Dentinal Crack Formation during Root Canal Preparations by the Twisted File Adaptive, ProTaper Next, ProTaper Universal, and WaveOne Instruments

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Abstract

Introduction: The aim of this study was to compare the incidence of root cracks after root canal instrumentation with the TF Adaptive, WaveOne, ProTaper Next, and ProTaper Universal systems. **Methods:** Seventy-five extracted mandibular central incisors with mature apices and straight root canals (<5°) were selected and kept in distilled water. The root canals were instrumented by using the ProTaper Universal, ProTaper Next, WaveOne, and TF Adaptive systems. All the roots were horizontally sectioned 3, 6, and 9 mm from the apex with a low-speed saw under water cooling. The slices were then viewed through a stereomicroscope at ×25 magnification. The samples were photographed with a camera to determine the presence of dentinal cracks. **Results:** The control group had no cracks, and the difference between the control group and the experimental groups was statistically significant ($P < .001$). The ProTaper Next and TF Adaptive systems produced significantly less cracks than the ProTaper Universal and WaveOne systems in the apical section (3 mm) ($P < .05$). **Conclusions:** Under the study conditions and within the limitations of this study, it can be concluded that the ProTaper Universal, ProTaper Next, WaveOne, and TF Adaptive instruments can result in dentinal cracks. *(J Endod 2015;41:261–264)*

Key Words

Dentinal crack, ProTaper Next, Twisted File Adaptive

Root canal preparation is one of the most important stages in successful root canal treatment (1) and can result in some complications such as perforations (2), canal transportation, ledge and zip formation (3), and separation of instruments (4). Vertical root fracture is a clinical complication that can lead to extraction of tooth (5). Preparation procedures can damage the root dentin, resulting in dentinal cracks (6–12) that have the potential to develop into vertical root fractures (13).

Research has shown that different root canal shaping systems damage the root canal wall to various degrees (14). Recently, a new system has been introduced called Twisted File Adaptive (TF Adaptive) (Axis/SybronEndo, Orange, CA). The TF Adaptive instrument can change to a reciprocation mode, with specifically designed clockwise and counterclockwise angles that vary from 600° to 0° up to 370° to 50°. Depending on the amount of pressure placed on the file, the manufacturer claims that this adaptive technology and twisted file design increase flexibility and allow the file to be adjusted to intracanal torsional forces in R-phase treatment (15). The TF Adaptive technique consists of 3 files.

The motion that occurs during root canal preparation system can result in dentinal damage. Liu et al (7) evaluated the incidence of root microcracks caused by different file systems and reported that a reciprocating motion caused less dentinal damage than the continuous rotation motion. However, Bürklein et al (9) found that reciprocating files produced significantly more incomplete cracks compared with rotary instruments at the apical level. To date, no studies have determined the incidence of dentinal microcracks resulting from the use of the TF Adaptive system. The aim of this study was to compare the incidence of root cracks after root canal instrumentation with the TF Adaptive, WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper Next (Dentsply Maillefer), and ProTaper Universal (Dentsply Maillefer) systems. The null hypothesis was that there would be no differences in crack formation among the groups.

Materials and Methods

Seventy-five extracted mandibular central incisors with mature apices and straight root canals (<5°) were selected and kept in distilled water. Proximal radiographs of the teeth were taken, and only single-rooted teeth with a single canal were included in the study. The coronal portions of all the teeth were removed by using an Isomet low-speed saw (Isomet 1000; Buehler, Lake Bluff, IL) under water cooling, leaving roots approximately 13 mm in length. All the roots were inspected with a stereomicroscope (Novex, Arnhem, The Netherlands) with ×12 magnification to detect any preexisting external defects or cracks. Teeth with such defects were excluded from the study and replaced by similar teeth.

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In all teeth, the canal width near the apex was compatible with a size 10 K-file (Dentsply Maillefer). The buccolingual and mesiodistal widths of the canals were measured at 9 mm from the apex on radiographs, and 5 groups were formed of 15 teeth each. The homogeneity of the 5 groups with respect to the canal width at the 9-mm level was assessed by using analysis of variance (P = 1.000). Fifteen teeth were left as a control group. The canal length was measured by inserting a size 10 K-file into the canal until the tip of the file became visible at the apical foramen. The distance between the tip of the file and the reference plane was defined as the canal length. The working length (WL) was established by subtracting 1 mm from this length. During the experimental procedures, roots were covered with 4-mm × 4-mm gauze and kept moist to avoid drying.

The surface of the roots was coated with a silicone impression material to simulate the periodontal ligament space. All the roots were then embedded in acrylic blocks.

The ProTaper Universal, ProTaper Next, WaveOne, and TF Adaptive were used in 4 experimental groups.

ProTaper Universal Group

In this group, the root canals were prepared with ProTaper Universal instruments, which were used at 300 rpm with 2 Ncm torque (X-Smart; Dentsply Maillefer). An SX file was used at one half of the WL, S1 and S2 files were used at two thirds of the WL, and F1 (20/.07) and F2 (25/.08) files were used at full WL. In the canals, the SX, S1, and S2 files were used with a brushing motion. The other files were used with a gentle in-and-out motion until the instrument had reached the full WL.

ProTaper Next Group

The root canals were prepared by using the ProTaper Next system with a gentle in-and-out motion at 300 rpm and 2 Ncm torque and a torque-controlled endodontic motor (X-Smart). The instrumentation sequences were SX, X1 (17/.04), and X2 (25/.06). The SX file was used at one half of the WL, and the X1 and X2 files were used at full WL.

WaveOne Group

The root canals were instrumented by using a WaveOne reciprocating single file (25/.08) with a gentle in-and-out pecking motion and a VDW Silver RECIPROC motor (VDW GmbH).

TF Adaptive Group

The root canals were prepared by using the TF Adaptive instruments with a gentle in-and-out motion and an Elements motor (SybronEndo, Glendora, CA). The instrument sequences were SM1 (20/.04) and SM2 (25/.06). The SM1 was used at two thirds of the WL, and the SM2 was used at full WL.

After each instrument or after 3 pecks by using the WaveOne files, the teeth were irrigated with 2 mL NaOCl. The irrigation was performed with a syringe and a 27-gauge needle (Hayat, Istanbul, Turkey) placed 1 mm from the WL. A total of 12 mL NaOCl was used for each tooth.

One operator performed all the root canal preparations, and 2 other examiners who were blinded to all the experimental groups performed the assessments of the cross sections.

All the roots were horizontally sectioned 3, 6, and 9 mm from the apex with a low-speed saw under water cooling. The slices were then viewed through a stereomicroscope at ×25 magnification. The samples were photographed with a camera (Nikon Coolpix 4500; Nikon Tokyo, Japan) to determine the presence of dentinal cracks. A crack was defined as any lines, microcracks, or fractures in root dentin (Fig. 1). No crack was defined as root dentin devoid of craze lines, microcracks at the external surface of the root, and microcracks at the internal surface of the root canal wall (Fig. 2). A χ^2 test was used for statistical analysis of differences between the experimental groups.

Results

The percentage and number of cracks in each group are shown in Table 1. The control group had no cracks, and the difference between the control group and the experimental groups was statistically significant ($P < .001$). There was no statistically significant difference among the experimental groups ($P > .05$). Regarding the different sections (3, 6, and 9 mm), no significant difference was found between the experimental groups at the 6-mm and 9-mm levels ($P > .05$). The ProTaper Next and TF Adaptive systems produced significantly fewer cracks than the ProTaper Universal and WaveOne systems only in the apical section (3 mm) ($P < .05$).

Discussion

The systems used in the current study caused dentinal cracks. This finding is in agreement with previous studies (6, 7, 9). No previous study evaluated the effect of the TF Adaptive and ProTaper Next instruments on the formation of dentinal defects. According to our

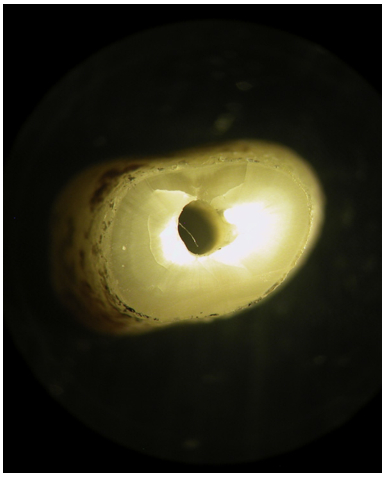

Figure 1. Cross section at 6-mm level showing dentinal crack.

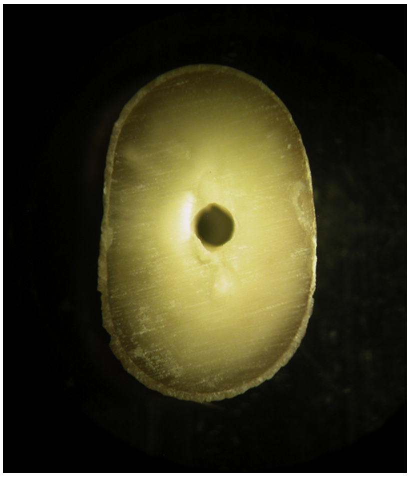

Figure 2. Cross section at 6-mm level without any dentinal crack.

TABLE 1. Number and Percentage of Cracks in the Different Cross-section Slices

	Absolute number of cracks (%)			Total cracked roots per group
	3 mm	6 mm	9 mm	
Control	0 (0)[b]	0 (0)	0 (0)	0 (0)[b]
ProTaper Universal	6 (40)[a]	5 (33)	6 (40)	17 (37.7)[a]
ProTaper Next	1 (6)[b]	6 (40)	4 (26)	15 (33.3)[a]
WaveOne	6 (40)[a]	4 (26)	5 (33)	15 (33.3)[a]
TF Adaptive	1 (6)[b]	5 (33)	7 (46)	13 (28.8)[a]
P value	.004	.112	.052	.000

Values with same superscript letters were not statistically different at $P = .05$.

results, both systems caused less dentinal cracks at the apical section than the ProTaper Universal and WaveOne systems. Kim et al (16) suggested that file design increased apical stress and strain during instrumentation. The TF Adaptive, ProTaper Universal, and WaveOne files have triangular or modified triangular cross sections (17, 18), whereas the ProTaper Next has a rectangular cross-section design. The different cross-section design of the ProTaper Next files may explain the reduced number of dentinal cracks at the apical section in the current study.

The TF Adaptive system uses an existing file set called Twisted Files, in conjunction with a new Elements motor featuring adaptive motion. According to the manufacturer, TF Adaptive files adapt to instrumentation stress. If the instrument is not exposed to stress in the canal, it will rotate continuously in a clockwise direction, with no backward movement. On the other hand, if the file is exposed to stress, the motion of the TF Adaptive instrument changes to a reciprocation mode, with specifically designed clockwise and counterclockwise angles that vary from 600° to 0° and 370° up to 50°. This adaptive movement might have decreased the stress concentration on the root canal wall at the apical section, resulting in less crack formation at this level.

The taper of the files used for preparation could be a contributing factor to the formation of dentinal cracks (19). Wilcox et al (13) stated that the likelihood of root fracture increases with the amount of tooth structure removed. In the present study, the WaveOne Primary file and ProTaper F2 file caused more crack formation at the 3-mm level. The WaveOne Primary file has a .08 taper in the apical 8 mm of the instrument. The taper then changes to .055 for the rest of the WL. Similarly, the ProTaper F2 has a .08 apical taper. However, ProTaper Next X2 and TF Adaptive SM2 files have .06 taper. The larger taper sizes of the F2 and WaveOne Primary instruments in the apical part might have led to more crack formation at the 3-mm level.

Mandibular central incisors were used in the study because of their smaller apical sizes. The teeth included in the study were examined under a stereomicroscope before the start of the experiment to determine the presence of cracks or fractures. Some cracks might have been internal and not visible on the outer surface of the root. However, there were no cracks or fracture formation in the negative control group. This is in agreement with several studies (6–8, 19). Thus, it can be concluded that the sectioning method has no effect on crack formation.

The TF Adaptive system has SM1 (20/.04), SM2 (25/.06), and SM3 (35/.04) files. For standardization of apical enlargement of all samples, the SM2 file was selected for the preparation of the teeth in the TF Adaptive group.

There are several methods to assess the weakening of the tooth after different endodontic procedures. Matsushita-Tokugawa et al (20) used infrared thermography to detect dentinal cracks and reported that thermography has some limitations because of the size of the thermography equipment. Ribeiro et al (21) used an Instron testing machine to assess the fracture resistance of roots filled with different endodontic filling materials. They applied an external force until the root fractured. However, another study reported that fracture resistance provides no information about the incidence of dentinal cracks in the root dentin (14). In the current experiment, the effect of the preparation systems on the root dentin was directly observed in the absence of external forces.

The present study evaluated dentinal crack formation associated with 4 different root canal preparation systems. In the study, the roots were distributed among the groups equally according to their root canal diameter at the 9-mm level. Standardization was achieved in the groups by including only teeth with a canal width near the apex compatible with a size 10 K-file and leaving all the roots approximately 13 mm in length.

In the present study, acrylic blocks and a silicone impression material were used to simulate bone and periodontal ligament, respectively. Although some studies stated that the silicon layer allows limited freedom of movement while avoiding external reinforcement (22, 23), Soros et al (24) stated that elastomeric material can collapse and cause direct tooth-to-acrylic-socket contact, which never occurs *in vivo* (with bone).

Conclusion

Under the study conditions and within the limitations of this study, it can be concluded that the ProTaper Universal, ProTaper Next, WaveOne, and TF Adaptive instruments can result in dentinal cracks. Further studies are required to assess the effect of these instruments on the formation of dentinal cracks.

Acknowledgments

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

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