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In Vitro Study of the Torsional Properties of New and Used ProFile Nickel Titanium Rotary Files

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The purpose of this study was to investigate torque and angle of rotation at fracture of new and used .06 ProFile instruments. ProFile sizes 15 to 40 were tested according to American National Standards Institute/American Dental Association Specification #28. Thirty new and used instruments were tested for each size. An analysis of variance was used to compare the torque and angle of rotation at fracture between new and used instruments. The relationship between torque at fracture and size of instrument was determined with a regression analysis. The used instruments had significantly lower torque and angle of rotation at fracture values compared with the new instruments ($p < 0.0001$). A stronger relationship was found between the size of the instrument and the torque at fracture for the new instruments ($p < 0.0001$) than for the used ones ($p < 0.0001$). In conclusion, the repeated use of .06 ProFile instruments significantly reduced the torque and angle of rotation at fracture.

Instrument separation is a serious concern in endodontic therapy. Several studies have evaluated the influence of various factors on the fracture of nickel titanium (NiTi) endodontic rotary instruments (1–6). It is important for the clinician to have detailed research information to provide a rational basis for instrument selection. According to American National Standards Institute/American Dental Association (ANSI/ADA) Specification #28, the torsional properties of endodontic instruments can be evaluated as torque and angle of rotation required to cause instrument fracture (7). Previous studies have investigated the torsional properties of NiTi endodontic rotary instruments (2, 8–10).

Flexural fatigue (1) is not the major cause of NiTi rotary instrument fracture (10–13). Instruments can lock into the canal (3) and be subjected to high levels of torsional stress leading to fracture. On the other hand, Sattapan et al. (8) showed that torque at fracture was significantly higher than torque during instrumentation. In their study, each set of instruments was used to prepare only one canal. Questions have been raised about whether repeated use of NiTi rotary instruments adversely alters their torsional properties, thus rendering them more prone to torsional fracture. To date, the influence of repeated use of .06 ProFile instruments (PRI)(Tulsa Dentsply, Tulsa, OK) on the torsional properties has not been evaluated.

This study compared torque and angle of rotation at fracture of new and used .06 ProFile instruments and investigated the relation between size of instrument and torque at fracture.

MATERIALS AND METHODS

Evaluation of New Instruments

Sizes 15 to 40 .06 PRI were evaluated. Thirty new instruments of each size were tested for resistance to fracture by twisting according to ANSI/ADA Specification #28 (7). Two parameters were measured: torque (gcm) and angle of rotation (degrees) at fracture in clockwise rotation. A digital torque meter memocouple (A-Tech Instruments, Scarborough, Ontario, Canada) measured torque with an accuracy of ±1 gcm and angle of rotation with an accuracy of ±2 degrees. Before testing, each instrument's handle was removed with a suitable wire cutter at the point where the handle was attached to the instrument shaft. The shaft end was clamped in a chuck connected to a reversible geared motor revolving at 2 rpm (Aerotech, Pittsburgh, PA). A digital display amplifier controlled the operation of the motor. Three millimeters of the tip of the instrument was clamped in another chuck connected to the digital torque meter memocouple and to a computer for measurement recording using LabView software (National Instruments, Austin, TX). A jig was constructed to ensure reproducible positioning of the tip of the instrument in the chuck.

Evaluation of Used Instruments

Thirty sets of new .06 PRI, sizes 15 to 40, were prepared using a crown-down technique. Each set of instruments was used with an 8:1 reduction handpiece powered by an electric torque control motor (Aseptico, Tulsa Dental, Dentsply, Tulsa, OK) to prepare five endodontic resin blocks (Dentsply/Maillefer, Ballaigues, Switzerland) with curved canals in crown-down. Torque was set at level 3 on the motor. The instruments were used at 150 rpm. Canals were irrigated using 2.5% NaOCl and a 27-g syringe. The canals were prepared by the same operator, who was experienced in the technique. The instruments were used according to the following principles: the apical pressure exerted on each instrument was

TABLE 1. Mean torque, gcm, at fracture and (SD) for new and used instruments

	Size 15	Size 20	Size 25	Size 30	Size 35	Size 40
New	70.61	76.71	78.39	110.12	118.97	162.74
	(4.55)	(4.67)	(4.24)	(11.83)	(9.10)	(9.82)
Used	65.00	68.69	68.34	99.77	106.59	149.25
	(4.62)	(6.27)	(6.93)	(12.10)	(10.61)	(11.01)

TABLE 2. Mean torque angle of rotation, degrees, at fracture and (SD) for new and used instruments

	Size 15	Size 20	Size 25	Size 30	Size 35	Size 40
New	619.43	819.49	685.47	875.75	1016.70	1287.92
	(40.74)	(29.98)	(52.48)	(128.15)	(39.36)	(61.70)
Used	421.19	621.25	487.23	677.51	818.46	1089.68
	(112.47)	(76.32)	(69.57)	(153.85)	(135.83)	(168.28)

light; each instrument was used with five to seven small in-and-out movements (3 to 5 mm) before switching to the next smaller instrument. Four to five recapitulations (waves) with ProFile sizes 40 to 15 were required to complete canal preparation. The canal preparation was considered complete when a size 30 ProFile reached the working length of 17 mm. The ProFile sets were sterilized before each use by steam autoclave at 135°C for 5 min; the entire sterilization cycle lasted 35 min. The instruments were inspected for deformation with ×2.5 magnification after each passage in the canal and before testing. The torque and angle of rotation at fracture of the instruments of the different sizes were determined as for the new instruments.

Statistical Analysis

Analysis of variance was used to compare the torque and angle of rotation at fracture among the new instruments, and between the same sizes of the new and used instruments, respectively. Pairwise comparisons using Duncan's multiple range test were performed to detect significant differences between instruments of the same size. The relationship between torque at fracture and size of instrument was determined with a regression analysis. Significance was determined at the 95% confidence level.

RESULTS

The mean torque at fracture and SD for the new and used instruments are reported in Table 1. The means between the different sizes of the new instruments were significantly different ($p < 0.0001$), except for sizes 20 to 25 ($p = 0.2473$). Between new and used instruments, for the same instrument size, the means were significantly different ($p < 0.0001$).

The mean angle of rotation at fracture and SD for the new and used instruments are reported in Table 2. The means between the different sizes of the new instruments were significantly different ($p < 0.0001$; sizes 15 to 25, $p = 0.003$; sizes 20 to 30, $p = 0.0112$). Between new and used instruments, for the same instrument size, the means were also significantly different ($p < 0.0001$).

A stronger relationship was found between the size of the file and the torque at fracture for the new instruments ($r^2 = 0.86$; $p < 0.0001$) compared with the used instruments ($r^2 = 0.81$; $p < 0.0001$).

DISCUSSION

The angle of rotation and torque give valuable information about the torsional fracture when an instrument binding in the root canal at its tip is rotated. The torsional properties of NiTi rotary instruments can be investigated according to ANSI/ADA Specification #28 (7). Sattapan et al. (8) considered such tests inappropriate for NiTi rotary instruments because they are performed in a static mode. However, recent studies showed that NiTi rotary instrument fracture is mainly a result of torsional stress (10, 11). When an instrument binding in a canal at its tip is rotated, the tip will be subjected to high levels of torsional stress. Instrument fracture will occur when the torsional stress at the point of fracture of the instrument becomes higher than the torque at fracture of the instrument. The test according to ANSI/ADA Specification #28 simulates an instrument binding at 3 mm from the tip in the root canal and is therefore suitable to analyze the torsional properties of rotary instruments. The tests in the present study were conducted at 2 rpm according to ANSI/ADA Specification #28, whereas in a clinical setting, the NiTi rotary instruments are used at a minimum speed of 150 rpm. As a general rule, in a torsional loading model, the torque is independent of the twisting rate (14). In the present study, torque at fracture increased with the diameter of the new instruments (2, 8–10).

The ProFile .06 instruments were used in endodontic resin blocks to simulate repeated clinical use. Compared with extracted teeth, the resin blocks reduced variations in the instrumentation technique by limiting the variability of parameters such as canal length and width, canal anatomy, angle of curvature, and radius of curvature. However, resin blocks do not simulate the use of files in dentin; consequently, the results should be interpreted with caution.

In a pilot study, our attempt to standardize the use of instruments (frequency and depth of insertions, frequency of recapitulations) led to noticeable variation in the amount of pressure applied on the instruments by the operator. Consequently, it was impossible to standardize the actual wear on the instrument in the present study. One way to limit wear variations was to standardize the master apical file size in addition to standardizing, as much as possible, the frequency and depth of instrument penetration and the frequency of recapitulations.

In a previous study (13), we noted that deformations went undetected if magnification was not used. The instruments were inspected for deformation with ×2.5 magnification after each passage in the canal and before testing. When in doubt, the operator used new and deformed (unwound) instruments of the same size and taper as controls. None of the used instruments presented deformations or signs of damage. The use of a light microscope could have decreased the incidence of false-negatives (undetected deformations).

The used instruments presented lower torque at fracture with significant differences compared with the new ones. An SEM study of NiTi endodontic rotary instruments showed a high incidence of surface defects where cracks are usually initiated (15). Cyclic fatigue, flexural or torsional, caused by the use of the instruments in a curved canal and by the repeated locking of the instruments in the canal (3) could have facilitated the crack propagation (15) and, therefore, affected the torque at fracture of the instruments. Peters and Barbakow (10) reported higher torque levels in canals in resin blocks compared with extracted teeth. The use of resin blocks probably subjected the instruments to higher levels of torsional stress, contributing to a higher incidence of crack propagation and lower torque at fracture values for the used instruments. Although the canals in the resin blocks had a size 20 at the working length, torque at fracture of used size 15 and 20 instruments changed significantly. This finding indicated that these instruments were likely subjected to stress at the 3-mm level recommended by ANSI/ADA Specification #28 for torsional fracture testing.

The regression analysis showed a linear relationship between torque at fracture and instrument diameter ($r^2 = 0.86$) (16). The data of Marsicovetere et al. (9) suggested an exponential relation. Direct comparisons cannot be made because different instruments were investigated in the three studies. A weaker relationship observed with the used instruments ($r^2 = 0.81$) reflected the effect of repeated use on the torsional properties.

The angle of rotation at fracture increased significantly with the diameter of the new instruments (2). Variations in the sample size and in the methodology could have contributed to differences in the results. In the present study, 30 instruments of each size were evaluated, compared with only eight in the study by Peters and Barbakow (10). Also, a jig was constructed to ensure precise positioning of the instrument tip in the chuck. In a preliminary study, the positioning of the instrument tip in the chuck without the use of the jig was inconsistent. The clamped length varied between 2 to 5 mm. An instrument clamped at 5 mm from the tip would show a significantly different angle of rotation at fracture compared with an instrument clamped at 3 mm.

Lower angle of rotation at fracture values was obtained for the used instruments. Therefore, it seemed that torsional and flexural stress affected significantly the angle of rotation at fracture. CONCLUSIONS

The results of the present study suggested that the torque at fracture of new instruments increased with the diameter. The used instruments had significantly lower torque at fracture compared with the new instruments. The results also suggested that repeated use of ProFile .06 in resin blocks affected both the torque and the angle of rotation at fracture.

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