigue resistance followed by chloroform, control group and GuttaClear. Regarding the fragment lengths, there was no significant difference between them in terms of the mean fracture lengths (p=0.116).

The SEM analysis showed that the surfaces of retreatment files in all groups displayed the typical features of cyclic fatigue failure (Figure 2). They are characterized by a crack initiation site and fatigue zone. The fractographic analysis of cross-sectional fractured surfaces revealed crack sites at the peripheral surface, which indicated an initiation point of cyclic fatigue.

Discussion

Using Ni-Ti rotary file conjunct with chemical solvent is one of the commonly methods to remove root canal filling materials. Various types of NiTi rotary files were designed to facilitate the cleanliness of root canal during root canal retreatment. To the best of our knowledge, the present study aimed at investigations into the negative effect of various gutta-percha solvents on heat-treated NiTi rotary retreatment file.

The manufacturer claims that XP-Endo® finisher R has greater cyclic fatigue resistance. Based on the results of this study, XP-Endo® Finisher R show higher cyclic fatigue resistance than the others conventional NiTi rotary

Figure 1: Cyclic fatigue testing device.

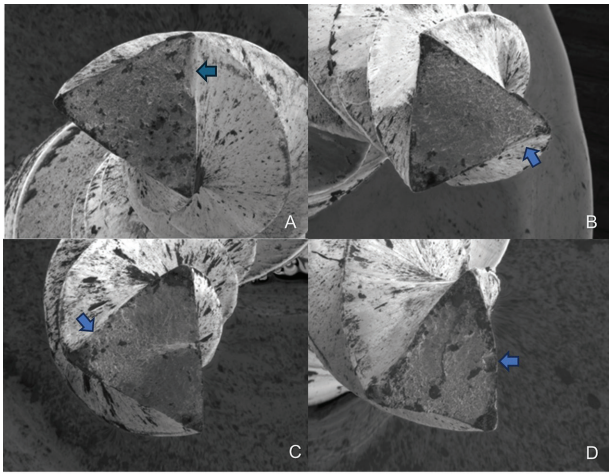

Figure 2: The fracture surfaces (200X magnification). (A) Control group; (B) Chloroform group; (C) Eucalyptus oil group; and (D) GuttaClear group. The arrows indicated crack initiation origin.

Table 1: Means ± standard deviations for NCF (cycles) and the length (mm) of fractured.

Data	Control	Chloroform	Eucalyptus oil	GuttaClear
Number of cycles to fracture (cycles)	1601.58±300.62	1636.83±292.01	1674.50±191.40	1568.75±311.41
Length (mm)	21.72±0.49	22.01±1.52	21.58±0.30	22.35±0.22

retreatment system.[14] This result can be explained by the fact that the NiTi rotary files in the previous study have the greater taper, whereas XP-Endo® Finisher R show zero taper.[15] Moreover, the design, geometrical shape and flexibility may have the effect on cyclic fatigue resistance. The retreatment rotary file systems such as ProTaper and R-Endo were designed for penetration into root filling materials. On the other hand, XP-Endo® Finisher R was designed to facilitate the removal of remnant root filling materials.[16]

In the current study, a static model was used during fatigue test. In the static model, stresses are concentrated in a particular area of the instrument which leads to change in the microstructure of the instrument. Compared to dynamic model, which the instrument moves axially, stresses are distributed along the shaft of the instrument. The differences in the distribution of stress concentration may affect the cyclic fatigue resistance of instruments.[17]

In this study, the retreatment instruments were placed in glass tube containing chloroform, eucalyptus oil, and GuttaClear to replicate the contact conditions as seen in prior research.[18] Previous studies indicate that retreatment instruments typically remove filling materials from root canals within approximately 5 minutes.[18,19] Therefore, a 5-minute immersion period was adopted to approximate clinical conditions in this study.

Our study was performed under static conditions, which do not replicate the actual clinical condition. In the clinical situation, the present of gutta-percha in root canal may affect the cyclic fatigue resistance of the files.

Various methods have been employed to assess the resistance to cyclic fatigue of NiTi instruments. In many studies, stainless steel canals have been utilized to prevent wear on the canal walls during instrumentation.[20] In this study, a device comprising a stainless steel canal with a 5 mm radius was employed to simulate curved canal. Using such devices ensures consistency in canal dimensions throughout the experiments. In this investigation, almost all the instruments fractured at the curvature, confirming the standardized positioning of the instruments within the test device.

An artificial stainless steel canal was used to standardize the anatomical variation of root canals. However, there are still no specifications or international standard block to ensure uniformity of methodology and comparable results for cyclic fatigue testing.

From the SEM image, it can be observed that crack initiation is present in the cross-sectional view. Additionally, the Ni-Ti rotary retreatment file does not exhibit unwinding in the longitudinal view, which is a characteristic of torsional fatigue. Therefore, it can be concluded that the fracture observed in this image is caused by cyclic fatigue.[21] Furthermore, a comparison between the control group and the group soaked in the solution for 5 minutes shows no change in surface condition. Thus, it can be concluded that soaking in various solutions does not affect the surface area (the cutting edge) of the material.

Conclusions

To summarize, the immersion in chloroform, eucalyptus oil and GuttaClear had no effect on the cyclic fatigue resistance of XP-Endo® Finisher R retreatment files.

Conflict of Interest

The authors declare no conflict of interest.

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