Torsional Profiles of New and Used Revo-S Rotary Instruments: An *In Vitro* Study

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Abstract

Introduction: This study investigated the torsional properties of new and used Revo-S Shaping Universal (SU) endodontic instruments. **Methods:** Torsional profiles were established following the American National Standards Institute/American Dental Association Specification No. 28. Unused SU instruments (group 1, control; n = 30) and instruments used in simulated root canals twice (group 2, n = 30) or six times (group 3, n = 30) were tested. Analysis of variance with the Bonferroni/Dunn post hoc test ($\alpha = 0.05$) was used to analyze the torque and angle of rotation at fracture. **Results:** The maximum torque at fracture did not differ significantly among instruments in group 1 and groups 2 and 3. The angle of rotation at fracture decreased significantly ($P < .01$) from group 1 to groups 2 and 3. **Conclusions:** The repeated use of the SU rotary instruments significantly reduced the angle of rotation at fracture but did not reduce the torque at fracture. *(J Endod 2011;37:989–992)*

Key Words

Fatigue, nickel-titanium, Revo-S, torque

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Endodontic instrument fracture is an undesirable occurrence in clinical practice and one of the major concerns when rotary instruments are used (1–3). Rotary endodontic instruments may fracture because of flexural fatigue, torsional load (4–6), or a combination of both (7). Flexural fatigue results from rotating an instrument freely in a curvature, subjecting it to repeated episodes of tension and compression at the point of maximum flexure. Torsional failure occurs when the rotational torque load applied to the instrument exceeds the instrument's torque limit. Typically, this occurs when the file tip binds within the canal while rotation continues, causing the tip of the instrument to fracture (2, 4). In clinical applications, rotary endodontic instruments are frequently subjected to composite flexural and torsional stresses (7).

The torsional specifications for rotary endodontic instruments and the method for testing torsional profiles are described in the American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. 28 (8). Torsional properties are defined as the torque and angle of rotation associated with fracture at 3 mm from the instrument tip (diameter D3). The testing method has been used in many studies to investigate the torsional profiles of various types of nickel-titanium (NiTi) rotary instruments (7, 9–12).

Recently, the new Revo-S NiTi instrument system (Micro-Mega, Besançon, France) has been introduced, which includes three shaping instruments; the shaping and cleaning instrument (SC) number 1 (SC1) is a #25/.06 taper rotary used to enlarge the coronal two thirds of the canal. SC2 is a #25/.04 taper instrument used to the working length, and universal shaper (SU) is a #25/.06 taper also used to the working length. The latter is the only rotary in this system expected to cut along the entire canal length, which may result in high stresses on the instrument. However, it features an innovative asymmetrical cutting profile, which is also present in the SC1 instrument (Fig. 1*A* and *B*) and is intended to reduce torsional stress on the instrument. The use of additional instruments for apical enlargement at sizes #30, 35, and 40 is optional. The manufacturer suggests that the Revo-S instruments can be used several times; however, to the authors' knowledge, no data have been reported on how repeated use of these instruments might affect their torsional properties. Therefore, the aim of this study was to develop a torsional profile for the Revo-S SU instrument, the one within the system that combines the new design feature and engages the root canal dentin along its entire cutting length, before and after repeated use.

Materials and Methods

A sample size calculation and power analysis for this experiment indicated that 30 instruments per group were required for an analysis with 88% power at a 5% level of significance. Accordingly, 90 sets of new Revo-S instruments were allocated into three equal groups (n = 30) as follows: group 1, unused instruments (control); group 2, instruments used to shape two simulated root canals (two uses); and group 3, instruments used to shape six simulated root canals (six uses).

A pilot study was conducted to calibrate the two operators in this study with regards to the use of the Revo-S system by having each operator prepare 10 simulated canals. All instruments were autoclaved at 134°C for 3.5 minutes (Stat/ML Cassette Autoclave; SCi Can, Pittsburgh, PA) initially and again after each use. Plastic blocks (ref. #61000002, Micro-Mega) were used to simulate canal preparation with the test instruments. The canals were 17-mm long and 0.015 mm in diameter, with a 45° curve in the apical 3.5 mm. The working length

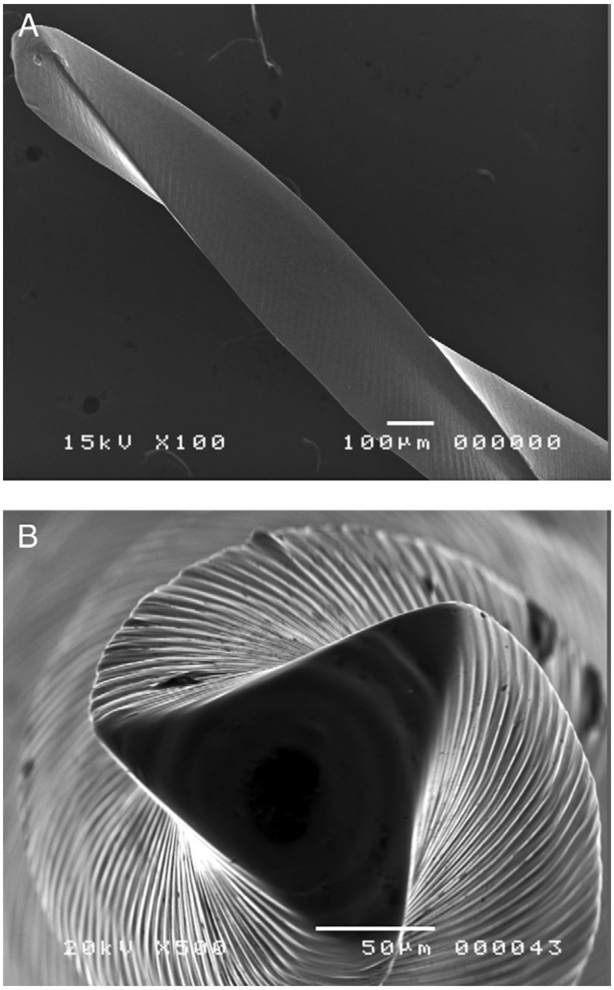

Figure 1. (*A* and *B*) Scanning electron micrographs (100× and 500×) of the Revo-S SU instrument showing the asymmetric cross-section. (Courtesy of Dr Diemer.)

was established at 16 mm and patency verified with a K-type hand file ISO #10 (Flexofile; Dentsply Maillefer, Ballaigues, Switzerland). Two experienced clinicians prepared the canals after training with the Revo-S rotaries; an 8:1 reduction handpiece powered by a torque control motor (AE U-20; Dentsply Tulsa Specialties, Tulsa, OK) was used at 300 rpm and at a torque setting level of 2 (1.5 Ncm). Canals were irrigated intermittently with 5 mL of 2.5% NaOCl using a 27-G needle and recapitulated with a size 10 K-type file. The Revo-S three-step crown-down sequence was used according to the manufacturer's instructions; SC1 was used with slow and unique downward movement in a free progression and without pressure, SC2 was used with a progressive three-wave movement (up and down movement), and SU was used with a slow and unique downward movement in a free progression and without pressure. Then, patency was checked, and an upward circumferential filing movement was performed. If SC2 or SU did not reach the working length on the first attempt, the protocol was repeated until SU reached working length. After use, instruments were wiped clean with alcohol-soaked gauze, inspected for deformation with 2.5× magnification (Optical Microscope; Global Surgical Corporation, St Louis, MO), and sterilized before subsequent use in another simulated canal. Deformed instruments were replaced before canal preparation was continued.

All new and used SU instruments were tested in accordance with ANSI/ADA Specification No. 28 (8). The torque and angle of rotation at fracture during clockwise rotation were measured using a custom torque bench described in detail elsewhere (7, 10). The instrument shank was secured into a brass chuck connected to a stepper motor (Type ZSS; Phytron, Gröbenzell, Germany) mounted on a stable metal plate and rotated at 2 rpm. The instrument tip at 3 mm was secured in a precision-milled chuck with soft brass jaws, which allowed reproducible positioning of the instrument tip. Data for torque and angle at fracture were recorded by a digital torque sensor (MTTRA 2, Microtest; Microtec Systems, Villingen, Germany) connected to a computer program (ENDOTEST; Division of Endodontology, University of Zurich, Switzerland) controlling the stepper motor equipped with a 12-bit interface sensor (PCI-MIO-16XE; National Instruments, Austin, TX) and digitized at 10 Hz.

Preliminary variable distributions were generated and outliers identified. The main outcome measures were torque (Ncm) and angle of rotation (°) at fracture. The torque value was determined as the average of five data points immediately before a sudden drop to zero. The maximum torque was also recorded. The experimental variable was the number of uses (zero, two, and six). After normality conditions were verified, data were contrasted using chi-square tests (incidence of permanent deformation) and analysis of variance with the Bonferroni/Dunn tests for post hoc comparisons (StatView, Berkeley, CA). The alpha-type error was set at 0.05.

Results

The results recorded did not differ significantly ($P > .05$) between the experiments conducted by the two operators; therefore, the data from both operators were pooled. Signs of permanent deformation were noted in 3 of 30 (10%) and 13 of 30 (43%) of the SU instruments

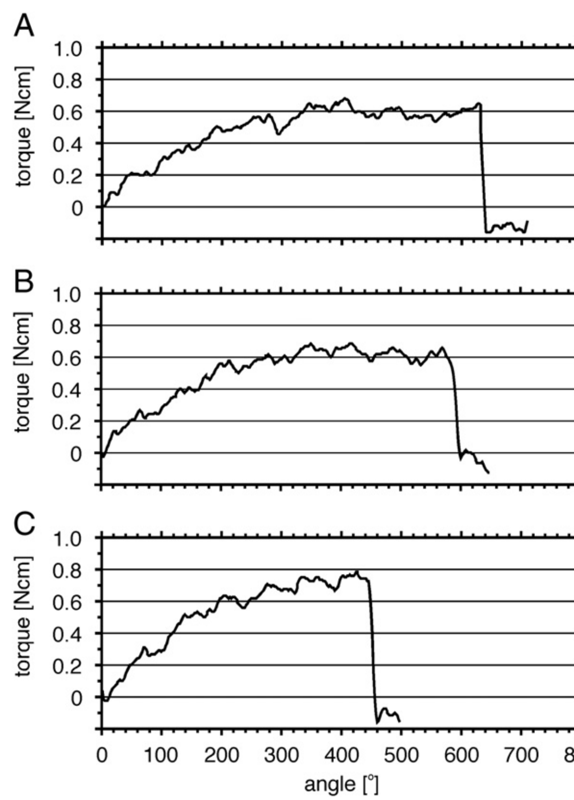

Figure 2. Representative torque profiles of Revo-S instruments in unused (new) conditions (group 1, *A*) and used in 2 resin blocks (group 2, *B*) or six resin blocks (group 3, *C*). The torque and angle of rotation are indicated in the y- and x-axis, respectively.

TABLE 1. Mean (and standard deviation) Torque and Angle at Fracture Recorded for Revo-S SU Instruments Tested Unused or after Use to Shape Simulated Canals (n = 30 per group)

Group	Mean torque (standard deviation) (Ncm)	Mean angle (standard deviation) (°)
1 (new)	0.65 (0.16)	657.5 (92.8)[ab]
2 (two uses)	0.71 (0.18)	573.7 (105.0)[ac]
3 (six uses)	0.72 (0.18)	477.5 (132.1)[bc]
Analysis of variance	$P = .2166$	$P < .001$

Significant differences between groups are indicated by letters ($P < .01$).

in groups 2 (two uses) and 3 (six uses), respectively. This difference was significant ($P < .05$). Typical torque curves (Fig. 2) showed a rapidly increasing phase followed by some yielding and an extended level (plateau) phase. Occasionally, a point of maximum torque was recorded before instrument fracture, but in other cases the maximum torque coincided with the fracture. Overall, the mean maximum torque value (0.85 Ncm) was ~21% higher than the mean torque at fracture (0.70 Ncm), but this difference was not statistically significant.

Means and standard deviation values of torque and angle of rotation at fracture for the three groups are shown in Table 1. The differences among the three groups in torque at fracture were not statistically significant ($P > .05$). The angle at fracture differed significantly among the groups ($P < .001$, Table 1), decreasing significantly ($P < .01$) from group 1 (new instruments) to group 2 (two uses) and from group 2 to group 3 (six uses) ($P < .01$).

Discussion

Understanding the causes of instrument fracture is critical to minimize its occurrence in a clinical scenario. Because the design features may affect an instrument's susceptibility to fracture, the characterization of the risk parameters for fracture is imperative for every new instrument design. Also, it has been shown that the susceptibility of NiTi rotary instruments to fracture increases with repeated use (5, 7). With these issues in mind, the torsional profiles of unused and used SU instruments of the new Revo-S series were investigated.

The asymmetric cross-sectional geometry of the Revo-S SU instrument is an innovative feature intended to decrease the stress during root canal preparation. The manufacturer predicts that this new instrument geometry will facilitate canal penetration and upward removal of debris, both of which are expected to reduce the stress on the instrument. However, a finite-element analysis predicted that cross-sections with sharp and fine points may have poorer stress distribution than those with a convex or triple-helix configuration (13).

The comparable results recorded by both operators indicated that the calibration experience adequately prepared the operators for the usage of the test instruments. Resin blocks were used to standardize the canal diameter, length, curvature, radius, and wall hardness, which is seldom attainable with extracted teeth. Considering that resin has approximately half the hardness of dentin (14), the use of two and six resin blocks was chosen to reflect their clinical usage in a single canal or a molar, respectively, even though the difference between real dentin and resin blocks is more than just hardness. The testing followed the ubiquitous ANSI/ADA Specification No. 28 to ascertain the universality of the results and to allow comparisons with data obtained for other instruments.

No significant differences in the torque at fracture and the maximum torque were observed between the new and used SU instruments. Ullmann and Peters (7) suggested that unless instruments are considerably prestressed to make them susceptible to fracture, differences in torque values at fracture are small. However, a significant reduction of the angle at fracture was observed between new and used instruments and between instruments used in two or six canals in the present experiment. This increased brittleness of the instruments is believed to result from torsional loading stress and flexural fatigue during use, leading to the development of tension and compression zones that propagate microfractures induced during instrument manufacture. Plastic deformation of the instrument's flutes may also result from stress that leads to fracture of the instrument (15).

Data for direct comparison between the Revo-S and other rotary instruments are currently unavailable. When comparing our results with data recorded in previous studies with similar methodology, different values were observed. Although the mean torque at fracture for the Revo-S SU instrument was 0.69 Ncm, higher values of 0.86, 1.41, and 2.11 Ncm have been reported for 20/.06 GTX, K3 25/.06, and ProTaper F2 25/.06 instruments, respectively (7, 11, 16). This variance in the torsional profile results may be explained by the differences in raw alloy and the design used in the manufacture of various instruments. With regards to design, the core of the instrument plays an important role in the instrument's susceptibility to torsional fatigue leading to fracture. The core should be resistant enough to prevent fracture while being sufficiently flexible to permit the instrument to negotiate severe curvatures.

We attempted to simulate the clinical usage of cleaning and shaping instruments by using a glide path, NaOCl irrigation, sterilization cycles between instrument uses, and prestressing of the instruments before torsional testing. However, the findings reported herein should not be directly extrapolated to clinical situations. Further investigations in extracted tooth models are required to refine the characterization of the torsional profiles and the susceptibility to fracture of the new Revo-S instruments. This appears to be critical in light of the current discussion on the reuse of NiTi rotaries, either because of the potential transmission of disease or the increased fracture risks. The current and future data will also be critical for the proper programming of the torque-control motors used to drive instruments during canal preparation. Such programming when incorporated with the clinical judgment on the number of instrument uses and the selection of cases would be useful to provide a margin of safety that will allow the clinician to withdraw the instrument in time to avoid catastrophic fracture.

Conclusion

The recurring use of Revo-S rotary instruments did not produce significant differences in the torque at fracture. However, an apparent increase in brittleness did result in a smaller angle of rotation at failure.

Acknowledgments

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The authors deny any conflicts of interest related to this study.

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