Cyclic and Torsional Fatigue Resistance of Reciprocating Single Files Manufactured by Different Nickel-titanium Alloys

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Abstract

Introduction: The aim of this study was to evaluate the cyclic and torsional fatigue resistance of the following reciprocating single-file systems: ProDesign R 25.06 (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil), Reciproc R25 (VDW GmbH, Munich, Germany), and Unicone L25 (Medin SA, Nové Město in Moravě, Czech Republic). **Methods:** Sixty instruments of the ProDesign R, Reciproc R25, and Unicone L25 systems ($n = 20$) were used. Cyclic fatigue resistance was tested measuring the time to failure in an artificial stainless steel canal with a 60° angle and a 5-mm radius of curvature ($n = 10$). Torque and angle of rotation at failure of new instruments ($n = 10$) in the 3 mm from the tip portion were measured during torsional testing according to ISO 3630-1. The fractured surface of each fragment was examined by scanning electron microscopy. Data were analyzed using 1-way analysis of variance and Tukey tests, and the level of significance was set at 5%. **Results:** The cyclic fatigue resistance values of ProDesign R 25.06 were significantly higher than the other groups ($P < .05$). Reciproc R25 showed higher fatigue resistance than Unicone L25 ($P < .05$). In relation to the torsional test, the ProDesign R 25.06 and Unicone L25 systems showed higher angular rotation until fracture than Reciproc R25 ($P < .05$). However, Reciproc R25 and Unicone L25 showed higher torque load than ProDesign R 25.06 ($P < .05$). Scanning electron microscopic analysis showed similar and typical features of cyclic and torsional failure for all instruments tested. **Conclusions:** ProDesign R presented the highest cyclic fatigue resistance and angular rotation to failure compared with Reciproc and Unicone. However, Reciproc showed higher torsional strength to failure. *(J Endod 2017;■:1–6)*

Key Words

Cyclic fatigue, nickel-titanium, reciprocating systems, torsional resistance

Significance

New reciprocating systems were introduced with different designs and NiTi alloys. Instrument separation can occur, and the causes are flexural and torsional stress. ProDesign R presented higher cyclic fatigue resistance and Reciproc showed higher torsional strength to failure.

Nickel-titanium instruments (NiTi) show flexibility and elasticity to provide safe root canal preparation in curved canals (1, 2). However, unexpected instrument separation can occur, and many variables may contribute to this occurrence. The most common causes are flexural and torsional stress (3, 4).

Cyclic flexural fatigue occurs by repeated compressive and tensile stresses when the instrument rotates in a curved canal (3), which often happens clinically (3, 5). Torsional failure occurs when the tip of the instrument is locked in the canal while the shank continues to rotate (3). This can happen in straight or curved canals, especially in the preparation of narrow and constricted canals when the file is susceptible to high torsional loads (3, 5). Torsional failure is characterized by a maximum torsional load and angle of rotation. This property reveals the ability of the file to twist before fracture (6). Therefore, to minimize this drawback, the manufacturers developed several strategies such as new cross sections, designs, thermomechanical processes, and kinematics (1, 2, 6–8).

The reciprocating motion used in reciprocating single-file systems has been shown to be safe and effective in the preparation of curved root canals, reducing cyclic fatigue, torsional stress, and working time (9–11). Reciproc (VDW GmbH, Munich, Germany) is fabricated from M-Wire alloy. This NiTi alloy shows more flexibility and mechanical strength than NiTi wire (2, 12). M-Wire instruments are produced by transforming an NiTi wire in the austenite phase into the R-phase, an intermediate phase formed during the transformation from martensite to austenite on heating and reverse transformation on cooling the material (2, 12).

Recently, new reciprocating systems were introduced using different designs and NiTi alloys. ProDesign R (Easy Equipamentos Odontologicos, Belo Horizonte, MG, Brazil) has 2 instruments with #25 and #35 tip sizes and 0.06 and 0.05 tapers, presents an S-shaped cross section, and is manufactured by a special thermomechanical process

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that controls the memory of the NiTi. These instruments are mainly in the martensite phase, which provides more flexibility, cyclic fatigue resistance (2, 7, 12, 13), and high deformation capacity during torsional testing (12–14). Unicone (Medin, Nov e Mesto na Morave, Czech Republic) is an NiTi (proprietary treatment not reported by the manufacturer) reciprocating instrument with an inactive tip and a convex triangular cross section; it is composed of 3 instruments with #20, #25, and #40 tip sizes and a 0.06 taper size. Some authors have reported that this instrument has low flexibility and a short lifetime during cyclic fatigue test (15, 16).

There are no studies regarding the cyclic and torsional fatigue resistance of ProDesign R. Furthermore, there is no report of the torsional properties of Unicone. The aim of this study was to evaluate the cyclic and torsional fatigue (maximum torque load and angular rotation) of the ProDesign R 25/.06 and Unicone 25/.06 systems and compare them with the Reciproc R25 instrument. The null hypotheses tested were as follows:

1. There are no differences in the cyclic fatigue resistance among the instruments.
2. There are differences in the torsional resistance among the instruments.

Methods

The sample calculation was performed using G*Power v3.1 for Mac (Heinrich Heine, University of Düsseldorf, Düsseldorf, Germany) by selecting the Wilcoxon-Mann-Whitney test of the *t* test family. An alpha-type error of 0.05, a beta power of 0.95, and a ratio N2/N1 of 1 were also stipulated. A total of 8 samples per group were indicated as the ideal size required for noting significant differences. Ten samples per group were used because an additional 20% was calculated to compensate for possible outlier values that might lead to sample loss.

A sample of 60 NiTi instruments (length = 25 mm) of 3 different reciprocating systems (n = 20 per system) were used in this study as follows: ProDesign R (size #25, 0.06 taper), Reciproc R25 (size #25, 0.08 taper), and Unicone L25 (size #25, 0.06 taper). Every instrument was inspected for defects or deformities before being tested under a stereomicroscope (Carl Zeiss, LLC, Oberkochen, Germany) at 16× magnification; none were discarded. All files used were 25-mm long, with 10 instruments of each brand used for cyclic and torsional fatigue testing.

Cyclic Fatigue Test

The static cyclic fatigue tests were performed using a custom-made device that allowed a reproducible simulation of an instrument confined in an artificial curved canal as previously described (17). The artificial canal was manufactured by reproducing the instrument size and taper, thus providing the instrument with a suitable trajectory with a 60° angle of curvature and a 5-mm radius of curvature (Fig. 1*A* and *B*). The curvature of the stainless steel artificial canal was fitted onto a guide cylinder made of the same material (angle of curvature = 60°, radius = 5 mm). Both the arch and the guide cylinder had a 1-mm-deep groove located 5 mm from the top to match the height of the counterangle. The groove served as a guide path for the instrument, which remained curved and free to rotate between the cylinder and external arch.

Ten instruments of each reciprocating system were activated by using a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) powered by a torque-controlled motor (Silver Reciproc, VDW) using the preset programs “Reciproc ALL” and “WaveOne ALL” to activate Reciproc R25 and ProDesign R 25.06 and Unicone L25, respectively. The preset programs were selected according to the manufacturers’ instructions. To reduce the friction of the instrument as it came into contact with the artificial canal walls, a special high-flow synthetic oil prepared for lubrication of mechanical parts (Super Oil; Singer Co Ltd, Elizabethport, NJ) was applied. The time from motor activation was recorded and stopped as soon as a fracture was detected visually and/or audibly on a digital timer. During this step, a video recording was performed simultaneously, and the recordings were observed to ensure the accurate time of instrument fracture.

Torsional Fatigue Test

The torsion tests, based on ISO 3630-1 (1992), were performed by using a torsion machine described in detail elsewhere (18). All files used were 25-mm long, and 10 instruments of each system were used to

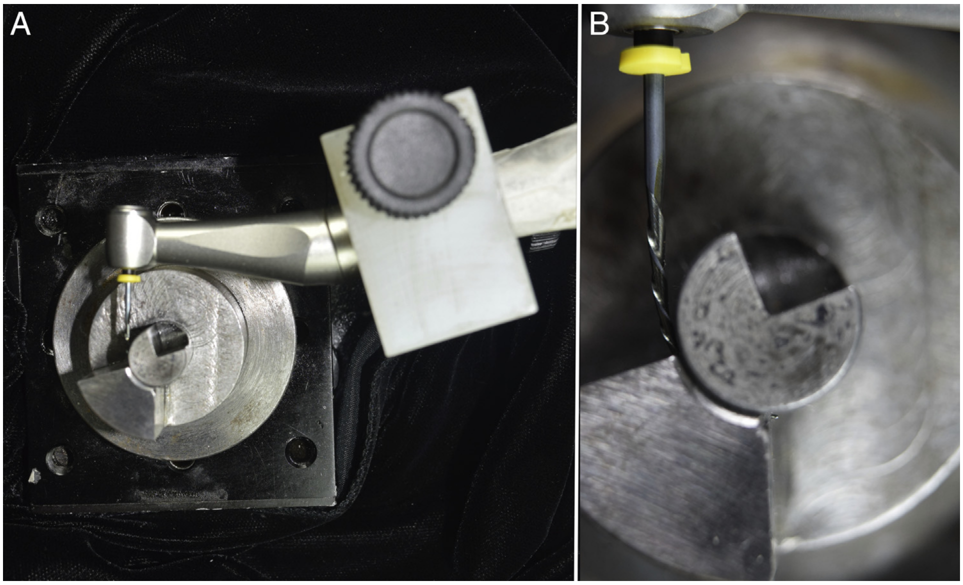

Figure 1. (*A*) The instrument positioned in the cyclic fatigue test device. (*B*) The artificial canal with an angle of curvature of 60° and a radius of 5 mm.