Effect from Rotational Speed on Torsional Resistance of the Nickel-titanium Instruments

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Abstract

Introduction: The purpose of this study was to evaluate differences in torsional resistance using up-regulated speed of rotational spindle. **Methods:** Three NiTi rotary instrument systems were selected in this study: K3XF (SybronEndo, Glendora, CA), BLX (B&L Biotech, Ansan, Korea), and OneShape (MicroMega, Besançon, France). The tip size and taper for all files were #25 and 0.06. Experimental groups (n = 10/group) were assigned to 2-, 60-, 350-, and 600-rpm groups by the rotational speed of spindle. Forty new files were used for each test. The file tip of 5-mm length was secured between brass plates. While keeping the file straight, it was rotated clockwise at a constant rotational speed until fracture occurred. The parameters of torsional resistance, torsional load (Ncm), and distortion angle (°) were measured using an AEndoS-*k* (DMJ System, Busan, Korea), and the toughness until fracture was computed from these data. The 1-way analysis of variance test was used to analyze the torsional resistance at a significance level of 95%. All fractured fragments were observed under a scanning electron microscope to evaluate the topographic features of the fractured surfaces. **Results:** No significant difference in torsional resistance was found among groups when they were compared for ultimate strength at the maximum torque, fracture angle, and toughness. Scanning electron microscopic examination of the fractured cross-sectional surfaces revealed typical features of torsional fractures, concentric abrasion marks, and fibrous dimples from the torsional center. **Conclusions:** Under the conditions of the study, the torsional resistances of the rotary instruments were not affected by the rotational speed. *(J Endod 2016;■:1–4)*

Key Words

Instrument fracture, nickel-titanium rotary file, rotational speed, test methods, torsional resistance

Significance

Different rotational speeds (eg, 2, 60, 350, and 600 rpm) do not change the torsional resistance of nickel-titanium rotary files regardless of the alloy or heat treatment of the instruments.

The majority of previous studies on nickel-titanium (NiTi) rotary file separation have reported cyclic fatigue and/or torsional resistance (1–5). Cyclic fatigue resistance has been determined by counting the number of cycles until fracture (NCF) when the files have been repetitively flexurally stressed in a curved canal structure. Torsional fracture resistance has been determined by measuring the ultimate strength at the maximum torque of the file and the distortion angle of unwinding during rotation of the files while their apical tip has been locked in place (6–8).

The cyclic fatigue test has been performed under these artificial root canal conditions in an attempt to simulate a curved canal. For the most part, the files have been rotated in the canal at the manufacturers' recommended rotational speed, commonly around 300 rpm. However, when investigating the torsional resistance test, the rotational speed has most commonly been reported to be 2 rpm, and the instrument was chucked at the point of 3 or 5 mm from the tip (6, 7). Those experimental designs of the torsional resistance test were based on the American Dental Association (ADA) specification no. 28 (9), which set a limit on the rotational speed (2 rpm) of the spindle and the level (2 mm) of apical chuck. Although the ADA method was originally designed to test the mechanical performance of stainless steel (SS) hand files, it has also been used for NiTi rotary instruments, even though they have a much higher recommended rotational speed of spindle (10–13).

Many different NiTi instrument systems are supposed to be used at around 300 rpm according to the manufacturers' instructions. Some more contemporary NiTi instruments systems, such as iRaCe (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), BioRaCe (FKG Dentaire SA), HyFlex CM (Coltene Endo, Cuyahoga Falls, OH), and BLX (B&L Biotech, Ansan, Korea), are recommended to be used at a higher rotational speed (eg, 500–1000 rpm). Li et al (14) evaluated cyclic fatigue resistance depending on revolutions per minute using ProFile (Dentsply Maillefer, Ballaigues, Switzerland) and found that the time to failure significantly decreased as the rotational speeds were increased although the cycles until fracture were not significantly affected. To the best of our knowledge, there is no published evidence about proper revolutions per minute to test the torsional resistance of NiTi rotary instruments or any potential effect from the rotational speed on torsional resistance.

Therefore, the aim of this study was to evaluate the difference of torsional resistance to failure with different speeds of the rotational spindle. The null hypothesis

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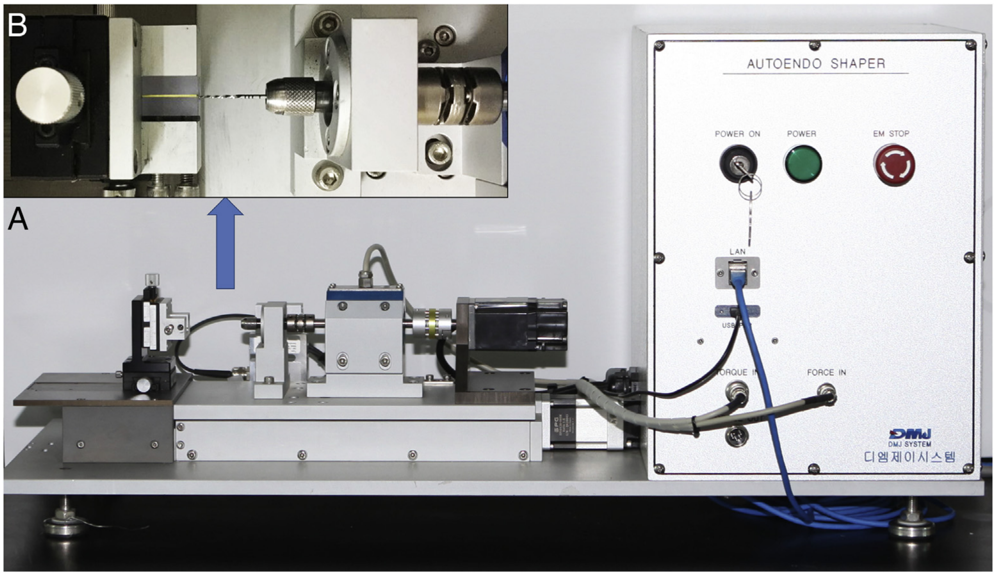

Figure 1. (*A*) The custom-ordered test device (AEndoS-*k*, DMJ System, Busan, Korea) used in this study. (*B*) The NiTi rotary instrument secured between 2 brass plates for torsional loading.

was that there was no difference in the torsional resistance with an increase in the spindle speed.

Materials and Methods

Three NiTi rotary instrument systems were selected for this study: K3XF (SybronEndo, Glendora, CA), BLX, and OneShape (MicroMega, Besançon, France). The selected tip size was #25, and the taper was 0.06. The experimental rotational speeds were selected as 2, 60, 350, and 600 rpm. Forty new files from each file system were used in this study, 10 files for each of the different speeds (n = 10/group).

The parameters of torsional resistance were measured using an AEndoS-*k* (DMJ System, Busan, Korea) (Fig. 1*A* and *B*) as described Ha et al (7). Briefly, 5 mm of the file tip was secured between 2 brass plates. While keeping the file straight, it was rotated clockwise at a constant rotational speed until fracture occurred. During the file rotation, the torsional load (Ncm) and distortion angle (°) were recorded at the rate of 20∼6000 Hz depending on their rotational speed to ensure the same amount of data acquisition (torsional load per rotational degree unit) for each rotational speed. The toughness until fracture was computed from the area under the plot presenting the distortion angle (x-axis) and torsional load (y-axis) by using Origin v6.0 Professional (Microcal Software Inc, Northampton, MA).

The data were first analyzed using the Kolmogorov-Smirnov test to evaluate the assumption of normality. The 1-way analysis of variance test was used to analyze the torsional resistance at a significance level of 95% using SPSS software (SPSS v22.0 for Mac; IBM Corp, Somers, NY).

After the torsional test, all fractured fragments were observed under a scanning electron microscope (SU8220; Hitachi High-Technologies Corporation, Tokyo, Japan) to evaluate the topographic features of the fractured surfaces.

Results

The results for the torsional resistance test for each file are shown in Table 1. No significant difference in torsional resistance was found among groups when they were compared for ultimate strength at the maximum torque, fracture angle, and toughness. Therefore, the null hypothesis tested was accepted, and there were no mechanical effects on the torsional resistance by rotational speed.

Scanning electron microscopic examination of the fractured cross-sectional surfaces revealed typical features of torsional fractures, concentric abrasion marks, and fibrous dimples from the torsional center (Fig. 2*A–C* and *a–c*). There was no topographic difference between files in the different speed groups.

Discussion

Although over 2 decades have passed since the first introduction of NiTi rotary instruments, the methodology of evaluating mechanical properties has not been completely adjusted to the new technology and alloys. Because instrument fracture is a serious clinical problem, a lot of studies have been performed to investigate the reasons and

TABLE 1. The Results of the Torsional Resistance Test according to Revolutions per Minutes (rpm) of the Testing Motor (Mean ± Standard Deviation)

Product	rpm	Distortional angle (°)	Ultimate strength at maximum torque (Ncm)	Toughness (° • Ncm)
BLX	2	352 ± 22	1.81 ± 0.16	449.9 ± 44.2
	60	341 ± 33	1.81 ± 0.20	430.2 ± 43.0
	350	335 ± 20	1.84 ± 0.14	427.2 ± 40.9
	600	341 ± 19	1.83 ± 0.09	467.0 ± 28.4
P value		.465	.968	.105
K3XF	2	581 ± 66	2.47 ± 0.23	1045.2 ± 130.9
	60	583 ± 69	2.41 ± 0.17	1117.4 ± 131.8
	350	580 ± 63	2.48 ± 0.23	1192.6 ± 159.9
	600	575 ± 77	2.44 ± 0.22	1091.9 ± 142.1
P value		.994	.856	.148
OneShape	2	434 ± 70	2.10 ± 0.22	673.3 ± 111.0
	60	418 ± 31	2.24 ± 0.20	674.6 ± 057.8
	35	410 ± 74	2.15 ± 0.23	616.5 ± 122.7
	600	408 ± 60	2.14 ± 0.19	696.2 ± 111.3
P value		.766	.444	.366

For all products, there were no significant differences for distortional angle, ultimate strength of maximum torque, and toughness (1-way analysis of variance, $P < .05$).