Torsional Fatigue Resistance of Blue-treated Reciprocating Instruments

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Abstract

Introduction: The aim of the present study was to evaluate the influence of blue thermal treatment on the torsional resistance behavior of M-Wire Reciproc files (VDW, Munich, Germany). **Methods:** Ten M-Wire Reciproc R25 (25/0.08v) and 10 Reciproc Blue R25 (25/0.08v, VDW) instruments were used. The torque and angle of rotation at failure of new instruments ($n = 10$) were measured according to ISO 3630-1. Three millimeters of each instrument tip was clamped to a small load cell by a lever arm linked to the torsion axis. The fracture surface of all fragments was examined with a scanning electron microscope. Results were statistically analyzed using the Student t test at a significance level of $P < .05$. **Results:** The maximum torsional strength of M-Wire Reciproc was higher than Reciproc Blue instruments ($P < .05$). Reciproc Blue instruments showed significantly higher angular rotation to fracture than M-Wire Reciproc instruments ($P < .05$). Scanning electron microscopy of the fracture surface showed similar and typical features of torsional failure for the 2 types of instruments, including concentric abrasion marks and the fibrous dimple marks at the center of rotation. **Conclusions:** Reciproc Blue instruments showed a higher angle of rotation to fracture but a lower torque to failure than M-Wire Reciproc instruments. *(J Endod 2018;■:1–4)*

Key Words

Reciproc Blue, reciprocating instruments, torsional resistance

Significance

Reciproc Blue instruments were recently introduced with a different thermal treatment when compared with its predecessor M-Wire Reciproc. The present study pointed out significant differences in the torsional resistance behavior between the 2 instruments.

The introduction of nickel-titanium (NiTi) rotary instruments in endodontics has brought many advantages such as faster preparation time, cutting efficiency, and canal centering capacity compared with stainless steel hand files (1, 2). However, despite the numerous benefits, its use presents the risk of fracture by torsional stress or cyclic fatigue, which might contribute negatively to the treatment prognosis (3). For that reason, several approaches have been proposed to minimize the occurrence of such fractures including changes in the instrument design, NiTi alloy, and activation kinematics (1, 4–6).

Reciprocating kinematics has been shown to be safe and effective in the preparation of curved root canals, reducing cyclic fatigue, torsional stress, and working time (6–8). Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) files are the main examples of commercially available systems for root canal preparation using reciprocating motion. Both instruments are fabricated from M-Wire alloy. M-Wire instruments are produced using a proprietary thermomechanical procedure developed with the objective of producing a superelastic NiTi alloy optimizing the microstructure and transformation behavior of the traditional NiTi alloy (9, 10). The M-Wire fabrication process can substantially increase the flexibility and mechanical strength compared with conventional NiTi wire (9, 10). The new generation of reciprocating instruments, such as Reciproc Blue (VDW) and WaveOne Gold (Dentsply Maillefer), undergo complex heating-cooling proprietary treatments that results in a visible titanium oxide layer in the surface of the instrument. This treatment controls the transition temperatures, creating a shape memory alloy, which is claimed by the manufacturers to result in superior mechanical properties and performance of the NiTi instruments. It has been recently shown that Reciproc Blue showed improved all-around performance when compared with conventional M-Wire Reciproc, demonstrating improved flexibility and fatigue resistance and reduced microhardness while maintaining similar surface characteristics (4). However, to date, no data are available on the mechanical properties such as torsional stress of the new Reciproc Blue instruments. Therefore, the aim of the present study was to investigate the torsional resistance behavior (maximum torque load and angular rotation) of Reciproc Blue R25 instruments and

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compare it with the M-Wire Reciproc R25 instruments. The null hypotheses tested were as follows:

1. There are no significant differences in the maximum torque load of the instruments, and
2. There are no significant differences in the maximum angular rotation of the instruments.

Material and Methods

A sample of 20 new instruments of 2 different NiTi reciprocating systems (n = 10 per system) were used in this study: M-Wire Reciproc (size #25, 0.08v taper) and Reciproc Blue (size #25, 0.08v taper). All files used were 25-mm long, with 10 instruments of each type used in torsional resistance behavior tests. For standardization and reliability of the experiment, the tested instruments were previously examined for defects or deformities under a stereomicroscope; none was discarded.

Torsional Resistance Behavior Test

The torsional load was applied until fracture to estimate the mean ultimate torsional strength and angle of rotation of the instruments (n = 10 for each system) tested using a custom-made device produced following ISO 3630-1 (11). Each file was clamped at 3 mm from the tip using a chuck connected to a torque-sensing load cell; after that, the shaft of the file was fastened into an opposing chuck able to be rotated with a stepper motor. All instruments were rotated in the counterclockwise direction at a speed of 2 rpm until file separation. The torque load (Ncm) and angular rotation (°) were monitored continuously using a torsiometer (Odeme, Luzerna, SC, Brazil), and the ultimate torsional strength and angle of rotation at failure were provided by a specifically designed computed program (Odeme Analysis TT, Odeme).

Scanning Electron Microscopic Evaluation

A scanning electron microscope (JSM 5800; JEOL, Tokyo, Japan) was used to analyze the fracture surfaces of all the tested instruments in order to observe the fracture mode. Different magnifications were used (×250 and ×1000).

Statistical Analysis

Because the preliminary analysis of the raw pooled and isolated data revealed a bell-shaped distribution (Shapiro-Wilk normality test), statistical analysis was performed by using parametric methods (Student t test). Post hoc pair-wise comparisons were performed using the Tukey test. The alpha-type error was set at 0.05. Biostat (Instituto Mamirauá, Tefé, Brazil) was used as the analytic tool.

Results

The maximum torsional strength of M-Wire Reciproc was higher than Reciproc Blue ($P < .05$). Reciproc Blue instruments showed significantly higher angular rotation to fracture than Reciproc instruments ($P < .05$). The mean and standard deviations of the maximum torque load and angle of rotation until fracture for each instrument are presented in Table 1.

Scanning electron microscopy of the fracture surface showed similar and typical features of torsional failure for the 2 types of instruments. The concentric abrasion marks and the fibrous dimple marks at the center of rotation for torsional failure are shown in Figure 1.

TABLE 1. The Mean and Standard Deviation (SD) of Torque (Ncm) and Angle of Rotation (°) of the Tested Instruments

Instrument	Torque (Ncm) mean (SD)	Angle of rotation (°) mean (SD)
Reciproc	1.66 (0.15)^A	408 (18)^A
Reciproc Blue	0.82 (0.10)^B	779 (24)^B

Different superscript letters in the same column indicate statistic differences among groups ($P < .05$).

Discussion

Fracture of NiTi rotary files may occur because of cyclic fatigue or torsional stress (12). In the first scenario, fracture is produced by repetitively compressive and tensile stress acting on the instrument while it rotates in a curved canal. Torsional fracture occurs when the instrument tip binds to the canal while the base of the instrument continues to rotate (13). Although it might be difficult to correlate the findings of laboratory tests to a clinical situation because of the amount of variables acting together to result in the fracture of the instrument (14), it is important to investigate the mechanical properties of endodontics instruments in order to present valid information for the clinician (1, 2). In a comprehensive literature review, there was no study evaluating the torsional resistance behavior of Reciproc Blue instruments. For this reason, the aim of the present study was to evaluate these properties of Reciproc Blue and to compare them with those obtained by M-Wire Reciproc instrument.

The methodology used in the torsional resistance behavior test was reported and validated in previous studies (15–17). In this study, 3 mm of the tip was fastened, and rotation in a counterclockwise direction was set for both instruments. The torque was applied in a counterclockwise direction for both instruments because of the direction of their spiraling flutes. Several variables such as instrument tip size, taper, cross-sectional design, and manufacturing techniques affect the clinical performance of endodontic files and their resistance to fracture by torsion (15–17). However, in the present study, the influence of file design on the tested parameters was virtually eliminated by testing instruments that differ only in their NiTi alloy. The present study measured the ultimate torsional strength by single-direction rotation at a constant but slow speed. One may contest the methodology to assay instruments designed to be used in a reciprocating motion because this fixed torsional test does not reflect the clinical application of reciprocating instruments. However, it is obvious that an instrument with a higher resistance behavior in this test would have better durability against the repetitive torsional stresses. Besides that, it is important to emphasize that Reciproc instruments (M-Wire or Blue) complete a rotation of 360° after clockwise and counterclockwise movements in different angulations, being susceptible to torsional fracture.

The results of the torsional resistance behavior test showed that the maximum torsional strength of Reciproc Blue was lower than M-Wire Reciproc ($P < .05$). Therefore, the first null hypothesis was rejected. These findings indicate that M-Wire Reciproc is more resistant to torsional fracture than Reciproc Blue and requires a higher strength to fracture. This might result in a lower chance of M-Wire Reciproc breaking in a clinical situation when the tip of the instrument binds to the canal (eg, in constricted canals that might induce higher torsional load stresses). This is related to the type of alloy used in its manufacturing process. Previous studies have shown that the blue thermal–treated alloy has greater flexibility and lower torsional load than conventional M-Wire alloy (4, 18).