Dentinal Microcrack Formation during Root Canal Preparations by Different NiTi Rotary Instruments and the Self-Adjusting File

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Abstract

Introduction: The purpose of this study was to compare dentinal microcrack formation while using hand files (HFs), 4 brands of nickel-titanium (NiTi) rotary files and the self-adjusting file. **Methods:** One hundred forty mandibular first molars were selected: 20 teeth were left unprepared and served as control, and the remaining 120 teeth were divided into 6 groups. HFs, HERO Shaper (HS; Micro-Mega, Besancon, France), Revo-S (RS, Micro-Mega), Twisted File (TF; SybronEndo, Orange, CA), ProTaper (PT, Dentsply Maillefer), and SAFs were used to prepare the 2 mesial canals. Roots were then sectioned 3, 6, and 9 mm from the apex, and the cut surface was observed under a microscope and checked for the presence of dentinal microcracks. **Results:** The control, HF, and SAF groups did not show any microcracks. In roots prepared with the HS, RS, TF, and PT, dentinal microcracks were observed in 60%, 25%, 44%, and 30% of teeth, respectively. There was a significant difference between the control/HF/SAF group and the 4 NiTi rotary instrument groups ($P < .0001$). However, no significant difference was found among the 4 NiTi rotary instruments ($P > .005$). **Conclusions:** All rotary files created microcracks in the root dentin, whereas the SAF file and hand instrumentation presented with satisfactory results with no dentinal microcracks. *(J Endod 2012;38:232–235)*

Key Words

Microcracks, NiTi instruments, root canal preparations, self-adjusting file, vertical root fracture

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Biomechanical preparation of root canals is one of the main steps in achieving endodontic success due to enabling bacterial elimination, removal of debris, and facilitating obturation. Perforations (1), canal transportation, ledge and zip formation (2), and separation of instruments (3) are some of the complications encountered during root canal preparation and retreatment cases. Vertical root fracture and crack formation can also be seen in root dentin during and after endodontic procedures.

Vertical root fracture is one of the frustrating complications of root canal treatment, which often results in tooth extraction (4). The root fracture might occur as result of a microcrack or craze line that propagates with repeated stress application by occlusal forces. Bier et al (5) showed dentinal damage (microcracks) in teeth that were prepared with several nickel-titanium (NiTi) rotary instruments with the exception of S-Apex rotary files (FKG Dentaire, La-Chaux-de-Fonds, Switzerland). They found the highest defect ratio when ProTaper was used, whereas no defect was observed with hand files. It has been shown that root canal filling procedures could also create cracks (6). Shemesh et al (7) observed significantly more dentinal defects (microcracks) in teeth that were obturated with spreader than when no spreader was used. Retreatment procedures, biomechanical preparation, and obturation techniques could all lead to dentinal damage in different degrees.

In the last decades, many new NiTi rotary instruments have been developed and introduced by various manufacturers. Most clinicians prefer these systems because of their advantages such as saving time (8) and better cutting efficiency (9). Nevertheless, some functions of NiTi rotary systems such as cleaning ability, increased stress, and the inability to adequately prepare oval canals are still controversial. Additionally, Kim et al (10) have found a potential relationship between the design of NiTi instruments and the incidence of vertical root fractures. They concluded that file design affected apical stress and strain concentrations during root canal instrumentation.

Recently, the self-adjusting file (SAF) (ReDent Nova, Ra'anana, Israel) was introduced into the NiTi instrument family with a totally new design. SAF is a hollow file designed as a compressible, thin-walled, pointed cylinder composed of a thin NiTi lattice. During its operation, the file is designed to be compressed while inserted into a narrow root canal; then, it attempts to regain its original dimensions, thus applying a constant delicate pressure on the canal walls. When inserted into a root canal, it adapts itself to the canal's shape, both longitudinally and also along the perimeter of the cross-section (11). The purpose of the present study was to compare the dentinal microcrack formation while using hand files, 4 brands of NiTi rotary files, and the SAF.

Materials and Methods

One hundred forty mandibular first molars were selected and stored in purified filtered water. Teeth with severely curved mesial roots were excluded from the study. The coronal portions and distal roots of all teeth were removed by using a diamond coated bur with water cooling, leaving roots approximately 11 mm in length. All roots were inspected with transmitted light and stereomicroscopy under 12× magnification to detect any preexisting craze lines or cracks. Teeth with such findings were excluded from the study and replaced by similar teeth. A silicon impression material was used for coating the cemental surface of roots to simulate periodontal ligament space. Then, all roots were embedded in acrylic blocks. Twenty teeth were left unprepared and served as control, and the remaining 120 teeth were subjected to the procedures described later.

Canal patency was established with a #15 K-File (Dentsply Maillefer, Ballaigues, Switzerland) in both mesiobuccal and mesiolingual canals. In the hand file (HF) group, HFs were used to prepare the canals to file #40. In the HERO Shaper (HS; Micro-Mega, Besancon, France), Revo-S (RS; Micro-Mega), Twisted File (TF; SybronEndo, Orange, CA), and ProTaper (PT, Dentsply Maillefer) groups, canal preparation was performed with rotary files using a torque and speed-controlled motor (X-Smart; Dentsply Tulsa Dental, Tulsa, OK) at a torque and speed recommended by the manufacturer for each specific system used. In the HS group, HS NiTi files were used in a crown-down red sequence to file #30 at 300 rpm. In the RS group, RS rotary files were used to prepare canals up to apical size #30. NiTi files were used at 300 rpm in a sequence of SC1, SC2, SU, and AS 30. In the TF group, canals were prepared with the following sequence of the TF and were used at 500 rpm: 25/.08, 25/.06, 25/.04, and 30/.06 files. In the PT group, the following sequence of PT rotary NiTi files were used to prepare the canals at 300 rpm. The Shaping File X was used in coronal enlargement, and S1, S2, F1, F2, and F3 files, which correspond to apical size 30, were used at the working length. In the SAF group, the SAF was used to enlarge canals. For this procedure, canals were first prepared with a K-file until #20 at the working length and then the SAF 1.5-mm file, which corresponds to an apical size of 20, was used with an in-and-out vibrating handpiece head (RDT3; ReDent-Nova, Ra'anana, Israel) at an amplitude of 0.4 mm and at 5,000 vibrations per minute as described by Metzger et al (11). The SAF file was applied with a pecking motion to the working length for 4 minutes in each canal. Continuous irrigation with 2.5% sodium hypochlorite was applied by a pump (VATEA, ReDent-Nova) at a rate of 3 mL/min.

In the HF, HS, RS, TF, and PT groups, irrigation was performed with 2.5% sodium hypochlorite between each instrument during the preparations of root canals. A total of 12 mL of sodium hypochlorite was used in each canal.

Sectioning and Microscopic Examination

All roots were sectioned perpendicular to the long axis at 9, 6, and 3 mm from the apex using a diamond coated saw (Exakt 300 CL; Exakt Apparatbau, Norderstad, Germany) under water cooling. Digital images of each section were captured at 40× magnification using a digital camera (DP-70; Olympus, Tokyo, Japan) attached to a stereomicroscope (BX50, Olympus). Each specimen was checked by 2 operators for the presence of dentinal defects (microcracks). "No defect" was defined as root dentin devoid of any craze lines or microcracks either at the external surface of the root or at the internal surface of the root canal wall. "Defect" was defined if any lines, microcracks, or fractures were present in root dentin. A total of 60 sections were examined in each group.

The results were expressed as the number and percentage of roots in each group. The chi-square and Fisher exact tests were used for statistical analysis of differences between groups. Bonferroni correction was used for multiple comparisons. The level of significance was set at $\alpha = 0.017$.

Results

The unprepared canals (the control group), the HF group, and the SAF group presented no defects. Defects were found in all NiTi rotary file groups (groups HS, RS, TF, and PT). The percentages of roots with defects in each group are shown in Figure 1. Only a single case of complete fracture was observed, and it was in the PT group. There was a statistically significant difference between the NiTi rotary file groups and the control/hand file/SAF file groups, which presented no defects ($P < .0001$).

Figure 2 presents representing microscopic images from each experimental group. The RS group had the lowest number of defects (5/20 roots); PT (6/20), TF (8/20), and HS had the highest incidence of defects (12/20). However, no significant difference was detected among the 4 NiTi rotary file groups ($P > .005$).

Discussion

When NiTi rotary instruments are used, a rotational force is applied to root canal walls. Thus, they can create microcracks or craze lines in root dentin. The extent of such a defect formation may be related to the tip design, cross-section geometry, constant or progressive taper type, constant or variable pitch, and flute form. The SAF is a NiTi file but not a rotary instrument. It works with a back and forth grinding motion that removes dentin from the canal walls. The present study was aimed to compare the extent to which different NiTi rotary instruments, HFs,

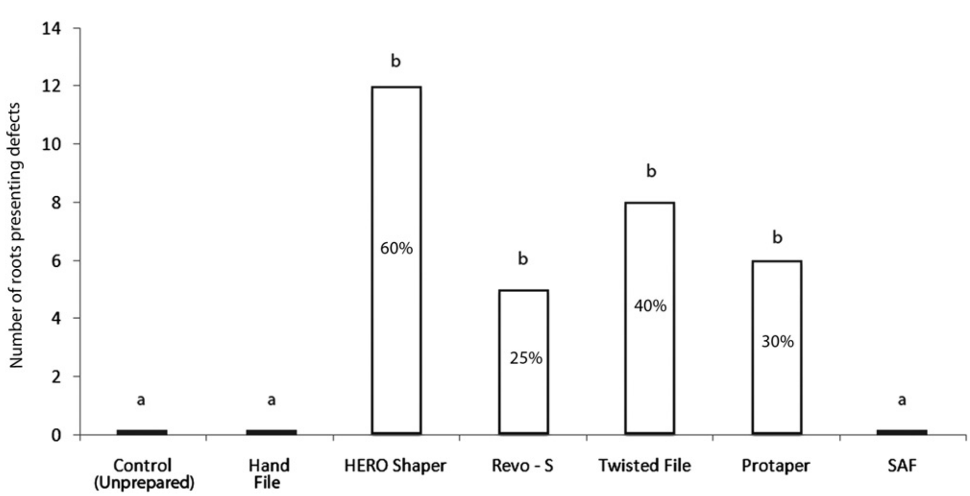

Figure 1. The percentage and number of roots presenting a defect after canal preparations with different instruments. Groups with the same letter denote no statistical significance between them ($P > .05$).

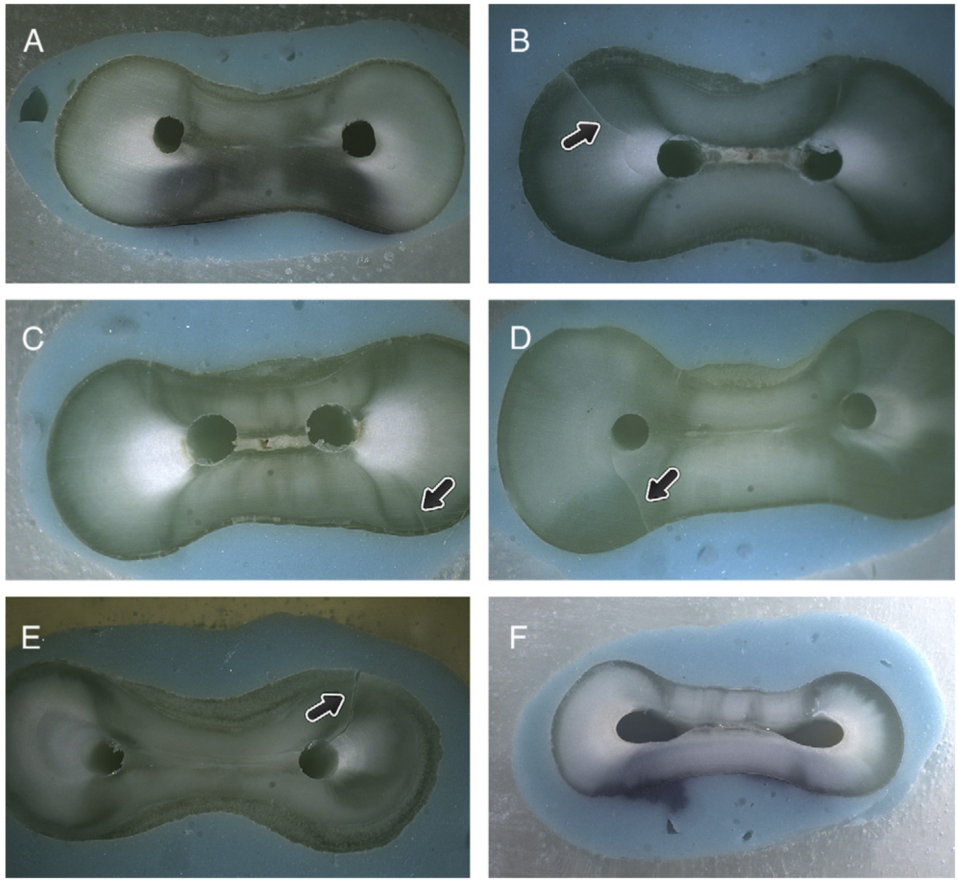

Figure 2. Representative microscopic images from each experimental group. *Arrows* point at dentinal defects. (*A*) Hand files , (*B*) Hero Shaper, (*C*) Revo-S, (*D*) Twisted File, (*E*) ProTaper (complete fracture), and (*F*) SAF.

and SAFs induce dentinal damage in the form of microcracks in root dentin.

Resistance to tooth fracture is an important aim in endodontics because such fractures may decrease the long-term survival rate. Experimental studies have shown that excessive removal of dentin during root canal preparation, post space preparation, and obturation procedures with spreader can create fractures in teeth (7, 12). However, in the current study, only one complete fracture was seen, and it seems that the reason of fracture was not the weakening of the tooth structure that may have been caused by the excessive removal of dentin (Fig. 2*E*). Wilcox et al (13) and Shemesh et al (6, 7) reported various degree of fracture rates 40%, 16% to 25% and 12%, respectively, when obturation and retreatment procedures were included. The present study did not test the effects of obturation or retreatment; therefore, the results showed a relatively low fracture rate. Bier et al (5) suggested that fractures did not occur immediately after canal preparation. However, craze lines occurred in 4% to 16%, which may develop into fractures during retreatment or after long-term functional stresses like chewing (13). In this regard, root canal preparation with NiTi rotary systems and every following additional procedure in endodontics as obturation and retreatment with rotary systems can create fractures or craze lines.

In this study, microcracks occurred in between 25% to 60% of the roots. Many *ex vivo* studies showed a lesser incidence of microcracks (5, 7). However, our study is in accordance with the studies of Wilcox et al (13) and Shemesh et al (6). Most *in vitro* studies that assess the incidence of dentinal damage after root canal treatment procedures used single-rooted teeth for sampling. Both mesiobuccal and mesiolingual canals of mesial roots of mandibular first molars were instrumented in this study. Therefore, repeated ($\times 2$) instrumentation of these roots might also increase the defect rates in the present study.

Kim et al (10) suggested that file design affected apical stress and strain concentrations during instrumentation, which were linked to an increase in dentinal defects and canal deviations. These, in turn, were associated with increased vertical root fracture susceptibility because root canal obturation and final restoration can initiate or propagate cracks from such defects. Furthermore, significantly more rotations in the canal are necessary to complete a preparation with rotary NiTi files as compared with HFs (14). This, in itself, may contribute to the formation of dentinal defects.

NiTi instruments' torsional and bending behavior (15), cyclic fatique (16), flexibility (17), and other mechanical properties have been tested and compared with each other. All rotary NiTi instruments do not have the same mechanical behavior. Arbab-Chirani et al (15) confirmed the suggestion that Mtwo (Sweden & Martina, Padova, Italy) has a lower level of torque and bending force than PT F1 and HS, namely Mtwo is about twice as flexible as HS and 3 times as flexible as PT. The relatively low flexibility of the HS may have contributed to the highest number of defect in this study. Furthermore, the high level of stiffness of the PT F1 may be explained by a larger cross-section because of its progressive taper (15). In the present study, all tested NiTi instruments had in common a triangular cross-section geometry with different designs in each group. The incidence of defects showed no significant difference among the 4 NiTi rotary file groups. This similarity in results may be attributed to the similar cross-section geometry of tested NiTi instruments.

The lowest defect number was seen in the RS group. A literature search did not reveal any previous studies regarding this file system. However, manufacturers suggest that RS provides less stress on the instrument because of the asymmetrical cross-section and the extended cutting part in the coronal region, which increases instrument flexibility (18). The TF group showed 40% defect rate. In a study that evaluated torsional resistance of NiTi files, the TF showed the least resistance to repeated torsional stresses (19).

In the current study, no defect was observed in the control, HF, and SAF groups. In these groups, rotational movement was not applied; instead, Ingle's standardized preparation technique was used with HFs, and in-and-out grinding motion was used for SAF. The SAF file easily compresses into the canal and then attempt to regain its original dimensions; thus, apply a constant delicate pressure on the canal walls, which allows for uniform removal of dentin along the whole perimeter of the root canal cross-section (20). It might be the reason why SAF did not create any defects in experimental samples.

This study is in agreement with Bier et al (5) in that they did not observe any defect in the HF group. In addition, studies that performed fracture testing with a spreader have controversial results; in one study, HFs were found to be the most resistant (21). In another study, however, they were found to be the worst resistant (22). Although this gives insight into the minimum force necessary to fracture a root, it does not mimic clinical settings (13). Additionally, it has been suggested that the total volume of dentin removed from the root canals was significantly greater with NiTi rotary systems in comparison with hand files, which implicates more problems that might affect prognostic stability of the teeth, but HFs' cleaning ability and inefficiency in preparing canals are still controversial (23).

In the samples evaluated, it is noteworthy that NiTi instruments made a round cross-section, but SAF made a teardrop-shaped cross-section similar to the canal's original shape; this was observed in most samples. Metzger et al (11) emphasize that most rotary file systems would find the widest part of the canal and gradually machine it, using several files of increasing diameter, to a wider canal with a round cross-section. If the canal happens to be relatively narrow, the whole original canal may be included in the preparation. If the canal, however, is flat, oval, teardrop shaped, or simply large, this mode of preparation may leave untreated recesses, mainly buccally or lingually to the machined part of the canal (11). The SAF file touches the inner canal wall in all points as a result of compressible and expansive structure of lattice. This characteristic might not create any microcrack in dentin because of the inhibition of stress formation along the root canal. Additionally, the surface of the lattice threads is lightly abrasive, which allows it to remove dentin with a back-and-forth grinding motion rather than the machining action with the rotating blade of the NiTi rotary files (20). Such machining by the rotary files may reduce the thickness of the remaining dentin on the inner side of the curvature to such an extent that it increases the risk of vertical root fracture (24) or may even result in a strip perforation.

Even though this *in vitro* study did not reflect the clinical settings, we can conclude that NiTi instruments tend to induce various degrees of dentinal damage during root canal preparation. On the other hand, the SAF file and hand instrumentation represent satisfactory results with no microcrack defects.

Acknowledgments

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

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