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Effect of Sodium Hypochlorite Activated by Heating on the Cyclic Fatigue Resistance of OneShape Rotary Instruments

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Abstract

Introduction: The present study aims to evaluate the effect of sodium hypochlorite, which was activated by heating to different temperatures on the cyclic fatigue resistance of OneShape rotary system instruments.

Materials and Methods: This study included 30 OneShape rotary system instruments with size 25.06. The instruments were randomly divided into 3 groups as one control group and two 5.25% sodium hypochlorite groups, which were activated by increased temperature (either 37°C or 50°C) (n=10). The instruments in the irrigation solution groups were immersed into the irrigation solutions and kept rotating for 10 minutes. The instruments in the control group did not receive any pretreatment. All instruments were tested with in the artificial canal with a radius of curvature of 5mm and angle of curvature of 60°c. The dynamic cyclic fatigue testing of the instruments was performed with a fully automated device. Each instrument was tested until fracture, when the device automatically stopped at the time of it. The number of cycles per formed by each instrument was determined. The data were analyzed using one way ANOVA and Tukey tests.

Results: No significant difference between the control and the irrigation group heated to 37°C ($p>0.05$); whereas the specimens from the irrigation group heated to 50°C exhibited significantly higher cyclic fatigue resistance than the control and irrigation group heated to 37°C ($p<0.05$).

Conclusion: Activation of NaOCl by increasing its temperature to 50°C increases the cyclic fatigue resistance of OneShape 25.06 instruments.

Keywords: Instrument Fracture; Nickel Titanium; Cyclic Fatigue

Introduction

The introduction of nickel-titanium (NiTi) rotary instruments to endodontic practice has provided a great advantage to clinicians in cleaning and shaping procedures, which is considered as the most important step of the root canal treatment [1]. The super elastic properties and high torsional fracture resistance of NiTi alloys have provided instruments to perform safer and more successful root canal preparation [2]. Root canal preparation complications such as canal blockage, elbow, step, apical transportation, and perforations were reported to occur less frequently in preparations performed by using NiTi rotary instruments when compared to stainless steel hand instruments [2]. However, nickel-titanium rotary instruments can still be separated without any signs or visible surface changes during clinical use [3].

The irrigation agents used during root canal treatments or sterilization processes implemented subsequently to root canal treatments may cause chemical reactions leading to the corrosion and/or formation of surface irregularities in the surfaces of NiTi rotary instruments. These irregularities and distortions can lead to instrument fracture during clinical use [4]. NiTi rotary instruments are broken due to two main reasons as torsional or cyclic fatigue failure. Torsional failure occurs when the instrument continues to rotate despite its tip is screwed in root canal, whereas cyclic fatigue failure occurs when the canal instrument is subjected to consecutive compression and tensile stresses at the level where metal fatigue is exceeded during rotation in a curved root canal [5]. Cyclic fatigue resistances of root canal instruments are tested using static and dynamic laboratory cyclic fatigue test models.

Sodium hypochlorite (NaOCl) is the most commonly used irrigation solution for the disinfection of root canal system. NiTi instruments come into contact with NaOCl in cleaning or sterilization processes during or after the root canal treatment. It has been reported that NaOCl removes nickel ions from the surface of NiTi instruments, thus forming micro-holes [6]. This corrosive effect has been reported to cause stress accumulation and cause crack propagation on the instrument. Therefore it has been stated that contact between NaOCl and instruments might negatively affect the mechanical properties of NiTi instruments [7,8]. Previous studies evaluated the effect of NaOCl on NiTi instruments manufactured from conventional, memory-controlled and heat-treated NiTi alloys and reported distortions on the surfaces of NiTi instruments as a result of NaOCl contact [9-12]. Various techniques have been suggested to activate the NaOCl including ultrasonic activation,

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increasing the concentration of the solution, heating, and increasing irrigation period [13,14]. It has been reported that heating the NaOCl solution enhances the tissue dissolution efficiency and antimicrobial properties of the solution [15,16].

OneShape (Micro Mega, Besancon, France) is a single instrument system used with continuous rotation and made from conventional NiTi alloy. OneShape instruments have triangular cutting tips and 2 additional cutting edges along with the working part. The design of the cross-sectional area, changing between 2 and 3 cutting edges in both apical and coronal section provides an optimal cutting efficiency [17]. Our literature research revealed that there was no study that investigated the effect of NaOCl on the cyclic fatigue resistance of OneShape instrument. The purpose of the present study is to evaluate the effect of the heated NaOCl solution on the cyclic fatigue resistance of OneShape instrument. The null hypothesis of the study is that the contact with heated NaOCl does not affect the cyclic fatigue resistance of OneShape instrument.

Materials and Methods

Specimen collection and pretreatment

OneShape NiTi rotary instruments (25.06) were collected. The surfaces of the instruments were examined under 3.5x magnification (Eyemag Pro F, Carl Zeiss, Germany) and 30 instruments without any visible surface and/or shape deformation were selected. The instruments were divided into 3 groups randomly, including the control and 2 groups of NaOCl solution heated up to 37˚C and 50˚C (n=10). An artificial canal made of stainless steel with an inner diameter of 1.5mm, 60˚ angle of curvature, and a curvature radius of 5mm, was used for cyclic fatigue testing. In a fully automatic cyclic fatigue testing device, an artificial tube made from stainless steel, which the instruments to be tested in could freely rotate without any contact was prepared (Figure 1).

In the control group, the cyclic fatigue resistance test was performed without any pretreatment. 5.25% NaOCl (Wizard, Guide Chemistry, Istanbul, Turkey) was used for two experimental groups. The instruments were attached to the endodontic motor (VDW Silver, VDW Munich, Germany) and placed into the tubes containing 5.25% NaOCl heated up to either 37˚C or 50˚C, according to the experimental group at the speed and torque values recommended by the manufacturer, in such a way that the instruments could freely rotate in the tubes and the shaft of the instruments did not come into contact with the solution. During the operation of the instruments, the temperature of the solution was checked with a digital thermostat (Elimko, Elimko Electronics Manufacturing, Ankara, Turkey). The instruments were removed from the tube following rotation for 10 minutes at the speed (350rpm) and torque (2.5Ncm) values recommended by the manufacturer. The instruments were flushed with 5% sodium thiosulfate solution (Tekkim Kimya, Bursa, Turkey) and subsequently with distilled water to neutralize the effects of sodium hypochlorite and then dried.

Cyclic Fatigue test

The instruments in the test and control groups were used with a 6:1 VDW Silver Reciproc motor (VDW, Munich) at the speed of 350rpm and torque of 2.5Ncm, in accordance with the manufacturer's instructions. The artificial canals were lubricated with synthetic oil (WD-40, Milton Keynes, UK) to reduce the friction between the instrument and metal. For simulation of the clinical use, the cyclic fatigue test device's axial movement speed was determined to be 3mm/second and the time elapsed until fracture was recorded in seconds using a digital display. All instruments were rotated until fracture occurred and test device stopped automatically at the time of fracture. Number of cycles to failure (NCF) of each instrument was calculated by multiplying the rotation speed (rpm) and fracture time (minutes).

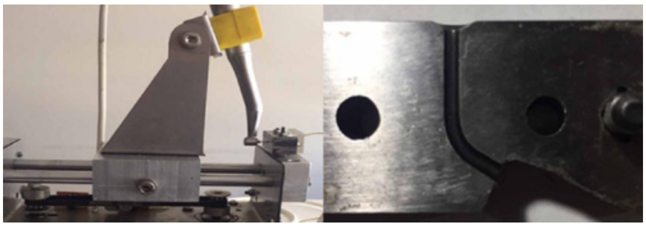

Figure 1: Cyclicfatigue test device and artificial stainless steel canal.

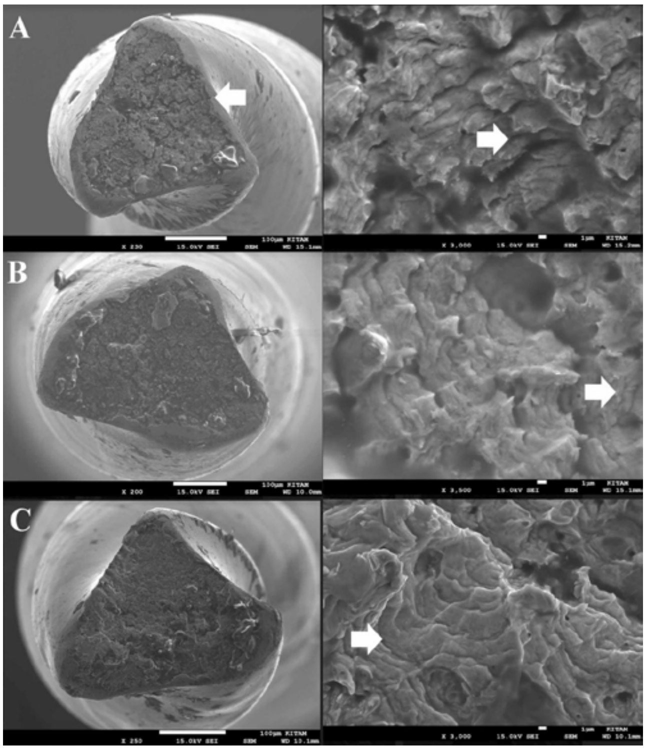

Figure 2: Fatigue striation lines in the specimens of control (A), NaOCl heated to 37˚C (B) and NaOCl heated to 50˚C groups.

Statistical analysis

Following Shapiro-Wilk test confirmed that the data was normally distributed one-way analysis of variance and Tukey multiple comparison tests were performed with 5% significance threshold. The broken surfaces of two instruments from each group were visualized at x200-250 and x3000-3500 magnifications under scanning electron microscope (SEM) (Jeol JSM-7001F, Tokyo, Japan) (Figure 2).

Results

The mean numbers of cycles until fracture and standard deviation

Table 1: Mean numbers of rotation to failure (s) and lengths of fractured fragments (mm).

Experimental groups	Number of rotations to failure (Mean ± Standard deviation)	Length of the fractured fragments (mm) (Mean ± Standard deviation)
Control	3443.38 ± 1068.85	4.12 ± 0.87
NaOCl heated to 50˚C	3966.08 ± 561.25	4.72 ± 1.53
NaOCl heated to 37˚C	5219.66 ± 1232.12	3.52 ± 0.96

values are presented in Table 1. No significant difference was found between the cyclic fatigue resistances of NaOCl group activated by heating to 37˚C and those of control groups (P > 0.05). The cyclic fatigue resistance of the NaOCl group activated by heating to 50˚C was significantly higher than both the control group and the NaOCl group activated by heating to 37˚C (P <0.05). The mean lengths and standard deviations of the broken fragments were measured as 4.12 (±0.87) for the control group, 4.72 (±1.53) for the NaOCl group activated by heating to 37°C and 3.52 (±0.96) for the NaOCl group activated by heating to 50˚C. Fatigue striation lines were determined on the broken surfaces pointing out the cyclic fatigue as the reason of the fracture in the SEM images (Figure 2).

Discussion

The introduction of NiTi rotary instruments has allowed root canal preparation to be completed more rapidly and decreased the frequency of complications such as preparation-related transportation or loss of the working length [2,3]. However, root canal instruments are subjected to great stresses, which might cause instrument fracture during the clinical use. There are many factors including the root canal anatomy, the size, the number of use, and the manufacturing, the design and the alloy of the instrument, the curvature angle of the root canal, the radius of curvature and the operator experience can play a role in instrument separation [18]. The present study aimed to evaluate the effect of NaOCl solutions activated by heating on the cyclic fatigue resistance of the OneShape (25.06) rotary instrument.

Cyclic fatigue tests can be performed with test models in which the instrument is fixed in a position and rotates until fractured or by using dynamic test models to simulate clinical conditions more realistically [19]. Previous studies reported that the dynamic test models, in which the axial motion of the instrument is simulated, increased the rotation number until the fracture significantly compared to the static test models [19-21]. The present study utilized the dynamic test model to simulate clinical conditions and provide more realistic data regarding the life of instruments. Li et al. stated that the axial motion should be determined between 1mm and 3mm in the dynamic test models [20]. This axial movement simulates the pecking movement in clinical use. In this study, the axial movement extension was selected as 3mm in accordance with Li et al.'s recommendation [20].

OneShape instrument is manufactured from conventional austenite NiTi alloy. The cross-sectional areas OneShape has changing triangular or modified triangular cross sectional shape and 3 cutting edges in the apical and middle thirds and S-shaped cross section with 2 cutting edges near the shaft. That changing design with varying cutting edges provides optimal cutting efficiency during operation and prevents instrument locking into the root canal [22]. Dagna et al. and Wang et al. compared the cyclic fatigue resistance of OneShape (25.06) with ProTaper F2 which is made from the same NiTi alloy. The authors reported that the cyclic fatigue resistance of OneShape is significantly higher than that of ProTaper F2 instrument [23,24]. The higher cyclic fatigue resistance of the OneShape canal instrument was attributed to the special design of the variable edges [23,24].

Single instrument systems were designed with the primary aim of completing the root canal preparation with a single root canal instrument. In this way, time and cost required for the endodontic treatment can also be decreased. However, the completion of the root canal preparation with a single instrument also means that instrument will be exposed to both great torsional and cyclic stresses. As stated by the manufacturer, OneShape is a single use system; therefore the instruments are not subjected to the stress due to thermal sterilization processes. However, it comes into contact with irrigation solutions during root canal preparation [7]. Previous studies reported that micro structural defects occur as a result of contact between NiTi instrument and NaOCl, however these defects do not cause significant reduction in the mechanical properties and clinical performance of the instruments [25-27]. O'Hoy et al. evaluated the effect of 10 cleaning cycles with 1% NaOCl on the mechanical properties of instruments in the disinfection procedures. The authors reported no decrease in the shear fatigue resistance and torque value at the time of fracture [7]. NaOCl solution is activated by heating to increase its organic tissue dissolving efficiency. It has also been reported that NaOCl heated to 50˚C reduces the smear layer that emerges after root canal preparation [28]. Berutti et al. kept the ProTaper F2 instrument for 5 minutes in 5% NaOCl solution activated by heating to 50˚C and examined the micro structural changes and the mechanical properties of the instruments [29]. It has been stated that when instrument is immersed into solution completely, galvanic reactions occur among the different metals at the shaft and cutting parts of the instrument and lead distortions on the instrument surface, which cause decreased cyclic fatigue resistance. No negative change in the mechanical properties has been reported when the shaft was not immersed into solution [29]. The shaft of the instrument does not come into contact with irrigation solution during clinical use. In the present study care was taken not to expose shaft to NaOCl to simulate clinical conditions and prevent possible galvanic reactions. Compatibly with the previous literature, the present study found that there was no significant change in the cyclic fatigue resistance of the instruments, which contacted with NaOCl heated to 37˚C. However, the cyclic fatigue resistance of the instruments in the NaOCl group activated by heating to 50˚C increased significantly when compared to the control group and the experimental group which was heated to 37˚C. Stress is concentrated at the center of the simulated curvature during the cyclic fatigue testing. Therefore, cyclic fatigue resistance values would not be affected by the defects, which were not located in stress concentrated areas [30]. It has also been reported that the heat treatment of NiTi rotary instruments improves the mechanical properties [31].

Conclusion

In the present study, 10 minutes contact time of OneShape 25.06 instrument with NaOCl, which was heated up to 50°C, increased the cyclic fatigue resistance of the instrument. Consequently, the contact of OneShape 25.06 canal instruments with NaOCl heated to 37°C did not adversely affect cyclic fatigue resistance whereas contact with NaOCl heated to 50°C increased the cyclic fatigue resistance values.

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