# Effect of the Size of the Apical Enlargement with Rotary Instruments, Single-cone Filling, Post Space Preparation with Drills, Fiber Post Removal, and Root Canal Filling Removal on Apical Crack Initiation and Propagation

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## Abstract

**Introduction:** The purpose of this study was to investigate the incidence of apical crack initiation and propagation in root dentin after several endodontic procedures. **Methods:** Sixty intact mandibular premolars were sectioned perpendicular to the long axis at 1 mm from the apex, and the apical surface was polished. Thirty teeth were left unprepared and served as a control, and the remaining 30 teeth were instrumented with ProTaper Universal instruments (Dentsply Maillefer, Ballaigues, Switzerland) up to size F5. The root canals were filled with the single-cone technique. Gutta-percha was removed with drills of the Rebilda post system (VOCO, Cuxhaven, Germany). Glass fiber–reinforced composite fiber posts were cemented using a dual-cure resin cement. The fiber posts were removed with a drill of the post system. Retreatment was completed after the removal of the gutta-percha. Crack initiation and propagation in the apical surfaces of the samples were examined with a stereomicroscope after each procedure. The absence/presence of cracks was recorded. Logistic regression was performed to analyze statistically the incidence of crack initiation and propagation with each procedure. **Results:** The initiation of the first crack and crack propagation was associated with F2 and F4 instruments, respectively. The logistic regression analysis revealed that instrumentation and F2 instrument significantly affected apical crack initiation ($P < .001$). Post space preparation had a significant effect on crack propagation ($P = .0004$). The other procedures had no significant effects on crack initiation and propagation ($P > .05$). **Conclusions:** Rotary nickel-titanium instrumentation had a significant effect on apical crack initiation, and post space preparation with drills had a significant impact on crack propagation. *(J Endod 2015;41:253–256)*



## Key Words

Crack initiation and propagation, cracks, dentinal damage, fiber post removal, post space preparation, retreatment, root canal filling, root canal instrumentation, root fracture, single cone


Endodontic procedures, including root canal enlargement (1, 2), filling (3), post preparation, and retreatment (4), cause loss of tissue and put excessive pressure on the teeth, making them susceptible to vertical root fractures (VRFs). The amount of the remaining tooth structure is an important determinant in VRFs (5). Moreover, cracks that occur during endodontic procedures can propagate by occlusal forces, with repeated stress finally resulting in VRFs (6). The prognosis of a tooth with a VRF is poor (7).

The final apical preparation size is an important factor in root canal cleanliness (8). However, enlargement of the apical region with larger instruments may cause excessive crack formation and root canal transportation, especially in curved canals. There is currently no consensus on the optimum final apical preparation size. Numerous studies have concluded that root canal instrumentation with nickel-titanium (NiTi) rotary instruments leads to crack formation in root dentin (1, 9–11). However, there are limited data on the interrelation between the size of the apical preparation and crack formation (12).

A finite elemental analysis showed that root canal filling procedures initiate root fractures, with the fractures originating from the apical third (13). Root-filled teeth with significant loss of tissue are usually restored with posts for the retention of coronal restorations (14, 15). Among post systems, fiber posts have advantageous physical properties, in addition to improved esthetics (16). Fiber posts are usually fitted into the root canal with their corresponding drills. Post drills are known to be more aggressive than root canal shaping instruments. Of note, there are no studies in the literature on the effect of post drills on crack formation in root dentin although there have been many studies of crack formation with root canal shaping instruments.

Root canal retreatment is a challenging procedure, especially in teeth restored with intraradicular fiber posts, because of increased bonding to the root canal dentin. Many techniques and special devices are available for removing post systems, including ultrasonics (17), a diamond bur/Peeso reamer (18), and removal kits developed by the manufacturers of the posts (19). Research has shown that the heat produced by ultrasonic treatment during post removal could damage periodontal ligaments and alveolar

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bone (20). Similar to the lack of data on the impact of post drills on crack formation in the literature, there are no current data on the effect of post removal on crack formation.

The root canal wall may sustain greater damage after larger apical preparation sizes, fiber post space preparation, fiber post removal, and root canal filling removal because of the increased number of mechanical manipulations and tissue loss. Thus, the purpose of the present study was to observe the incidence of crack initiation and propagation in apical root dentin after each instrument change in root canals shaped with ProTaper Universal instruments (Dentsply Maillefer, Ballaigues, Switzerland) and filled with the single-cone technique followed by post space preparation with fiber post drills, removal of the fiber posts, and removal of the root canal filling.

# Materials and Methods

Freshly extracted (within 3 months) mandibular premolars with single straight root canals (0°–10°) were verified radiographically (21, 22). The samples were stored in distilled water until they were used. The teeth were inspected under a stereomicroscope (Olympus BX43; Olympus Co, Tokyo, Japan) to exclude external defects or cracks. Based on the study protocol of Adorno et al (23), 1 mm of the apical portion of the teeth was sectioned perpendicular to the long axis using a low-speed saw (Isomet; Buehler Ltd, Lake Bluff, IL) under water cooling. The apical surfaces of the samples were also inspected using a stereomicroscope to exclude any crack formation. Moreover, teeth with a deviated apical foramen were excluded from the study. According to these criteria, 60 teeth were selected, and 30 teeth were left unprepared as a control group. To ensure standardization, the teeth were sectioned perpendicular to the long axis under water cooling with a low-speed saw 14 mm from the apex. During the study, the teeth were stored in purified filtered water. To simulate the periodontal ligament space, a silicon impression material was used to coat the surface of the roots. The apical 3 mm of the root was left exposed for intraoperative image recordings. The exposed apical surface was polished with waterproof 1000-, 1200-, and 1500-grit silicon carbide abrasive paper to reduce any fine scratches and obtain clear images at high magnification (40×). The initial images of the apical surfaces were captured with a digital camera attached to a stereomicroscope. A "crack" was defined as all lines observed on the slice that extended from the root canal lumen to the dentin or from the outer root surface into the dentin (24). Until the samples were sectioned for microscopic evaluation, the apical 3 mm of the roots were immersed in water to avoid dehydration. Only the root canal filling procedure was performed without immersion in water (25).

## Root Canal Shaping

The working length of the canals was determined by inserting a size 10 K-type file into the root canal terminus (23). A glide path was performed with a size 15 K-type file. The root canals were instrumented with ProTaper Universal instruments up to size 50 (in a sequence of SX–S2, F1–5) with a low-torque motor (VDW Silver; VDW, Munich, Germany). One operator performed all the root canal instrumentations. After each instrument change, images of the apical surfaces of the samples were captured. The root canals were irrigated with 2 mL 1% sodium hypochlorite solution after each instrument change. After the instrumentation, each canal was flushed with 5 mL 17% EDTA and 5 mL sodium hypochlorite and then dried with paper points.

## Root Canal Filling

ProTaper Universal F5 cones were coated with a resin-based sealer (Adseal; Meta Biomed Co, Cheongju, Korea) and placed into the root canal to the working length. After the completion of the filling, the cones were condensed with a cold plugger. For post preparation, the samples were stored at 37°C with 100% humidity for 7 days, and images of the apical surfaces of the samples were then captured.

## Post Restoration

Gutta-percha was removed using a heated instrument, and the post space was created with Rebilda post system drills (VOCO, Cuxhaven, Germany) of 1, 1.2, and 1.5 mm, leaving 4 mm of filling material in the apical third. Images of the apical surfaces of the samples were obtained after each post drill change. After preparation of the post space, the root canals were cleaned with distilled water and dried with paper points. Glass fiber–reinforced composite fiber posts (Rebilda, VOCO) (size 1.5 mm) were cleaned with alcohol and cemented using a dual-cure resin cement (Grandio Core Dual Cure, VOCO) according to the manufacturer's instructions. The resin cement was cured for 40 seconds with a light-emitting diode light-curing unit (Monitex BlueLex GT1200, Taipei, Taiwan). After the post luting procedures, the roots were stored at 37°C and 100% humidity for 14 days.

## Retreatment

According to the manufacturer's suggestion, the fiber posts were removed with 1.5-mm post system drills. After removing the posts, images of the apical surfaces of the samples were captured. The retreatment procedure was completed after the removal of the gutta-percha. The ProTaper Universal Retreatment D3 (20/.07) file was used until the working length was reached. Using a brushing circumferential motion, the ProTaper Universal F5 file was used to completely remove the gutta-percha. After the removal of the material, final images of the apical surfaces of the samples were captured.

## Sectioning at Different Levels

After completing the procedures to compare locations of the cracks and to evaluate the number of total cracks, all the roots were sectioned perpendicular to the long axis at 2, 4, 6, and 8 mm from the apex using a low-speed saw under water cooling. Digital images of each section were captured. In brief, 18 images of a specimen were taken during the procedures. Each image was then compared with the preceding image to determine the presence of new cracks or the propagation of cracks during the procedures (Fig. 1*A–C*).

## Statistical Analysis

Logistic regression was performed to analyze statistically the incidence of crack initiation and propagation in each procedure. The incidence of dentinal cracks between the regions was analyzed with the Pearson chi-square test. The level of significance was set at $P < .05$. All the statistical analyses were performed using SPSS software (SPSS Inc, Chicago, IL).

# Results

No cracks were observed in the control group. Figure 2 summarizes the apical crack initiation and propagation after each step of the root canal shaping, filling, post space preparation, post removal, and gutta-percha removal. The initiation of the first crack and crack propagation was associated with F2 (tip size of 25) and F4 (tip size of 40) files, respectively. After the root canal shaping procedure, apical crack initiation was present in 20% of the samples. F2, F3, and F4 files caused 4, 1, and 3 new cracks, respectively, and the F5 file caused no new cracks. The logistic regression analysis revealed that the instrumentation had a significant effect on apical crack initiation ($P < .001$). Among the root canal shaping