In Vitro Assessment of Torque and Force Generated by Novel ProTaper Next Instruments during Simulated Canal Preparation

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Abstract

Introduction: The purpose of this study was to assess torque and force for simulated canal preparation with a new root canal instrument, ProTaper Next. **Methods:** Six sets of ProTaper Next Instruments (X1–X5) were used to prepare 36 artificial canals. Files were divided into 6 groups. Different settings of rotations per minute (250, 300, and 350 rpm) and numbers of in-and-out movements to reach working length (3 or 4 insertions [ins]) were applied in each group (250 rpm/3 ins, 250 rpm/4 ins, 300 rpm/3 ins, 300 rpm/4 ins, 350 rpm/3 ins, and 350 rpm/4 ins) by using an automated torque bench. Peak torques (Ncm) as well as positive and negative forces (N) were registered. Analysis of variance and Tukey post hoc tests were applied. Preliminary data for angle and stationary torque at failure were also obtained and compared with peak torque for each instrument. **Results:** Significant differences in peak torque ($P < .0001$), positive force ($P < .002$), and negative force ($P < .0001$) were found for ProTaper Next instruments overall. X2 showed the highest torque with all settings. X5 showed the highest positive force in all groups. X1 and X2 showed the highest negative forces for all groups except for 350 rpm/4 ins. Significantly lower torque ($P < .0001$) and positive force ($P < .007$) were measured in the group 350 rpm/4 ins for all instruments except for X4. In contrast, X1 showed a significantly lower negative force for 350 rpm/4 ins. Torque at failure according to American Dental Association no. 28/ISO 36030-1 was lower for X1, X2, and X3 than torque during simulated canal preparation ($P < .0001$). **Conclusions:** Under the conditions of this study, using ProTaper Next at 350 rpm and with 4 in-and-out movements resulted in lowest levels of peak torque as well as positive and negative forces. *(J Endod 2013;39:1615–1619)*

Key Words

Nickel-titanium, ProTaper Next, torque, simulated preparation

Nickel-titanium (NiTi) rotary instruments are increasingly used in root canal preparation. Development continues to design rotaries that render shaping not only easier and faster but are also more likely to lead to improved outcomes, compared with stainless steel hand instruments (1). However, despite increased flexibility and torsional strength compared with stainless steel instruments (2), NiTi rotary instruments still seem to have a risk of fracture in the clinical situation (3, 4).

Failure modes of NiTi instruments have been studied extensively (3–9). Flexural fatigue is caused by repetitive compressive and tensile stresses acting on outer fibers of a file rotating in a curved canal; torsional failure occurs when the tip of the instrument binds, but the shank of the file continues to rotate (3). Shear fracture of the material then occurs when the maximum strength of the material is exceeded (7).

The torque generated by a rotating instrument during root canal instrumentation depends on the contact area between the file and the canal walls, the applied apical force, instrument diameter, and preoperative canal volume (10–12). In turn, mechanical properties of endodontic instruments are affected by a variety of factors such as size, taper, design, alloy chemical composition, and thermomechanical processes applied during manufacturing (13–15).

It is believed that there is a strong positive correlation between the maximum torque an instrument can withstand and its diameter (12, 16). It has also been suggested that the cross-sectional shape of instruments affects the stress distribution pattern and thus their torsional resistance (17, 18). Moreover, flexural fatigue developed during curved root canal shaping may decrease the torsional resistance of endodontic instruments (12, 19–21).

ProTaper Next is a novel set of rotary instruments that are designed with variable tapers and an off-centered rectangular cross section. The set includes 5 shaping instruments with overall variable tapers; at the tip, X1 is #17/.04, X2 is #25/.06, X3 is #30/.075, X4 is #40/.06, and X5 is #50/.06. All the instruments are expected passively to follow the canal until the working length (WL) is achieved (22).

Such a single length technique possibly requires greater torsional strength of a given instrument because of greater contact with the dentin walls resulting in high stresses on its entire length (11). However, the system features an off-centered rectangular cross section, which is intended to reduce torsional stress on the instrument (22).

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These instruments are manufactured from so-called M-Wire raw material, which was shown to possibly extend fatigue life beyond conventional NiTi alloy (23).

Currently there are no data available on torque and force during canal preparation with ProTaper Next used according to the current Directions for Use. Hence, the aim of this study was to determine baseline peak torque as well as positive and negative forces among ProTaper Next instruments during simulated canal preparation. Also, different rotations per minute (rpm) and insertion settings were compared to suggest the optimum speed and overall handling those instruments should be subjected to during their use in root canal treatments.

Materials and Methods

Six sets of ProTaper Next Instruments (X1, X2, X3, X4, and X5) were used to prepare 36 simulated root canals in plastic blocks (A 0177; Dentsply Maillefer, Ballaigues, Switzerland) in a standardized fashion.

According to rotational speed (250, 300, or 350 rpm) and insertion pattern (3 or 4 insertions [ins]), rotaries were divided into 6 groups (250 rpm/3 ins, 250 rpm/4 ins, 300 rpm/3 ins, 300 rpm/4 ins, 350 rpm/3 ins, and 350 rpm/4 ins).

Canals were initially lubricated with liquid soap and instrumented by the same operator throughout the study. Sizes #10 and #15 K-files were used to confirm a glide path and to establish WL, which was set at 16 mm.

Subsequent tests were run in a standardized automated fashion in a torque-testing platform, which has been described in detail earlier (16, 20). In brief, plastic blocks were secured into a rigid holder that was attached to a strain gauge connected to a pre-amplifier (A&D 30; Orientec, Tokyo, Japan). The bench was then configured to determine torque and force during canal preparation. A torque sensor (MTTRA 2, with amplifier Microtest; Microtec Systems, Villingen, Germany) and a motor (Type ZSS; Phytron, Gröbenzell, Germany) were mounted on a stable metal platform, which moved along a low friction guide rail for a width of approximately 5 cm. A linear potentiometer (Lp-100; Midori, Osaka, Japan) was attached to the sliding platform to record linear movements.

Following preliminary experiments 2 sequences for instrument insertion were programmed to allow fully automated canal preparation: reaching WL with 3 more aggressive or 4 less forceful instrument insertions. These patterns were the same for all 5 ProTaper Next sizes.

The sequence originally recommended by the manufacturer was followed to shape the simulated canals; X1–X5 were used to WL. Before each use and on completion of simulated shaping procedures, instruments were inspected for plastic deformation.

Peak torques (Ncm) as well as positive and negative peak forces (N) were registered by using the custom-made Endotest software package (16) and collected for off-line analysis.

For comparison, an initial analysis of torsional limits of ProTaper Next was performed with 6 samples of each instrument. Stationary torque (Ncm) and angle (°) at failure during clockwise rotation were tested according to American National Standards Institute/American Dental Association Specification no. 28 (ISO3630-1) by using the same torque-testing device. In accordance with this specification, a soft brass chuck was fitted to the specimen holder, and the apical 3 mm of each instrument was secured. Rotation was set at 2 rpm, and torque was recorded in relation to angular deflection with an accuracy of 0.5° until failure.

Data for peak torque as well as positive and negative peak forces were found to be compatible with normal distribution, and standard deviations of subgroups were similar. Results were analyzed with analysis of variance, and when it showed significant differences, Tukey post hoc tests were used to compare subgroups.

One-sample *t* test was also used to compare peak torque during simulated canal preparation with stationary torque at failure for each individual instrument.

Results

The first set of analyses examined the impact of simulated torque. There were significant differences in peak torque ($P < .0001$) for the different settings. As illustrated in Figure 1, ProTaper Next X2 showed the highest torque (statistically significant in all groups), followed by X1 (statistically significant in groups 250 rpm/4 ins, 300 rpm/3 ins, and 350 rpm/3 ins). See Supplemental Table S1 for raw torque and force data. (Supplemental content is available online at www.jendodon.com.)

Table 1 shows the torque (Ncm) and angle (°) at failure at 3 mm from the tip. Torque at failure was lower for X1, X2, and X3 than torque during simulated canal preparation ($P < .0001$).

There were also significant differences in peak force ($P < .002$) for the different settings. As shown in Figure 2, X5 showed significantly higher peak force (statistically significant in all groups), followed by X4 (statistically significant in groups 250 rpm/4 ins, 300 rpm/4 ins, and 350 rpm/4 ins).

In relation to negative force and as illustrated in Figure 2, the only significant differences that were found were the highest negative force for X1 and X2 when compared with X3, X4, and X5 ($P < .0001$) for all groups except for 350 rpm/4 ins, in which the only file with a different higher significant value was X2.

When results of different groups were compared for each file, significantly lower torque ($P < .0001$) and lower peak force ($P < .007$) were shown in the group 350 rpm/4 ins for all instruments except for X4, which showed significantly lower torque ($P = .001$) and force after 4 insertions but when rotated at 300 rpm ($P < .0001$). X1 showed a significantly lower negative force when it was rotated at 350 rpm and 4 in-and-out movements were used to reach WL ($P < .0001$).

There was no breakage or plastic deformation through visual inspection of any of the rotaries after being used in 6 artificial root canals each.

Discussion

The aim of this study was to provide *in vitro* data that could guide the clinical use of novel ProTaper Next rotary instruments manufactured from M-Wire NiTi alloy (Sportswire, Langley, OK). Specifically, standard parameters such as peak torque and positive and negative forces were measured in simulated clinical conditions. At this time there is no information available for this particular instrument; however, other instruments manufactured from similar alloy have also been investigated recently (15, 23-27).

Plastic blocks with standardized simulated root canals were used in the present experiment, which is similar to previous studies (16, 28). Plastic blocks have been used not only for the assessment of shaping capabilities but also for the cutting behavior of NiTi rotaries (29); however, cutting of dentin varies from cutting plastic material. Nevertheless, torque values obtained during canal preparation in plastic blocks with curved canals were similar to those in mandibular incisors in an earlier study (16).

Another important issue for this type of study that may vary from real dentin and plastic is the "threading-in" effect of files, which is why peak negative force was also tested. The phenomenon of threading-in of a rotary during root canal preparation results in negative force when automatic insertion with a servomechanism such as in the current study is used.