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Original Research Article

Cyclic Fatigue Resistance of One Shape Nickel-Titanium Instruments Used in Interrupted Rotation

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Abstract: The present study aimed to evaluate the effect of interruption on the cyclic fatigue of One Shape rotary NiTi instruments. 10 One Shape 25.06, 10 One Shape Apical 1 30.06 and 10 One Shape Apical 2 37.06 were included to the study. The instruments were subjected to dynamic cyclic fatigue test in continuous and interrupted rotation. In Group 1 the instruments were operated in continuous rotation and in Group 2 the instruments were stopped for 1 s in every 10 seconds. The lengths of the fractured tips were also measured and fractured surfaces were examined under scanning electron microscope. Data were evaluated using one-way ANOVA and Tukey post-hoc tests in SPSS software with 5% significance level. The interrupted rotation reduced the cyclic fatigue resistance of One Shape 25.06 significantly *(P < 0.05)*. No statistically significant reduction was observed in One Shape Apical 1 and 2 instruments *(P > 0.05)*. Interruption of rotation should be noted as a decreasing factor for the cyclic fatigue resistance of One Shape 25.06 NiTi rotary instrument.
Keywords: Interrupted rotation, cyclic fatigue, nickel-titanium rotary instruments

INTRODUCTION

Instrument fracture during root canal preparation is an ongoing problem that complicates root canal treatment [1]. Instrument fracture occurs by two different mechanisms as cyclic and torsional failure [2, 3]. During operation in a root canal with curvature, the instrument exposes to consecutive tension and compression stresses at the area of maximum root canal curvature [4]. Cyclic fatigue resistance is dependent upon many factors including the instrument alloy, movement kinematics, operational settings, cross sectional shape of the instrument and operator's expertise [5-7]. Recently, interruption of rotation has been regarded as a contributing factor to reduce cyclic fatigue resistance of nickel titanium (NiTi) instruments [8].

During root canal preparation, interruption of rotation occurs in several situations [9]. First, electronic apex locator integrated motors stop the movement when the working length is reached in order not to harm periapical structures [10]. Secondly, activated auto-stop and auto-reverse modes because repeated interruptions to prevent the instruments locking into the canal [11]. Finally, an inexperienced operator might stop the file rotation during preparation. Pedulla et al evaluated the cyclic fatigue resistances of Mtwo and Protaper Next instruments with different sizes in interrupted rotations [8]. Authors reported that a one second of interruption in every 10 or 20 seconds reduced the cyclic fatigue resistance of instruments, which are greater than size 20. Moreover the frequency of the interruption was significantly associated with reduced cyclic fatigue resistance [8].

One Shape (Micromega, Besancon, France) is an up-to-date file system made by conventional nickel-titanium alloy and is used with continuous rotation. One Shape 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 [12]. That changing design with varying cutting edges provides optimal cutting efficiency during operation and prevents instrument locking into the root canal [12]. The cyclic fatigue resistance of One Shape has been studied [13, 14]. Dagna et al compared the cyclic fatigue resistance of the One Shape size 25.06 with Protaper Universal size F2 and reported the superiority of One Shape instrument [13]. To the authors' knowledge the effect of interrupted rotation on the cyclic fatigue resistance of One Shape instruments has not been investigated.

Therefore, the present study aimed to evaluate the effect of interrupted rotation on the cyclic fatigue resistance of One Shape instruments. The null hypothesis of this study was that there was no difference between the cyclic fatigues resistances of instruments used in interrupted or continuous rotation.

MATERIAL AND METHODS

Three groups of twenty One Shape sizes 25.06, 30.06 and 37.06 were collected and examined under 3.5 x magnifications via loupe (Eyemag Pro F, Carl Zeiss, and Germany) to exclude instruments with visible deformation. Dynamic cyclic fatigue device with stainless steel artificial canal with 60° curvature angle, 5 mm of radius curvature and 1.5 inner diameter according to the criteria reported in a previous study [4]. Synthetic oil (WD-40, Milton Keynes, UK) was used to lubricate the artificial canal to reduce friction between the instrument and stainless steel. The instruments were further divided into two groups (n = 10).

Group 1: Continuous rotation.

Group 2: 1 second interruption of rotation in every 10 seconds

All instruments were operated with VDW Gold endodontic motor (VDW, Munich, Germany) connected to the cyclic fatigue device according to the manufacturer's instructions. One Shape 25.06 instruments were operated at 350 rpm and 2.5 Ncm, whereas One Shape Apical 1 30.06 and Apical 2 37.06 instruments were operated at 350 rpm and 1 Ncm. In Group 1 the instruments were rotated until fracture. The device was automatically stopped at the time of fracture. In Group 2, a circuit was produced using a start/stop timer (Velleman, Belgium) and attached to the motor to stop the file movement for 1 s in every 10 seconds (Fig. 1). Time required for fracture (TF) was determined as the effective seconds of rotation. The lengths of fractured tips were measured using a digital caliper. Fractured fragments were examined under scanning electron microscope (SEM) (JEOL; JSM-7001F, Tokyo, Japan) in order to obtain photomicrographs of the fractured surfaces.

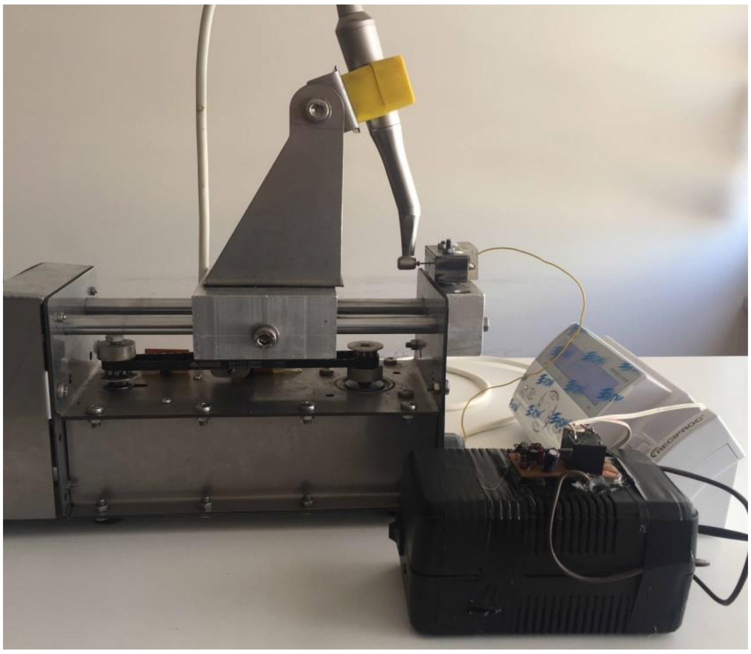

Fig 1: Cyclic fatigue test device

Assumption of normal distribution of the cyclic fatigue resistance and fractured tip length data were tested with Shapiro-Wilk test. Data were analyzed by one-way analysis of variance and Tukey post-hoc tests using SPSS software (IBM, SPSS Inc, Chicago, IL, USA) with a significance level set at 5%.

RESULTS

Table 1 presents the TF data for each instrument in continuous or interrupted rotation. The cyclic fatigue resistance of One Shape 25.06 that operated at continuous rotation was significantly greater than that of One Shape 25.06 operated at interrupted rotation ($P < 0.05$). The cyclic fatigue resistances of One Shape Apical 1 (30.06) and 2 (37.06) instruments were decreased by the occurrence of interruptions; however the differences were not statistically significant ($P > 0.05$).

The cyclic fatigue resistance of One Shape 25.06 was significantly higher than those of both One Shape Apical 1 (30.06) and 2 (37.06) ($P < 0.05$). No significant difference was observed between the cyclic fatigue resistances of One Shape Apical 1 and 2 instruments ($P > 0.05$).

Table 1: Mean and standard deviation values of estimated effective seconds of the time required for fracture of tested instruments (s)

	Time required for fracture (s)	
Instruments	**Continuous Rotation**	**Interrupted Rotation**
One Shape (25.06)	$^{A}620.29^{a} \pm 195.72$	$^{A}434.40^{b} \pm 105.11$
One Shape Apical 1 (30.06)	$^{B}331.40^{a} \pm 73.97$	$^{B}266.40^{a} \pm 128.59$
One Shape Apical 2 (37.06)	$^{B}311.50^{a} \pm 22.03$	$^{B}198.20^{a} \pm 49.72$

Different superscript lower letters in the same line show statistically significant difference ($P < 0.05$)
Different superscript capital letters in the same column show statistically significant difference ($P < 0.05$)

The lengths of the fractured fragments were not significantly different for all instruments and groups ($P > 0.05$) and ranged from 3.7 to 7.1 mm (mean = 5.20 mm). Examination of SEM surface appearances exhibited similar ductile fracture patterns with cones, dimples and fatigue striations on the fractured surfaces of tested instruments (Fig. 2).

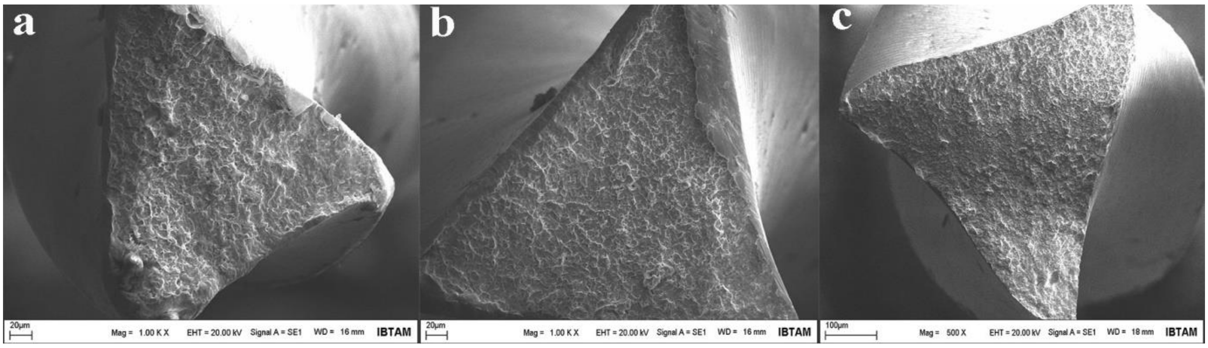

Fig 2: SEM images of the One Shape instruments subjected to fatigue tests in interrupted rotation (a= One Shape 25.06, b= One Shape Apical 1, c= One Shape Apical 2).

DISCUSSION

Pedulla *et al.;* indicated the interruption of rotation as a negative factor in the cyclic fatigue resistance of conventional NiTi and M-wire instruments with apical size 25 [8]. Interruption of rotation could easily occur during root canal preparation, for example when the determined torque values are exceed by the activation of auto-reverse or auto-stop modes or the working length determination during preparation [10, 11]. Moreover, unexperienced operator might stop the file movement during preparation unexpectedly. It is important for clinicians to know the factors influencing the clinical performance of file systems. Therefore, the present study evaluated the effect of interruption of rotation of the One Shape instruments. The null hypothesis was partially rejected, because interruptions significantly reduced the cyclic fatigue resistance of One Shape 25.06 instruments; however it did not influence the cyclic fatigue resistances of One Shape Apical 1 and 2 instruments.

Continuous rotation of NiTi instruments shows a stress induced austenite-to-martensite phase transition that results in elasticity and flexibility [15]. In the case of repeated interruptions, a reverse phase transition from martensite-to-austenite occurs and causes the instrument to be more prone to fracture [16]. When the instrument is stopped, the alloy returns to the austenite phase in which the fatigue crack propagation is faster [17]. SEM images exhibited typical fractographic ductile fracture appearances with dimples and cones. The surface characteristics were similar in both continuous and interrupted rotation groups. In the present study, the occurrence of interruptions reduced the cyclic fatigue resistance of all One Shape instruments. However, the reduction was significant only in One Shape 25.06 group. No study has tested instruments with sizes greater than ISO 25 in interrupted rotation, so direct comparisons cannot be made. Probably the cyclic fatigue resistance of the instruments was more affected by the greater mass diameter of the instruments rather than the repeated interruptions. This finding is consistent with the previous literature, which reported that the instruments with a greater cross-sectional area have lower fatigue resistance [18, 19].

There are many contributing factors that cannot be fully standardized such as the material properties or file geometry during the laboratory testing of the fatigue resistance of files. This limitation causes difficulties to quantify the effect of a single variable [20]. Nevertheless the use of artificial stainless steel canals are recommended for cyclic fatigue resistance test instead of the use of extracted human teeth [21]. Extracted human teeth might reflect clinical situations better, however they are not anatomically and morphologically standardized. In the present study, artificial stainless steel root canals were used and lubricated using oil to reduce the friction between file and canal. Cyclic fatigue tests can be performed in static or dynamic models [22]. The previous studies reported that the dynamic models increase the cyclic fatigue resistances of the test instruments compared to static models and simulate clinical conditions better [22-24]. Li *et al.;* proposed the axial motion ranged between 1 and 3 mm to simulate clinical use [23]. Therefore in the present study, dynamic test device with 3 mm axial motion was utilized.

CONCLUSION

The cyclic fatigue resistance of One Shape 25.06 is reduced by the occurrence of repeated interruptions. During root canal preparation with this instrument clinicians should consider the interruption as a negative factor that reduces the life of the instruments. The cyclic fatigue resistance of One Shape Apical 1 and 2 instruments were significantly lower than One Shape 25.06, which could be explained by the greater mass diameter, and were not affected by the interruptions.

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