Incidence of Apical Crack Initiation and Propagation during the Removal of Root Canal Filling Material with ProTaper and Mtwo Rotary Nickel-Titanium Retreatment Instruments and Hand Files

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Abstract

Introduction: The aim of this study was to determine the incidence of crack initiation and propagation in apical root dentin after retreatment procedures performed by using 2 rotary retreatment systems and hand files with additional instrumentation. **Methods:** Eighty extracted mandibular premolars with single canals were selected. One millimeter from the apex of each tooth was ground perpendicular to the long axis of the tooth, and the apical surface was polished. Twenty teeth served as the control group, and no preparation was performed. The remaining 60 teeth were prepared to size 35 with rotary files and filled with gutta-percha and AH Plus sealer. Specimens were then divided into 3 groups (n = 20), and retreatment procedures were performed with the following devices and techniques: ProTaper Universal retreatment files, Mtwo retreatment files, and hand files. After retreatment, the additional instrumentation was performed by using size 40 ProTaper, Mtwo, and hand files. Digital images of the apical root surface were recorded before preparation, after instrumentation, after filling, after retreatment, and after additional instrumentation. The images were then inspected for the presence of any new apical cracks and propagation. Data were analyzed with the logistic regression and Fisher exact tests. **Results:** All experimental groups caused crack initiation and propagation after use of retreatment instruments. The ProTaper and Mtwo retreatment groups caused greater crack initiation and propagation than the hand instrument group ($P < .05$) after retreatment. Additional instrumentation with ProTaper and Mtwo instruments after the use of retreatment instruments caused crack initiation and propagation, whereas hand files caused neither crack initiation nor propagation ($P < .05$). **Conclusions:** This study showed that retreatment procedures and additional instrumentation after the use of retreatment files may cause crack initiation and propagation in apical dentin. *(J Endod 2014;40:1009–1012)*

Key Words

Apical crack, retreatment, root canal

Mechanical instrumentation of the root canal system is an important phase of root canal preparation because it creates the space that allows irrigants and antibacterial medicaments to more effectively eradicate bacteria and eliminate bacterial by-products (1). However, it has been stated that root canal instrumentation has the potential to induce dentinal damage and generate cracks on the apical surface (2, 3).

Rotary instrumentation requires less time to prepare canals compared with hand instrumentation. However, rotary nickel-titanium (NiTi) files with large tapers can generate increased friction and stresses than hand files with .02 taper on the canal wall and may thereby create more craze lines or dentinal microcracks in root dentin (2). Root fracture could occur as result of a microcrack or craze line that propagates with repeated stress application by endodontic or restorative procedures and occlusal forces (4).

Nonsurgical endodontic retreatment is often indicated as the first choice to eliminate or reduce microbial infection when initial root canal treatment fails (5). The retreatment aims to completely remove the filling material from the canal system to allow effective cleaning, shaping, and filling of the root canal (6). Several techniques have been proposed to remove filling materials from the root canal system, including the use of endodontic hand files, NiTi rotary instruments, heat, ultrasonic instruments, and solvent (7, 8). Shemesh et al (9) stated that because retreatment requires more mechanical manipulations in the canal and further preparation of the root canal, greater damage to the root canal wall may be caused after this procedure.

Recently, a few studies have assessed the effect of endodontic procedures, including canal preparation and obturation, on apical crack initiation (10, 11). However, there has been no study evaluating the effects of hand files and rotary NiTi retreatment systems on the incidence of apical crack initiation and propagation during retreatment. Therefore, the purpose of this study was to evaluate the incidence of crack initiation and propagation in apical dentin after retreatment procedures performed by using 2 rotary NiTi rotary systems (ProTaper and Mtwo) and hand files with additional instrumentation.

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Materials and Methods

Tooth Selection and Preparation

Extracted human mandibular premolar teeth of similar length and with straight roots were selected. Radiographs were taken from buccolingual and mesiodistal angles to verify the presence of a single canal. The root surfaces of each tooth were observed under a stereomicroscope (BX60; Olympus, Tokyo, Japan) at ×20 magnification for evidence of fracture lines, open apices, or anatomic irregularities and were discarded if any of these characteristics were found. Teeth with a deviated apical foramen were excluded from the study to ensure standardization. This study used 80 teeth with similar canal widths, and the width of the root canal on both angles was measured at 5 mm from the apex. Teeth were then stored in purified filtered water throughout the study. Twenty teeth were left unprepared as the control group, but only the apical portions of these 20 teeth were trimmed as described below. The surfaces of the remaining 60 roots were coated with a silicone impression material (Elite HD, Zhermack, Italy) to simulate periodontal ligament space. These teeth were then embedded in a tube filled with self-curing acrylic resin (Imicryl, Konya, Turkey). The apical 4 mm of the root was exposed to allow intraoperative image recordings. In a similar study by Adorno et al (11), 1 mm of the apical portion of the teeth was ground perpendicular to the tooth axis with waterproof 320-grit silicon carbide abrasive paper. The apical surface was polished with waterproof 1000-grit and 1200-grit silicon carbide abrasive paper to reduce the fine scratches and to obtain a clear, highly magnified image. The exposed apical portion of the root was immersed in water during instrumentation to prevent dehydration (10).

A baseline image of the apical surface of each specimen was observed under stereomicroscope (BX60), and images were recorded. The crowns of 60 teeth were removed at 2 mm above the proximal cementoenamel junction to ensure straight-line access. The resulting coronal surface provided a reference plane that was parallel to the apical polished surface. A size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the canal until the file tip was observed at the apical plane. This measurement was determined as the working length (WL) (11). To ensure standardization, all roots were prepared by using Revo-S rotary files (Micro-Mega, Besancon, France) up to master apical size 35. The rotary files were used at 300 rpm in a sequence of SC1 (25/.06), SC2 (25/.04), SU (25/.06), AS 30 (30/.06), and AS 35 (35/.06). SC1 was used to enlarge the coronal two-thirds of the canal. SC2, SU, AS 30, and AS 35 instruments were used to the WL. The canals were irrigated with 2 mL 2.5% sodium hypochlorite (NaOCl) between each file size by using a syringe and a 29-gauge needle (NaviTip; Ultradent, South Jordan, UT). After completion of the preparation, the canals were irrigated with 5 mL 17% EDTA for 1 minute and subsequently rinsed with 5 mL distilled water. After preparation, images of the apical portions of 60 roots were taken, and crack initiation was checked. Specimens showing evidence of a crack were evenly distributed to the experimental groups as described below.

Root Canal Obturation

Sixty root canals were obturated with AH Plus sealer (Dentsply Maillefer) and Revo-S gutta-percha cones (Micro-Mega) by using the single cone technique. AH Plus sealer was introduced into the root canal by using a lentulo spiral filler (Dentsply Maillefer). A size 35/.06 taper master gutta-percha cone with good tug-back was coated with sealer and slowly inserted into the canal until the WL was reached. Excess material was seared off and condensed with a plugger 1 mm below the canal opening, and the root canal openings of all specimens were sealed with temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). Radiographs were then taken from the buccolingual and mesiodistal directions to ensure quality of the obturation. The specimens were then stored at 37°C in 100% humidity for 2 weeks to allow complete setting of the sealer.

Experimental Groups and Retreatment Procedures

Hand Instrument Group (*n* = 20 Teeth). In this group, Gates Glidden drills (Dentsply Maillefer) size 3 and subsequently size 2 at 1500 rpm were used to remove coronal filling material. The canals were reinstrumented with Hedström files (Dentsply Maillefer), sizes 30, 25, 20, and 15, in a circumferential, quarter-turn, push-pull filing motion to remove filling material until WL was achieved. Once WL had been reached with a size 15 file, sizes 20, 25, 30, and 35 were used at the WL. Additional instrumentation was then performed by using a Hedström file size 40 at the WL.

ProTaper Retreatment Group (*n* = 20 Teeth). In this group, the canal filling material was removed by using the ProTaper Universal retreatment instruments (Dentsply Maillefer). The retreatment instruments were used at a constant speed of 500 rpm for D1 and 400 rpm for D2 and D3, with a torque of 3 Ncm. The instruments were used in a brushing action with lateral pressing movements, according to the manufacturer's instructions: D1 (30/.09) worked in the coronal third, D2 (25/.08) in the middle third, and D3 (20/.07) throughout the entire WL. Additional instrumentation was then performed by using an F4 ProTaper file at a speed of 300 rpm at WL.

Mtwo Retreatment Group (*n* = 20 Teeth). The removal of canal fillings was performed by using an Mtwo R2 (25/.05) instrument at a speed of 280 rpm and a torque of 1.2 Ncm. A brushing action was performed against the canal walls in a crown-down direction until the WL was reached. Additional instrumentation was then performed by using the Mtwo instrument (40/.04) at a speed of 300 rpm and a torque of 1.6 Ncm at the WL.

All rotary NiTi instruments were used with a torque and speed-controlled motor (X-Smart; Dentsply Maillefer) at the torque and speed recommended by the manufacturer of each system used. In all experimental groups, 0.2 mL eucalyptol was used to soften the gutta-percha at the root canal orifice. During retreatment, the root canals were irrigated with 1 mL 2.5% NaOCl. Retreatment was judged complete when no gutta-percha or sealer was detected on the instrument surfaces, inside the root canal, or on the dentinal walls. A dental operating microscope (Zeiss Opmi; Carl Zeiss, Jena, Germany) was used throughout. One set of all hand and rotary instruments was used for the preparation of one root canal. All procedures were performed by a single operator to avoid interoperator variability.

Images were taken of each tooth in all experiment groups after retreatment procedure and additional instrumentation. The images were captured at ×20 magnification by using a digital camera (DP-70; Olympus, Tokyo, Japan) attached to a stereomicroscope (BX60). Each specimen in the experimental groups had 5 images taken (baseline, after preparation, after filling, after retreatment, and after additional instrumentation). Each image was compared with the preceding image, and any visible crack line on the apical surface that was not present in the preceding image was defined as a crack. The images were compared with the baseline image, and the presence of a new crack at any subsequent treatment (as shown in the preparation, filling, retreatment, or additional instrumentation images) or propagation of a crack occurring during procedures (filling, retreatment, and additional instrumentation) was noted.

A logistic regression test was used to analyze the incidence of crack initiation by instrumentation, filling, retreatment, and additional instrumentation. The Fisher exact test was used to analyze crack incidence between the groups and to analyze propagation of cracks caused by filling,

TABLE 1. Incidence of Crack Initiation and Propagation for Groups

	Instrumentation		Root canal filling		Retreatment		Additional instrumentation	
	Baseline	Initiation	Initiation	Propagation	Initiation	Propagation	Initiation	Propagation
Groups	*n*/*N*	*n*/*N*	*n*/*N*	ppc/npct	*n*/*N*	ppc/npct	*n*/*N*	ppc/npct
Control	0/20	—	—	—	—	—	—	—
Hand file	0/20	8/20	0/20	0/8	1/20	1/8	0/20	0/9
ProTaper	0/20	8/20	0/20	0/8	4/20	5/8	4/20	3/12
Mtwo	0/20	8/20	0/20	0/8	4/20	4/8	3/20	4/12

n, number of new cracks; *N*, total number of specimens; npct, number of previous cracked teeth; ppc, propagation of previous cracks.

retreatment, and additional instrumentation. All statistical analyses were performed at a 5% significance level by using the SPSS 16.0 software (SPSS Inc, Chicago, IL).

Results

Table 1 summarizes the apical crack initiation and propagation incidence for each group. No apical cracks were found in the baseline images (Fig. 1*A*). After initial root canal instrumentation, 24 of 60 teeth displayed apical cracks (Fig. 1*B*), and these teeth were evenly distributed to each group ($n = 8$). The experimental groups showed no new apical crack initiation and propagation after the root canal filling. The retreatment procedure had a significant effect on apical crack initiation ($P < .05$). The ProTaper and Mtwo retreatment groups caused a greater incidence of crack initiation than did the hand instrument group ($P < .05$), whereas there was no statistical difference between the ProTaper and Mtwo retreatment groups regarding crack initiation ($P > .05$). In addition, retreatment procedures had a significant effect on crack propagation (Fig. 1*C*) ($P < .05$). ProTaper and Mtwo retreatment groups caused more crack propagation than did the hand instrument group ($P < .05$), whereas there was no statistical difference between the ProTaper and Mtwo retreatment groups regarding crack propagation ($P > .05$). Additional instrumentation with ProTaper and Mtwo instruments caused new crack initiation and propagation, but the hand instrument group did not ($P < .05$). However, there was no significant difference between the ProTaper and Mtwo groups regarding crack initiation and propagation after additional instrumentation ($P > .05$).

Discussion

Nonsurgical endodontic retreatment requires the removal of preexisting root canal filling material to allow for adequate cleaning, disinfection, and obturation of the root canal space after the failure of previous root canal treatment (12). After retreatment procedures, the apical third generally has a greater mean percentage of root canal filling material than the middle and cervical thirds because there is increased anatomic variability and because of the difficulty of instrumentation in the apical third (13, 14). Therefore, increased instrumentation time to remove root filling material in the apical third may be necessary. Additional instrumentation with ascending instrument sizes is also used to improve removal of root canal filling after use of retreatment instruments (15, 16). In this situation, apical crack incidence may increase after use of retreatment instruments and additional instrumentation when compared with initial canal preparation. Thus, the present study aimed to evaluate apical crack initiation and propagation in apical dentin after use of retreatment instruments and additional instrumentation in retreatment.

Adorno et al (17) stated that the deviation of major apical foramen from the root canal axis might be a factor in the initiation of cracks. Therefore, teeth with deviated apical foramen were not included in the current study to ensure standardization and to reduce the number of variables. Similar to a previous study (11), in the present study the apical 1 mm of the roots was trimmed to more clearly assess crack initiation and propagation during all procedures. Initial canal preparation was performed with the same NiTi rotary system (Revo-S) in all groups to ensure standardization. The images after initial preparation showed that NiTi rotary system caused cracks in the apical dentin. Previous studies have shown that NiTi rotary instruments cause apical cracks to occur after instrumentation (10, 18). This may be due to the greater number of rotations in the canal that are necessary to complete a preparation (19). It has been stated that after root canal preparation every subsequent procedure, such as obturation and retreatment with rotary systems, can create dentinal cracks (4, 20). In the current study, the root canal filling was performed by using the single cone technique, with a gutta-percha cone matching the master apical file.

The images taken after filling showed that the single cone technique did not cause crack initiation and propagation. This may be attributed to the fact that the single cone technique applies minimal pressure compared with filling techniques that create compaction

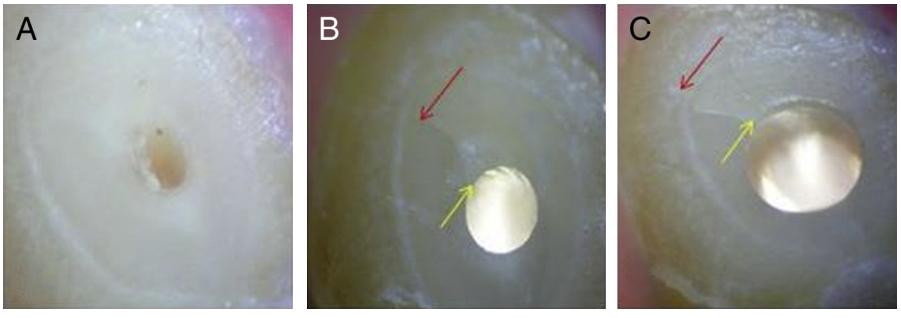

Figure 1. One specimen showing crack initiation and propagation. (*A*) No crack visible in the baseline image. (*B*) Crack initiation after instrumentation, starting point of the crack (*yellow arrow*) and end point of the crack (*red arrow*). (*C*) Crack propagation after retreatment, starting point of the crack (*yellow arrow*) and end point of the crack (*red arrow*).

forces on root canal walls (21). In the present study the effect of retreatment procedures on propagation of existing cracks was evaluated because the cracks occurred as a result of initial canal preparation. The findings showed that NiTi retreatment instruments caused more new apical crack initiation and propagation of cracks than did hand files. This could be attributed to the less aggressive movements of hand files in the canal compared with engine-operated NiTi rotary files. This finding for retreatment procedures differed from that of Shemesh et al (9), who did not observe any defect difference between hand file and ProTaper retreatment instrument groups. Shemesh et al only determined the root cracks occurring after using retreatment instruments. In the present study, after initial canal preparation, no cracked teeth were evaluated to determine the effect of the retreatment procedure on new crack initiation. On the other hand, cracked teeth after initial canal preparation were examined for crack propagation after the retreatment procedure. Therefore, the different findings between the studies may be due to experimental design differences.

It was claimed that the taper and tip design of files could be a contributing factor in the generation of cracks because of increased stress on canal walls caused by the tapered files (2, 4). The tip designs of ProTaper D3 and Mtwo R2 retreatment instruments are non-cutting and active cutting, respectively. Moreover, their tapers are also different (.07 for ProTaper D3 and .05 for Mtwo R2). Although these retreatment instruments are used in the WL and have different tip designs and tapers, there appeared to be no difference between them in terms of crack initiation. It can be concluded from this finding that there is no connection between the tip design and taper of NiTi rotary retreatment instruments used in this study and the formation of the apical crack initiation and propagation during retreatment.

The apical diameters of ProTaper D3 and MtwoR2 instruments were size 20 and size 25, respectively. These retreatment instruments, which are designed to reach the WL, may not provide complete removal of root canal filling material from the apical third. In the current study, therefore, supplementary instrumentation was performed by using size 40 files because the apical diameter of the master apical file (size 35) in the initial canal preparation was larger than that of the retreatment instruments.

Another finding from this study was that additional instrumentation with NiTi rotary instruments showed incidence of apical crack and propagation, but the hand file group showed none. This is because both rotary instruments have an active rotating movement that may cause more friction between the files and canal walls inside the root canal (19, 22) and may thereby increase the incidence of cracks in which root fractures can begin to form. A further cause may be that the ProTaper (.06 taper) and Mtwo (.04 taper) instruments have a taper that is larger than hand files (.02 taper) and remove more apical dentin compared with when hand files (2) are used. It has been stated that the more root dentin that is removed, the greater the risk of root defects (23).

Clinically, bacteria may proliferate in crack lines and later establish biofilms on the root surface (24). Moreover, localized crack lines may develop into root fractures through propagation after long-term functional stresses such as chewing (23). In this situation, a complete crack might contribute to leakage, resulting in the recurrence of periapical infection. Consequently, Lertchirakarn et al (25) stated that decreasing the applied force during endodontic or restorative procedures (obturation, post placement) significantly reduces the risk of fracture.

Conclusions

Under the conditions of this *in vitro* study, it can be concluded that NiTi rotary retreatment instruments cause more crack initiation and propagation in apical root dentin after retreatment procedures than do hand files. Also, the use of rotary files in additional instrumentation, after the use of retreatment instruments, can result in apical crack initiation and propagation, whereas hand files do not. When assessing the outcomes of nonsurgical endodontic retreatment and the prognosis of re-treated teeth, clinicians should consider the risk of causing apical cracks during retreatment procedures.

Acknowledgments

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

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