Effects of ProTaper Universal, ProTaper Next, and HyFlex Instruments on Crack Formation in Dentin

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Abstract

Introduction: The aim of the present study was to investigate the incidence of cracks in root dentin after root canal preparation with ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), HyFlex (Coltene-Whaledent, Allstetten, Switzerland), and ProTaper Universal (Dentsply Maillefer) rotary instruments. **Methods:** One-hundred mandibular premolars were selected. Twenty-five teeth were left unprepared and served as a negative control; another 25 teeth were instrumented with the ProTaper Universal system up to size F4 as a positive control, and the remaining 50 teeth were shaped with the following experimental groups with an apical size 40 file: ProTaper Next X4 and HyFlex 40/0.4. After root canal preparation, all of the roots were sectioned perpendicular to the long axis at 2, 4, 6, and 8 mm from the apex, and the sections were then observed under a stereomicroscope. The absence/presence of cracks was recorded, and the data were analyzed with a chi-square test. The significance level was set at $P = .05$. **Results:** No cracks were observed in the negative control group. Vertical root fractures were not observed in any of the groups. The ProTaper Next and HyFlex instruments caused fewer cracks (28%) than the ProTaper Universal instrument (56%) ($P < .05$). However, there were no significant differences in crack formation between the ProTaper Next and HyFlex groups ($P > .05$). **Conclusions:** Within the limitations of this *in vitro* study, all of the instrumentation systems used in this study created cracks in the root dentin. The ProTaper Next and HyFlex instruments tended to cause fewer dentinal cracks compared with the ProTaper Universal instrument. *(J Endod 2014;40:1482–1484)*

Key Words

Cracks, controlled memory, dentinal damage, ProTaper Next, ProTaper Universal, root canal instrumentation, root fracture, rotary nickel-titanium instruments

Dentinal crack formation can originate from several factors (1). Root canal shaping procedures and rotary instrumentation with nickel-titanium (NiTi) instruments have the potential to induce crack formation (2–4). Numerous studies reported that the use of rotary NiTi files causes cracks in root dentin (2, 3, 5, 6). Over the last decades, technological advancements in rotary NiTi instruments have led to new design concepts and easier, faster, and better root canal shaping (7). ProTaper Universal rotary files (Dentsply Maillefer, Ballaigues, Switzerland), which have been used for years, have a convex triangular cross-sectional design and various percentage tapers that enable an active cutting motion and the removal of relatively more dentin coronally (8). ProTaper Universal rotary files are made from a conventional superelastic NiTi wire. In previous studies, the ProTaper Universal system was associated with more cracks than other rotary NiTi instruments (2, 3).

Recently, ProTaper Next (Dentsply Maillefer) instruments have been introduced that have an off-centered rectangular design and progressive and regressive percentage tapers on a single file, which is made from M-Wire technology. Having an off-centered rectangular design decreases the screw effect, dangerous taper lock, and torque on any given file by minimizing the contact between the file and the dentin (9). HyFlex rotary instruments (Coltene-Whaledent, Allstetten, Switzerland) are another type of novel NiTi system. HyFlex instruments have a symmetrical cross-sectional design with 3 cutting edges.

To the best of our knowledge, there are no data in the literature about the influence of these novel NiTi rotary files on the occurrence of root canal wall cracks. Thus, the purpose of the present study was to observe the incidence of cracks in root dentin after root canal shaping procedures performed with the newly introduced ProTaper Next and HyFlex instruments compared with the ProTaper Universal instrument.

Materials and Methods

Mandibular premolars with a root canal curvature less than 10° that had been extracted for reasons unrelated to this study and kept in purified filtered water until use were selected. The external root surfaces were inspected under a stereomicroscope (Olympus BX43; Olympus Co, Tokyo, Japan) to exclude the possibility of any external defects or cracks. Radiographs taken from the buccolingual and mesiodistal angles verified that the teeth had a similar width to that of the root canals at 9 mm from the apex. According to these criteria, 100 mandibular premolars were selected. To ensure standardization, the teeth were sectioned under water cooling with a low-speed saw (Isomet; Buehler Ltd, Lake Bluff, IL) 16 mm from the apex. As suggested previously (4, 10), the root was covered with a single layer of aluminum foil and inserted in acrylic resin (Imicryl, Konya, Turkey) set in an acrylic tube. The root was then removed from the acrylic tube, and the aluminum foil suspended from the root

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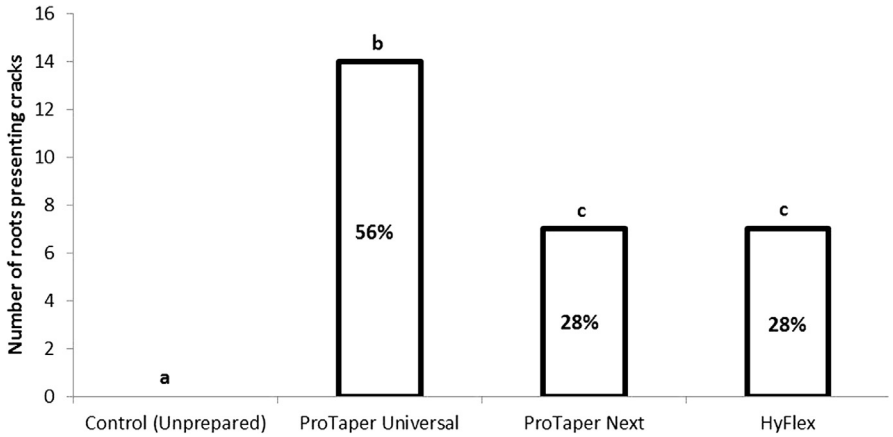

Figure 1. The number and percentage of roots exhibiting cracks after the preparation of the canals with different instruments. Different superscript letters indicate a significant difference between the groups ($P > .05$).

surface. A light body silicon-based material (Oranwash; Zhermack SpA, Rovigo, Italy) was used to fill the space created by the foil and to simulate the periodontal ligament, and the root was replaced to the impression material. Twenty-five teeth were left unprepared as the negative control group, and the remaining 75 teeth were assigned to 1 of 3 root canal shaping groups.

The working length of the canals was determined by inserting a size 10 K-type file into the root canal terminus and subtracting 1 mm from this measurement. A glide path was performed via a size 15 K-type file. The apical preparation was completed with a size 40 instrument. One endodontist, with 6 years of experience using rotary NiTi files, performed all of the root canal instrumentation. Each instrument was used in 5 canals and operated with a low-torque motor (VDW Silver; VDW, Munich, Germany). The root canals were irrigated with 1% sodium hypochlorite solution after each instrument change. A total of 12 mL 1% sodium hypochlorite was used in each canal. After preparation, the specimens from the prepared groups were rinsed with 5 mL distilled water. The root canal shaping procedures were performed according to the manufacturers' instructions for each instrument system as follows:

1. *Group 1* (positive control): For each ProTaper Universal file, the individual rotational speed (250 rpm) and the torque limit programmed in the file library of the motor were used. The sequence was as follows: SX, S1, S2, F1, F2, F3, and F4. The first 3 shaping files were used with a brushing motion away from the root concavities before light resistance was encountered, and the last 4 finishing files were used until the working length was reached.
2. *Group 2:* The ProTaper Next files were used in the sequence ProTaper Universal SX and then ProTaper Next X1, X2, X3, and X4 at a rotational speed of 300 rpm and 200 g/cm torque. Each file was used with a brushing motion similar to that used with the ProTaper Universal files.
3. *Group 3:* The HyFlex files were used in a gentle in-and-out motion with a rotational speed of 500 rpm and 250 g/cm torque. The HyFlex files were used in the sequence of 25/0.08 (two thirds of the working length), 25/0.06, 30/0.06, and 40/0.04 (the full working length).

Sectioning and Microscopic Examination

All of the roots were sectioned perpendicular to the long axis at 2, 4, 6, and 8 mm from the apex using a low-speed saw (Isomet) under water cooling. Digital images of each section were captured at 25× magnification using a digital camera attached to a stereomicroscope (Olympus BX43). In each group, a total of 100 slices were blindly examined for cracks. To define crack formation, 2 different categories were made (ie, "no crack" and "crack") to avoid the confusing description of root cracks. "No crack" was defined as root dentin without cracks or craze lines either at the internal surface of the root canal wall or the external surface of the root. "Crack" was defined as all lines observed on the slice that either extended from the root canal lumen to the dentin or from the outer root surface into the dentin (11).

Statistical Analysis

The results were expressed as the number and percentage of cracked roots in each group. The data were analyzed with a chi-square test. The testing was performed at the 95% confidence level ($P = .05$). All statistical analyses were performed using SPSS software (SPSS Inc, Chicago, IL).

Results

Figure 1 displays the number of roots in each group with cracks. No cracks were observed in the negative control group (unprepared). Vertical root fractures were not observed in any group. The ProTaper Next and HyFlex instruments caused fewer cracks (28%) than the ProTaper Universal instrument (56%) ($P < .05$). There were no significant differences in crack formation between the ProTaper Next and HyFlex groups ($P > .05$).

Discussion

In the present study, after root canal shaping with the ProTaper Universal, ProTaper Next, and HyFlex files, the incidence of cracks observed in root dentin was 56%, 28%, and 28% of the specimens, respectively. Similar to our findings, Liu et al (4) reported cracks in 50% of the roots instrumented with the ProTaper. However, Yoldas et al (5) observed cracks in 30% of the mesial roots of the mandibular teeth instrumented with the ProTaper. Moreover, Bier et al (2) found cracks in 16% of the roots of the mandibular premolars instrumented with the ProTaper system. These contradictory results may be attributed to a number of reasons, and the most likely one is the use of teeth with different root canal anatomy (12). Additionally, we performed a glide path with up to a size 15 hand file, whereas Bier et al (2) performed a glide path with up to a size 20 hand file. Previous studies showed that hand instrumentation caused less cracks than rotary instrumentation (3, 5, 13). The relatively higher crack formation after

instrumentation with the ProTaper Universal instruments in the present study may be caused by less enlargement of the root canals with the hand files before the rotary instrumentation when compared with Bier et al's study (2).

Previously, a finite element analysis study showed that tapered files cause increased stress on the canal walls (14). Bier et al (2) stated that the taper of the files could be a contributing factor in dentinal crack formation. In the apical portion, the ProTaper Universal finishing files (F1, F2, and F3) have more taper (0.07, 0.08, and 0.09, respectively) than the ProTaper Next (X1, X2, and X3; 0.04, 0.06, and 0.07, respectively) and HyFlex instruments (25/0.06, 30/0.06, and 40/0.04), which may explain the higher incidence of cracks observed in the ProTaper Universal group, as reported previously (2, 4, 6, 10). Yoldas et al (5) claimed that the tip design of rotary instruments, cross-sectional geometry, constant or variable pitch and taper, and flute form could be related to crack formation. All of the tested instruments in the present study have noncutting tips and a variable pitch. The ProTaper and HyFlex instruments have a triangular cross-sectional geometry, whereas that of the ProTaper Next is rectangular. In addition, both ProTaper Universal and Next instruments have a variable taper design, whereas the design of HyFlex tapers is constant. Thus, in the present study, it is difficult to conclude that these design factors contributed to the crack formation. Moreover, the design of the file could affect the shaping forces on root dentin (15). The forces generated during instrumentation have been linked to an increased risk of root fracture (14). The off-centered rectangular design of the ProTaper Next instrument may have contributed to the relatively smaller number of cracks in this study. This design generates a swaggering motion, which decreases the screw effect, dangerous taper lock, and torque on any given file by minimizing the contact between the file and the dentin (9).

Previous studies reported that endodontic instruments manufactured with M-wire alloy and controlled memory NiTi wire have more flexibility than those made from conventional NiTi wire (16, 17). The relatively high flexibility of the ProTaper Next and HyFlex (manufactured with M-wire alloy and controlled memory NiTi wire) instruments may have contributed to the small number of cracks in this study. Moreover, the ProTaper Next and HyFlex systems require fewer instruments than the ProTaper Universal system to shape root canals up to size 40. In addition, the crack formation could be related to the cutting efficacy of the instruments. Capar et al (18) reported that root canal instrumentation with ProTaper Next instruments up to size X2 (0.06 apical taper) and ProTaper Universal instruments up to size F2 (0.08 apical taper) changed the root canal volume to a similar extent. They concluded that because of its swaggering motion, the less tapered ProTaper Next instruments could change the root canal volume to the same extent as the higher tapered instruments.

The files tested in the study had varying recommended speed and torque values. The use of different speed and torque settings for each file system could be a limitation of the present study. Peters et al (17) stated that increased rotational speed was associated with increased cutting efficiency. The authors also concluded that the cutting efficacy of the HyFlex instrument is greater than that of the ProTaper Universal instrument. Because of its extended fatigue resistance (19), the recommended speed of the HyFlex instrument (500 rpm) is higher than that of the other instruments tested in the present study. Consequently, the smaller number of cracks in the HyFlex and ProTaper Next groups compared with the ProTaper Universal group might be related to their relatively higher cutting efficacy. The second limitation of the present study was that during instrumentation it was difficult to standardize the downward force used and the operator blinding.

Conclusions

Within the limitations of this *in vitro* study, the instrumentation of root canals with ProTaper, ProTaper Next, and HyFlex instruments can cause crack formation in root canal dentin. The ProTaper Next and HyFlex instruments have a tendency to cause fewer dentinal cracks compared with the ProTaper Universal instrument.

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

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