ARTICLE IN PRESS
+ MODEL
Journal of Dental Sciences (2018) xx, 1–6

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.e-jds.com

Journal of Dental Sciences

Original Article

Evaluation of dynamic and static torsional resistances of nickel-titanium rotary instruments

Ibrahim H. Abu-Tahun [a], Jung-Hong Ha [b], Sang Won Kwak [c], Hyeon-Cheol Kim [c*]

[a] *Department of Conservative Dentistry, School of Dentistry, The University of Jordan, Amman, Jordan*
[b] *Department of Conservative Dentistry, School of Dentistry, Kyungpook National University, Daegu, South Korea*
[c] *Department of Conservative Dentistry, School of Dentistry, Dental Research Institute, Pusan National University, Yangsan, South Korea*

Received 30 October 2017; Final revision received 25 November 2017
Available online ■ ■ ■

KEYWORDS
Fracture;
Nickel-titanium rotary instrument;
Torsional resistance;
Dynamic repetitive load;
Static rotation

Abstract *Background/purpose:* This study evaluated the torsional resistances of nickel-titanium rotary instruments by two methods: i) dynamic resistance: repetitive torsional loading (RTL) and ii) static resistance: single torsional loading (STL) based on the International Organization for Standardization.
Materials and methods: In RTL method, a pre-set rotational loading (0.5 N cm) was applied after fixing the 3-mm tip of the file, and this clockwise loading to the pre-set torque and counter-clockwise unloading to original position was repeated at 50 rpm until the file fractured. The number of repetition cycles until fracture was counted. In STL method, the torsional strength was determined by continuous clockwise rotation (2 rpm) until fracture. Results from both methods were compared after testing the torsional resistances of four instrument systems ($n = 15$): Hyflex CM, HyFlex EDM, V-Taper2, and V-Taper2H. A scanning electron microscope (SEM) was used to examine the topographic features of the fractured surfaces and longitudinal aspects ($n = 5$) from both methods.
Results: The RTL and STL methods had similar results: V-Taper2 had the highest resistance and the Hyflex CM had the lowest ($P < 0.05$). Spearman correlation test showed the results from two methods were strongly correlated (coefficient = 1). Under the SEM, specimens from the RTL showed ruptured aspects on cross-sections with multiple areas of crack propagation, while the STL showed the typical features of torsional failure such as circular abrasion marks and fatigue dimples.
Conclusions: This study suggests the clinically relevant torsional test (RTL) method yield similar results with the STL method, but they have different topographic findings.

* Corresponding author. Department of Conservative Dentistry, School of Dentistry, Pusan National University, Geumo-ro 20, Mulgeum, Yangsan, Gyeongnam, 50612, South Korea. Fax: +82 55 360 5214.
E-mail address: golddent@pusan.ac.kr (H.-C. Kim).

https://doi.org/10.1016/j.jds.2017.12.002

Introduction

Root canal preparation with nickel-titanium (NiTi) rotary files is not only easier and faster than preparation with hand instruments, but also causes fewer iatrogenic alterations to the shape of the root canal.[1] Notwithstanding the enhanced flexibility and strength compared with other endodontic files, NiTi rotary instruments are still subject to separation in the clinical use.[2–4]

It has been previously reported in the literature that NiTi endodontic instruments have two basic mechanisms of fracture.[3–6] Flexural or cyclic fatigue fractures occur when an instrument rotates in a curved canal, and are caused by repeated compressive and tensile stresses.[3,4,6] On the other hand, torsional failure correlates with the continuous rotation of the engine when the tip of the instrument binds in the canal.[4]

Cyclic fatigue resistance of NiTi rotary instruments has been assessed extensively, but there is little information available on torsional fracture resistance tests. The only method of testing for static rotational fracture is the comparing the torsional resistances of the instruments. This method was mainly based on the International Organization for Standardization (ISO) 3630-1.[7] However, its original purpose was for testing stainless steel manual endodontic instruments. According to this specification, the 3 mm file tip was fixed with the brass and 2 rpm of rotational speed was applied to create a torsional load. However, the test conditions with a rotational speed of 2 rpm to create torsional stress and the static rotation until a fracture are not sufficient for testing the rotary instruments that rotate at speeds much higher than 2 rpm or for the specific motors with "auto-reverse" mode.

During the clinical use of rotary NiTi instruments, the file undergoes repetitive locking and unlocking by the auto-reverse movements at a pre-fixed level of torsional stress. Fatigue may be defined as the failure of a material after repetitive stress at levels below its yield point.[8] Clinically, no one file will be fractured by static rotation until fracture by a continuous loading as the ISO test method. On the other hand, rotary instruments will be loaded by repeated locking (and release) by using the torque-control motor.[9] Especially, in narrow canals, rotary instruments are subject to higher torsional stresses than in the wider canals,[10] hence the chance of experiencing such repetitive torsional loads are increased.

Thus, in this study, the torsional resistances of various NiTi instruments were compared using the method with dynamic and repetitive torsional loads that incorporates the clinically relevant auto-reverse motion. The method was compared with the ISO based method.

Materials and methods

Two torsional test methods were conducted with four NiTi instrument systems: Hyflex CM (HCM; Coltene, Altstätten, Switzerland) made of CM-wire, HyFlex EDM (HDM; Coltene) produced via electro-discharge machining (EDM) using CM-wire, V-Taper2 (VT2; SS White, Lakewood, CA, USA) made of conventional NiTi alloy, and heat treated V-Taper2H (VTH; SS White). The files used in this study had the same ISO tip size of #25, a similar taper (0.06 taper for HCM and VTH, 0.08 taper for VT2 and variable taper for HDM), and 25-mm length. No defects or deformities were detected on any instrument upon inspection under a dental operating microscope (Zeiss Pico; Carl Zeiss MediTec, Jena, Germany) prior to the experiment.

Test I: determination of torsional resistance by repetitive torsional load (RTL)

The apical 3 mm portion each instrument ($n = 15$ per brand) was secured between brass plates. The file was driven at 50 rpm clockwise until it achieved the pre-set torque of 0.5 N cm, then it was returned to its original position using a custom-made device (AEndoS; DMJ system, Busan, Korea) (Fig. 1). This was considered one torsional loading cycle. Dwell time was set as 50 ms. The loading was repeated automatically until the file broke. The custom-made device automatically recorded the number of repetitive load cycles until fracture (NRCF) of each instrument.

Test II: determination of the torsional resistance by static rotational torsional load (STL)

The ultimate torsional strength (N·cm) until fracture was determined for each instrument ($n = 15$ per brand) using the same device. The apical 3 mm portion of the instrument was secured between brass plates. They were then rotated at a constant rate of 2 rpm in a clockwise direction until fracture, while keeping the files straight. The torsional loading during rotation including the maximum strength (N·cm) and distortion angle (degree) were recorded during the rotation of the files at the rate of 20 Hz (20 data of torque values were collected per 1 s). The toughness until the point of fracture was computed from the area under the plot by using Origin v 6.0 Professional (Microcal Software Inc., Northampton, MA, USA).

The data were first examined using the Kolmogorov–Smirnov test for normality of distribution. The results were statistically analysed using a one-way analysis of variance (ANOVA) and Duncan post-hoc