Occurrence of Dentinal Microcracks in Severely Curved Root Canals with ProTaper Universal, WaveOne, and ProTaper Next File Systems

Shu-hui Li, MD, Ying Lu, MD, Dongzhe Song, MD, Xuedong Zhou, DDS, PhD, Qing-hua Zheng, DDS, PhD, Yuan Gao, DDS, PhD, and Ding-ming Huang, DDS, PhD

Abstract

Introduction: This study aims to compare the incidence of dentinal microcracks produced by the ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), WaveOne (Dentsply Maillefer), and ProTaper Next (Dentsply Maillefer) file systems during root canal procedures in severely curved canals using a dyeing technique. **Methods:** Sixty extracted human molars with 25° to 40° root curvatures were divided into 3 groups of 20 canals each. ProTaper Universal, WaveOne, and ProTaper Next file systems were used for root canal procedures. Untreated root canals of 60 molars served as negative controls. After preparation, all roots were stained with 1% methylene blue for 24 hours. Roots were then sectioned at the most curved plane and 2 mm below and above the most curved plane with a low-speed saw under cold water. A stereomicroscope was used to inspect dentinal microcracks at 60× magnification, and differences between these 3 instrument groups were analyzed using the chi-square test. **Results:** The ProTaper Next system induced less complete and incomplete dentinal microcracks compared with the ProTaper Universal and WaveOne systems ($P < .05$), and there were no significant differences between the ProTaper Universal and WaveOne systems ($P > .05$). The ProTaper Universal and WaveOne systems induced significantly more complete cracks in the plane 2 mm above the most curved plane compared with either of the other 2 planes ($P = .004$). **Conclusions:** The ProTaper Next system induces less dentinal microcracks during root canal procedures in severely curved root canals compared with the ProTaper Universal and WaveOne systems. *(J Endod 2015;41:1875–1879)*

Key Words

Curved root canals, dentinal cracks, microcracks, nickel-titanium instruments, root canal procedure, vertical root fracture

Vertical root fracture (VRF) is a frequent complication of root canal treatment, which usually requires extraction of the affected tooth (1). Root canal procedures cause stress in dentin and may initiate dentinal cracks that affect the long-term integrity of the tooth, which can extend to complete fractures under functional load (2).

An increase in canal curvature causes increased stress on the rotary file system used in a root canal procedure and, consequently, on the root canal. Stress concentrations in the root canal can cause canal transportation, straightening, and deviation and thereby result in thinner areas of dentin. Thinner dentin weakens the root structure and increases the risk for apical cracking, leading to VRF (3–7). Several studies that use finite element analysis have shown that rotary file systems used in root canal procedures experience the most stress in curved root canals (6, 8).

Evidence suggests that the ProTaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland) produces significantly more dentinal cracks in the apical section than the ProTaper Next (Dentsply Maillefer) and WaveOne (Dentsply Maillefer) systems (9–12). However, these observations are based on studies that investigated the development of cracks in straight canals (root canals with a curvature <10°). A high incidence of curved root canals can be observed in clinical practice. It is currently unknown whether rotary file systems cause more dentinal cracks in severely curved canals.

Previous studies have correlated root canal procedures and the development of dentinal defects primarily on the basis of root sectioning and with direct observation by stereomicroscopy (13). However, dentinal cracks observed through these methods may have occurred during a tooth resection procedure or may have been previously present. Methylene blue dye can be a useful aid in endodontic surgery. The differential staining of methylene blue outlines roots, delineates root dentin from bone, and demarks isthmuses between 2 canals in a single root (14). In combination with transillumination, methylene blue is the preferred technique for assessing dentinal cracks (15, 16). However, its differential staining ability after being used to stain a whole root canal system for 24 hours remains unknown. Therefore, we aimed to differentiate dentinal cracks produced by the ProTaper Universal, ProTaper Next, and WaveOne rotary file systems from cracks caused by tooth resection in severely curved canals using a dyeing technique.

Materials and Methods

Selection and Preparation of Specimens

This study was approved by the ethics committee of the West China College of Stomatology, and informed consent was obtained from each patient. Sixty human

From the State Key Laboratory of Oral Diseases, Sichuan University; and West China College and Hospital of Stomatology, Sichuan University, Chengdu, China.

Address requests for reprints to Dr Ding-ming Huang or Dr Yuan Gao, Department of Conservative Dentistry and Endodontics, State Key Laboratory of Oral Diseases, West China College and Hospital of Stomatology, Sichuan University, No. 14 3rd Section, Renmin South Road, Chengdu 610041, China. E-mail address: dingminghuang@163.com or gaoyuan@scu.edu.cn

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molars, each with at least 1 curved root and root canal, were extracted and maintained in Hank's balanced salt mixture at 4°C until use (17, 18). External root surfaces were inspected under a stereomicroscope (Olympus SZ61; Olympus Co, Tokyo, Japan) to exclude teeth with external defects or cracks. Then, teeth were sectioned under cold water with a low-speed saw (Struers Minitom, Copenhagen, Denmark) at the cementoenamel junction. A mark was made at the junction of the cut root face and the convex side of the selected root to standardize the orientation of the resection plane for subsequent analysis.

Standardized radiographs were obtained before the root canal procedure with a size 10 K-file inserted into the curved canal. The tooth was placed in a radiographic mount composed of a silicone-based impression material (Silagum Putty; DMG, Hamburg, Germany). All radiographs were obtained at constant exposure conditions (time, 0.12 seconds; voltage, 60 kV; current, 7 mA), source-to-film distance, and object-to-film distance. The degree and radius of the canal curvature were determined using a computerized digital image processing system (Gendex Dental Systems, Hatfield, PA) (19). Teeth with a curvature angle between 25° and 40°, comparable degrees and radii of curvature, and comparable distances between the apical foramen and orifice were included and randomly allocated into 3 rotary file system groups (20 teeth per group, Table 1). Unprepared root canals of the same 60 roots were used as negative controls.

Root Canal Procedure

The orifice was preflared with a ProTaper Universal auxiliary shaping file or Shaper X (Dentsply Maillefer, Ballaigues, Switzerland). The working length of the canals was determined by inserting a size 10 K-file into the root canal terminus, and 1 mm was subtracted from this measurement. The working length within each canal was negotiated with a size 15 K-file hand instrument. One endodontist with 7 years of experience performed all procedures using rotary nickel-titanium (NiTi) files to minimize operator variation. The procedure was manually performed with the tooth surrounded by gauze soaked in Hank's balanced salt mixture. The root tip was kept moist throughout the procedure. Each instrument was used in 5 canals and operated with a low-torque motor (VDW Silver; VDW, Munich, Germany). Root canals were irrigated with 1% sodium hypochlorite solution after each instrument change. A total of 10 mL 1% sodium hypochlorite was injected into each canal. After preparation, extracted specimens from each group were ultrasonicated with distilled water for 30 seconds using a Satelec P5 Newtron XS ultrasonic unit (Acteon Group, Mount Laurel, NJ) with a power setting of 5. Root canal procedures for each system were performed according to the manufacturer's instructions as follows:

Group 1 (positive control): ProTaper Universal shaping files S1 and S2 as well as ProTaper Universal finishing files F1 and F2 were sequentially used with a continuous inward-outward movement until a working length was reached. Torque and other parameters for each file were set based on the manufacturer's recommendation.

Group 2: A primary reciprocating size 25 WaveOne file with a taper of 0.08 was used in a reciprocal, slow, inward-outward pecking motion according to the manufacturer's instructions until a full working length was reached. Flutes of the instrument were cleaned after 3 pecks. The WaveOne file was used with the WaveOne all program of the motor.

Group 3: ProTaper Next files were used in the sequence ProTaper Next, X1, and X2 at a rotational speed of 300 rpm and 200 g/cm torque. Each file was used with a brushing motion similar to the ProTaper Universal files.

Staining, Embedding, Sectioning, and Microscopic Examination

After the root canal procedure, we developed a new technique to dye all roots before sectioning so that any cracks produced during subsequent procedures would not be stained. A syringe with an intravenous needle containing 200 L 1% methylene blue dye was first fixed into the prepared root canal using light-cure flowable resin (Beautifil Flow Plus F03; Shofu Inc, Kyoto, Japan). Apical foramens of the main and accessory canals were sealed with the same resin after the dye had effused from them wherein the syringe, needle, and root canal formed a closed lumen. The syringe piston was pushed and fixed at 1 mL from a previous position of 2 mL using a transparent adhesive tape so that all roots could be stained with 1% methylene blue dye at a pH of 7 for 24 hours. Subsequently, roots were embedded in autopolymerizing epoxy resin blocks to prevent roots from shrinking because of dehydration. Then, roots were sectioned perpendicular to the long axis at the most curved plane and 2 mm below and above the most curved plane with a low-speed saw (Struers Minitom, Copenhagen, Denmark) under cold water. Each slice was sequentially polished with a 3,000- and 5,000-grit waterproof abrasive paper (991A; Matador Wasserfest, Germany) for 60 seconds to reduce any fine scratches and obtain clear images at high magnification. Then, slices were examined for the presence of dentinal cracks at 60× magnification using a stereomicroscope (SZX16; Olympus, Tokyo, Japan). For each group, 120 slices were examined for the presence of dentinal defects (microcracks) by operators blinded to the instrument type. Each specimen was examined by 2 independent operators. In case of discrepancies with regard to the number of dentinal defects identified by the 2 operators, a consensus was reached through discussion.

Definitions of Defects

A *crack* was defined as a defect with complete crack lines extending from the inner root canal space up to the outer surface of the root and incomplete crack lines extending from the canal walls into the dentin without reaching the outer surface. Roots were classified as

TABLE 1. Characteristics of Curved Root Canals

Group (n = 20 teeth per group)	Curvature (°)			Radius (mm)			Distance
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Orifice foramen (mm)
PU	30.85 ± 5.84	25	40	8.57 ± 2.59	4.76	12.55	10.62 ± 1.40
WO	28.85 ± 3.67	25	35	8.42 ± 2.45	4.71	14.26	10.00 ± 1.04
PN	30.46 ± 3.71	25	38	7.71 ± 2.91	4.63	13.85	9.81 ± 1.12
P value (ANOVA)	.496			.685			.212

ANOVA, analysis of variance; Min, minimum; Max, maximum; PN, ProTaper Next; PU, ProTaper Universal; SD, standard deviation; WO, WaveOne.