The Effects of Torsional Preloading on the Torsional Resistance of Nickel-titanium Instruments

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Abstract

Introduction: This study evaluated the effect of torsional preloading on the torsional resistance of nickel-titanium (NiTi) endodontic instruments. **Methods:** WaveOne Primary (Dentsply Maillefer, Ballaigues, Switzerland) and ProTaper Universal F2 (Dentsply Maillefer) files were used. The ultimate torsional strength until fracture was determined for each instrument. In the phase 1 experiment, the ProTaper and WaveOne files were loaded to have a maximum load from 2.0 up to 2.7 or 2.8 Ncm, respectively. In the phase 2 experiment, the number of repetitions of preloading for each file was increased from 50 to 200, whereas the preloading torque was fixed at 2.4 Ncm. Using torsionally preloaded specimens from phase 1 and 2, the torsional resistances were calculated to determine the ultimate strength, distortion angle, and toughness. The results were analyzed using 1-way analysis of variance and Duncan post hoc comparison. The fracture surfaces and longitudinal aspect of 5 specimens per group were examined under a scanning electron microscope. **Results:** All preloaded groups showed significantly higher ultimate strength than the unpreloaded groups ($P < .05$). There was no significant difference among all groups for distortion angle and toughness. Although WaveOne had no significant difference between the repetition groups for ultimate strength, fracture angle, and toughness, ProTaper had a higher distortion angle and toughness in the 50-repetition group compared with the other repetition groups ($P < .05$). Scanning electron microscopic examinations of the fractured surface showed typical features of torsional fracture. **Conclusions:** Torsional preloading within the ultimate values could enhance the torsional strength of NiTi instruments. The total energy until fracture was maintained constantly, regardless of the alloy type. *(J Endod 2017;43:157–162)*

Key Words

M-wire, nickel-titanium rotary file, preloading, torsional load, torsional resistance

Significance

The appropriate torsion-limit setting in an endodontic motor may reduce the torsional fracture of nickel-titanium instruments because of the increased torsional strength by repetitive torsional stress.

Numerous attempts to date have been made to prepare the root canal effectively and safely. These include modification of the preparation technique, the development of shaping instruments, and the use of irrigation devices and various intracanal medicaments. The introduction of nickel-titanium (NiTi) rotary instruments is one such attempt. Currently, NiTi rotary instruments have been extensively used in endodontic practice.

Root canal preparation with NiTi rotary files is not only easier and faster but also causes fewer iatrogenic alterations in the shape of the root canal than preparation with hand instruments (1). Although the flexibility and strength have been enhanced (1) when compared with other endodontic files, NiTi rotary instruments are still subject to separation in the clinical situation (2–5). Because of the lower yield strength and ultimate tensile strength of NiTi alloy in comparison with stainless steel, NiTi instruments are more susceptible to fracture at a lower force than stainless steel instruments (6–8).

The separation of NiTi instruments has been studied extensively using a variety of methodologies (5, 9–14). Previous literature has reported that NiTi endodontic instruments have 2 modes of fracture (9, 11–14). Flexural or cyclic fatigue occurs when an instrument rotates in a curved canal and is thus exposed to repeated compressive and tensile stresses. Cyclic fatigue is highly associated with the lifetime of NiTi files (4, 5, 9, 11). On the other hand, torsional failure occurs when the tip of the instrument binds in the canal, but the engine continues being rotated (5).

Clinically, cyclic fatigue seems to be more prevalent in curved root canals, whereas torsional failure might happen even in a straight canal (5, 12). Most of the previous studies regarding the fracture of instruments have been conducted separately for cyclic fatigue or torsional failure tests (5, 9, 12–14). However, the stress generated during clinical root canal preparation is of a complex type rather than 1 mode of cyclic fatigue or torsional failure. A few reports (15, 16)

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have correlated the 2 fracture modes simultaneously and indicated that flexural preloading of NiTi rotary files would reduce the torsional resistance significantly. In addition, other articles reported that a certain degree of torsional preloading would enhance the cyclic fatigue resistance (10, 17).

In the clinical situation, as a result of the diversity of canal dimensions, NiTi rotary instruments may be subject to torsional stress of various degrees during root canal preparation, especially during the early stages of canal enlargement. Various types of torque control motors for endodontic NiTi instruments are available for rotational movement and reciprocating movement. During rotational or reciprocating movements, files may have momentary torsional stresses depending on the torque setting, root canal conditions, or operator's handling (18, 19). Thus, it was worthwhile to investigate how repetitive torsional preloads influence the torsional resistance of NiTi rotary instruments. Therefore, the objective of the present study was to evaluate the effect of torsional preload on the torsional resistance of selected NiTi endodontic instruments.

Materials and Methods

Selection of Materials

Two NiTi instrument systems, WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), a reciprocating system, and ProTaper Universal (Dentsply Maillefer), a system that continuously rotates in 1 direction, were selected for this study. WaveOne and ProTaper are made from M-wire and conventional NiTi, respectively. The sizes of the WaveOne and ProTaper were Primary and F2, which have an identical #25 (standard endodontic file) tip size with 8% taper at the apical few millimeters. They were selected because they possess similar cross-sectional and longitudinal designs, except for the helical direction of the flute, and thus a similar cross-sectional area at the same length.

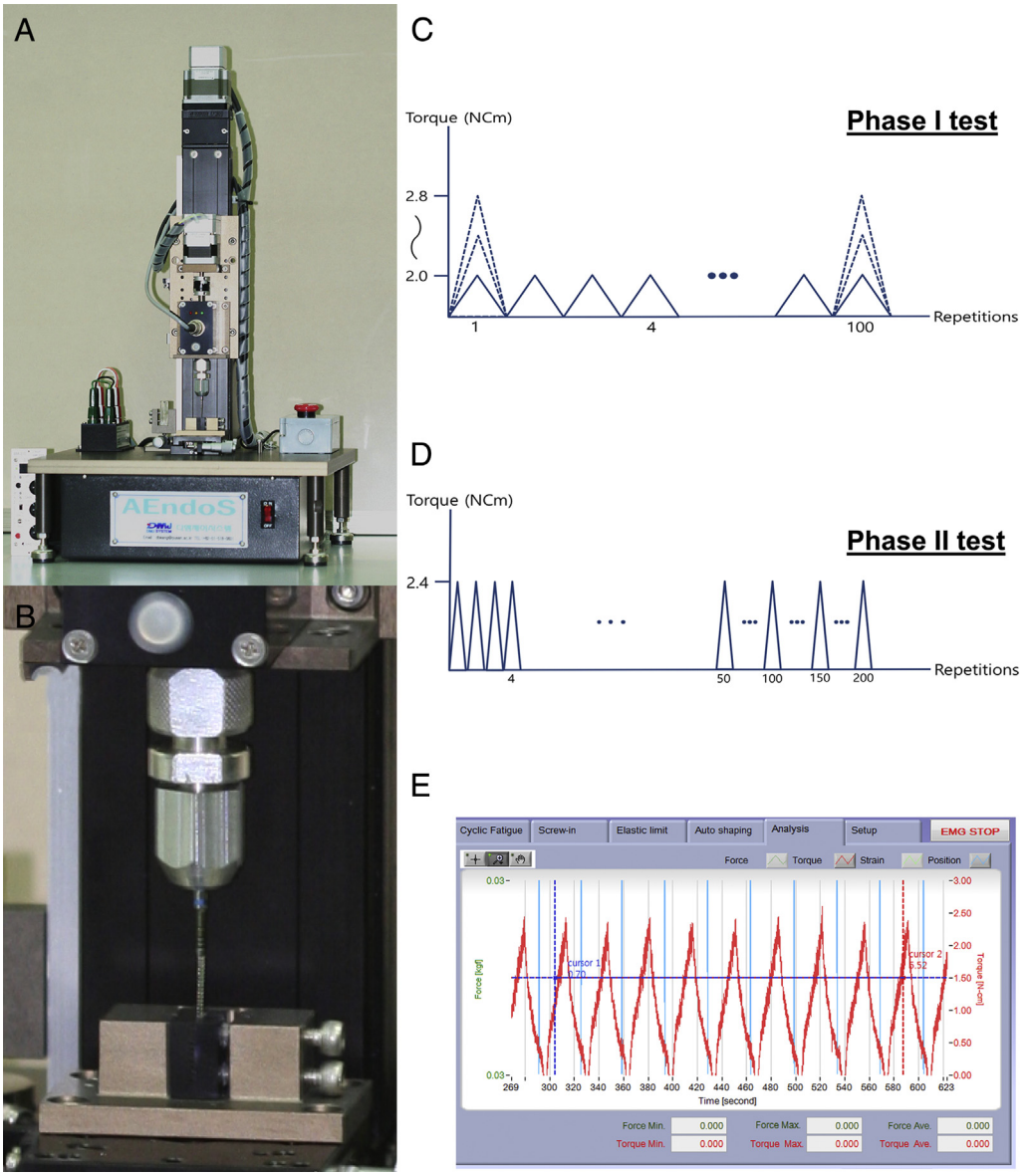

Figure 1. (*A*) The device (AEndoS) for applying torsional loads. (*B*) The part of the AEndoS used to hold a file between resin blocks during the repetitive torsional load test. (*C*) Various torsional preloading conditions from 2.0 up to 2.8 Ncm for 100 times in the phase 1 test. (*D*) Up to 200 repetitions compared with 50 repetitions at 2.4 Ncm in the phase 2 test. (*E*) Representative loading-unloading curve during the preloading for WaveOne Primary with the preset torque of 2.4 Ncm.