ORIGINAL ARTICLE

Turk Endod J 2021;6(3):76–79
doi: 10.14744/TEJ.2021.48030

Static cyclic fatigue resistance evaluation of Neoniti rotary files at different insertion angles

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Purpose: Different insertion angles of the rotary files during the root canal shaping may influence the cyclic fatigue resistance (CFR). The present study aimed to evaluate the effects of different insertion angles on a file's static CFR at body temperature.

Methods: Eighty new Neoniti (Neolix, Châtres-la-Forêt, France) 25 mm long files were used. The stainless-steel metal block had four artificial canals with different insertion angles (0°, 10°, 20°, and 30°). The files were subjected to a static cyclic fatigue procedure at simulated body temperature (36 ± 1). The number of cycles to failure (NCF) and fractured instrument length were recorded. The Kruskal–Wallis H test analyzed the data at a 95% confidence interval ($p = 0.05$).

Results: For #20.06 and #25.06 instrument, the 10°, 20°, and 30° insertion angles resulted in decreased static fatigue resistance as compared to straight (0°) insertion angle ($p < 0.05$).

Conclusion: When the insertion angle increases, the static CFR decreases. An inclined insertion into the canals decreased the CFR of the endodontic instruments.

Keywords: Cyclic fatigue, insertion angle, Neoniti.

Introduction

Access cavity preparation is an essential step in successful root canal therapy (1). Traditional endodontic cavity (TEC) provides straight-line access and increases the effectiveness of root canal preparation. However, the tooth becomes more prone to fracture due to TECs (2,3). Recently, a minimally invasive dentistry approach has emerged to prevent tooth fracture in long-term survival (4). Unlike TECs, the conservative access cavity preserves more pericingular or peri-cervical dentin. Peri-cervical dentin has greater importance for long-term success as it distributes functional loads (5).

The contracted space resulting from such a conservative access cavity creates a curved insertion angle. This angle can cause transportation or an increase in the tension-compression stress cycle that exceeds the limits of the root canal file, resulting in instrument separation. Instrument separation is one of the problems encountered during

Cite this article as: Ali A, Gözen NU, Kul AK, Ishaq A, Vadera V. Static cyclic fatigue resistance evaluation of Neoniti rotary files at different insertion angles. Turk Endod J 2021;6:76-79.

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Submitted: May 22, 2021 Accepted: August 25, 2021

root canal treatment. It occurs due to cyclic or torsional fatigue. In torsional fatigue, the tip of the instrument is fastened in the canal, while the shank continues to rotate, and cyclic fatigue occurs due to repeated cycles of tension and compression. Cyclic fatigue can be static and dynamic. In dynamic cyclic fatigue testing, the instrument moves back and forth into the root canal with uniform distribution of stress along the length of the instrument, while in static cyclic fatigue, no such movement occurs. However, clinically this insertion angle is not static; its value decreases during the canal shaping as the endodontic file cuts the coronal dentin. Thus, the initial instruments are subjected to a more tension-compression stress cycle than the final shaping files. Two studies evaluated the instruments' static resistance in different access cavity designs (6–8).

Several modifications in the endodontic instrument design have been introduced to improve fracture resistance. This includes improvements in instrument design, metallurgy, and surface treatment. In this study, Neoniti (Neolix, Châtres-la-Forêt, France) single rotary file system was used. It has a rectangular cross-section design that is non-homogenous. The manufacturer stated that Neoniti files went through the heat treatment and developed by the wire-cut electric discharge machining process, which provides the file with high flexibility and rapid root canal preparation. The system is available with three different sizes (20/0.06, 25/0.06, 40/0.04), an orifice opener (25/0.12), and a GPS file (15/0.03) (9,10).

Pedulla et al. (6) evaluated three insertion angles (0°, 10°, and 20°) and two radii (5 mm and 3 mm) in a stainless-steel block with 60° curvature. They observed a significant reduction in numbers of cyclic to failure (NCF) at 20° and 10° in the 3-mm radius canal with HCM #25/.06 and all .04 taper instruments. In the 5-mm radius of curvature, .06 taper instruments had no significant NCF reduction while .04 taper files exhibited significant NCF reduction when tested at 20°. However, creating insertion angles on the metal block may influence the results. The proposed null hypothesis is that the insertion angles do not affect endodontic files' cyclic fatigue resistance (CFR) in an artificial stainless-steel metal block. Thus, the present study aimed to evaluate the effect of different insertion angles on files' static CFR at body temperature.

Materials and Methods

The sample size was determined according to the study results by Pedullà et al. (6). According to the effect size (0.697) obtained from the study by Pedullà et al. (6) (3 mm Radius 60), the sample size for each instrument size was 40 (power = 0.95). Due to the use of two instrument sizes (#20.06, #25.06) in this study, the total sample size was 80.

In this study, 25 mm long, 80 new Neoniti (Neolix, Châtres-la-Forêt, France) rotary files were used. An optical stereomicroscope 8X magnification (Lawrence and Mayo, London) determined the deformations or manufacturing defects on all the instruments. If deformation was detected, it was excluded from the study.

Specimen Grouping

Size#20.06 and #25.06 Neoniti files were tested within each insertion angle (0°, 10°, 20°, and 30°). A stainless-steel 20 mm long and 1.5 mm inner diameter artificial canal on metal block was used for the static cyclic fatigue test. All insertion angles were set at the coronal first 4 mm of the canal (0°, 10°, 20°, and 30° respectively). The artificial canal was straight between 5th and 16th millimeters. Apical 5 mm of the canal was curved with a 5-mm radius and a 60° angle of curvature. The Neoniti rotary files were divided into four groups (n = 20) based on the insertion angles (0°, 10°, 20°, and 30°) design of the artificial canals in the stainless-steel metal block and were labeled as group I, II, III, and IV based on 0°, 10°, 20°, and 30° insertion angles respectively.

Cyclic Fatigue Testing

The metal block was immersed in saline solution during the testing. The surrounding temperature was kept at 36 ±1 by an aquarium thermometer (Hopar, Guandong, China), to simulate the body temperature (Fig. 1). The Neoniti files were used per the manufacturer's instructions (300 rpm, 1.5N cm torque) until the file fractured. A torque-controlled motor, e Connect Pro (Changzhou Sifary Medical Technology Co. Ltd., Changzhou, China), was used in full continuous rotation motion. The positions of all instruments were fixed with a contra-angle handpiece on artificial canals. A synthetic lubricant decreased the friction between the canal and instruments. The time of the fracture was recorded using a digital chronometer; a digital caliper measured the lengths of fractured parts. The numbers of cycles to failure (NCF) calculation were made according to the following formula (11):

NCF = rpm of instrument × time to fracture (seconds) ÷ 60

Statistical Analysis

In order to compare the data statistically, the normally distributed data were first determined and the data were shown as mean and standard deviation. The Kruskal–Wallis H test analyzed data at a 95% confidence interval ($p = 0.05$).

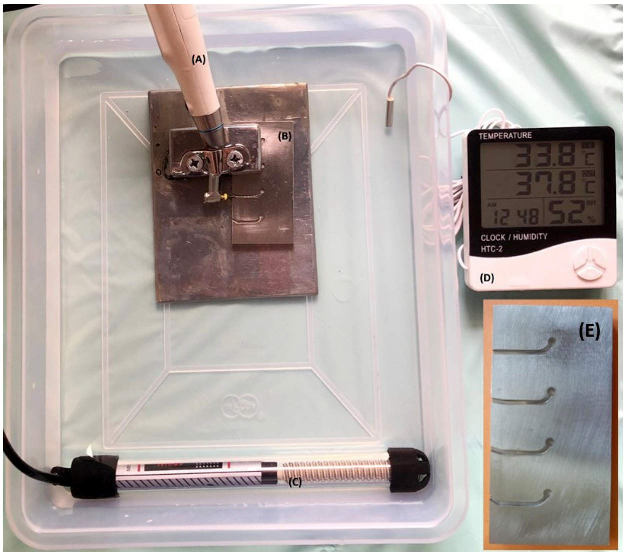

Fig. 1. Experimental setup showing the (A) endomotor, (B) cyclic fatigue test device, (C) aquarium thermometer, and (D) digital temperature verifying device in a plastic container filled with water. Cyclic fatigue test device submerged in a water bath at 35 ± 1 °C. (E) An experimental metal block (magnified view) having the artificial canals with an angle of curvature of 60° and a radius of 3 mm and different insertion angles (0°, 10°, 20°, and 30°).

Results

A statistically significant reduction in NCF was observed among all the groups. The Neoniti rotary files showed a statistically significant reduction in resistance to fracture with the increase in insertion angle. Table 1 summarizes the results of the cyclic fatigue test according to the instruments and insertion angles (means and standard deviations). Group I (artificial canal with 0° insertion angle) Neoniti files exhibited the highest static CFR compared to other groups. For #20.06 and #25.06 Neoniti instrument, 10° (Group II), 20° (Group III), and 30° (Group IV) insertion angles resulted in decreased static fatigue compared to straight insertion angle ($p< 0.05$). No significant difference in the length of the fractured file occurred with the mean value of 3 ± 0.2 mm.

Discussion

Radius and angle of the curvature, heat treatment technology, size and taper of the file, instrumentation technique, surface condition, rotational speed, sterilization cycles, and operator-related variables may affect the cyclic fatigue of NiTi files (12,13). However, among them, canal curvature and excessive insertion angle have critical importance (14). In the present study, the static cyclic fatigue test was performed, at the different insertion angles in simulated canals with the same canal curvatures. Moreover, insertion angles (0°, 10°, 20°, 30°) were fixed in the metal block. The degree of the angles would always remain constant throughout the shaping procedure, unlike the clinical condition where the insertion angle was reduced due to the coronal canal shaping. Thanks to this, there was a low possibility of any deviation in the results. The effect of the angle of file access on cyclic loading has been previously evaluated, but the insertion angles were not fixed on the metal block (6). In that study (6), there were no significant differences among the insertion angles for 3 mm radius and 60° for all types of instruments (HyFlex CM #25.04 and #25.06, 2Shape #25.04 and #25.06). Pedullà et al. (6) noticed that as the insertion angle increases, a downward trend occurs. In the present study, the sample size was determined using this study's data, and insertion angles were fixed in the metal block. The aforementioned reasons could explain the differences between the studies.

Table 1. Results of the cyclic fatigue test according to the instruments size and insertion angles (means and standard deviations of NCF)

Insertion angle	20.06	25.06
0°	1287.4 ± 104.4^{a}	1490.4 ± 104.1^{a}
10°	1260.5 ± 194.7^{ab}	1410.4 ± 156.9^{b}
20°	1216 ± 151.5^{bc}	1360.2 ± 109.9^{b}
30°	1188.9 ± 164.6^{c}	1329.5 ± 145.9^{c}

Values with the different superscript letters were statistically significant at $p< 0.05$.

However, despite increased flexibility, Neoniti files resisted cyclic loading to a certain extent. In this study, different values were found at different angles. Also, values were different from file to file likely due to different tapers and sizes.

The effect of Contracted Endodontic Cavity (CEC) on root canal geometry was evaluated by Alovisi et al. (15). In their study (15), the insertion angle was 20° when access was gained with the TEC approach. However, another tooth's angle degree was 30 when the CEC was applied (7). Also, the effect of CECs on root canal parameters was evaluated by Marchesan et al. (16). In that study (16), the insertion angle which formed after the final preparation of mandibular first molar was above 30°. Thus, the present study evaluated insertion angles up to 30°.

Environmental temperature affects the results of fatigue studies (17). Even if body temperature is mimicked in this *in vitro* study, it is quite difficult to mimic the exact clinical situation. Different structures of dentine and metal may cause different results of *in vitro* and *in vivo* studies. Also, during preparation of the tooth canal, the file is exposed to different stress points than in the artificial metal canal.

When the time taken to fracture was examined, files that prepared 30° insertion angles were broken in the shortest time regardless of the file type. In addition, when the lengths of the broken pieces were examined, those prepared in the 30° canal were shorter. These results may be because the canal with a 30° insertion angle causes more cyclic loading on the files.

During the cyclic fatigue testing, the clinical simulation of the insertion angles could not be maintained throughout the procedure. As the endodontic shaping causes the cutting of tooth dentin in the coronal part and the radicular part, the insertion angle of rotary files decreases. In the present study, the metal block was used, which will maintain the same insertion angles as determined for the study and eliminate bias.

The experimental model of the present study lacks simulation of natural tooth structure. Also, the static model of cyclic fatigue testing does not simulate the dynamic clinical shaping procedures. The present study lacks scanning electron microscopy analysis of the fracture types. Hence, further studies are needed to investigate similar parameters in the actual clinical scenario.

Conclusion

Insertion angles of rotary files are relatively greater than 10° during the initial phases of canal shaping, especially in cases of minimally invasive access cavity design. As a result of this *in vitro* study, it was observed that as the insertion angle increases, the static CFR decreases. Thus, the file can be broken faster when treating the teeth accessed with contracted cavity design, thereby altering the insertion angles in the root canal.

Authorship Contributions: Concept: A.A.; Design: A.A., N.U.G.; Supervision: A.A.; Materials: A.A., N.U.G.; Data: A.A., N.U.G.; Analysis: A.A., N.U.G., A.K.K.; Literature search: A.A., N.U.G., A.K.K., A.I.; Writing: A.A., N.U.G., A.K.K., A.I.; Critical revision: A.A., N.U.G., A.K.K., V.V.

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Pacific Dental College & Hospital Ethics Commitee (date: 30.05.2020, protocol no: PDCH/20/EC-189).

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