The Ability of Different Nickel-Titanium Rotary Instruments To Induce Dentinal Damage During Canal Preparation

Carlos Alexandre Souza Bier, DMD, Hagay Shemesh, DMD,† Mário Tanomaru-Filho, DDS, MSc, PhD,* Paul R. Wesselink, DDS, PhD,† and Min-Kai Wu, MD, MSD, PhD†*

Abstract

The purpose of this study was to compare the incidence of dentinal defects (fractures and craze lines) after canal preparation with different nickel-titanium rotary files. Two hundred sixty mandibular premolars were selected. Forty teeth were left unprepared ($n = 40$). The other teeth were prepared either with manual Flexofiles ($n = 20$) or with different rotary files systems: ProTaper (Dentsply-Maillefer, Ballaigues, Switzerland), ProFile (Dentsply-Maillefer), SystemGT (Dentsply-Maillefer), or S-ApeX (FKG Dentaire, La Chaux-de-Fonds, Switzerland) ($n = 50$ each). Roots were then sectioned 3, 6, and 9 mm from the apex and observed under a microscope. The presence of dentinal defects was noted. There was a significant difference in the appearance of defects between the groups ($p < 0.05$). No defects were found in the unprepared roots and those prepared with hand files and S-ApeX. ProTaper, ProFile, and GT preparations resulted in dentinal defects in 16%, 8%, and 4% of teeth, respectively. Some endodontic preparation methods might damage the root and induce dentinal defects. *(J Endod 2009;35:236–238)*

Key Words

Craze lines, dentinal defects, nickel-titanium instruments, root canal preparation

From the *Department of Restorative Dentistry, Araraquara Dental School, São Paulo State University, UNESP, Araraquara, SP, Brazil; and †Department of Cariology, Endodontology, Pedodontology Academic Centre of Dentistry Amsterdam, the Netherlands.

Carlos Alexandre Souza Bier was supported by the Brazilian agency Capes, grant no. 2094/07.

Address requests for reprints to Dr Hagay Shemesh, ACTA, CEP, Louwesweg 1, 1066 EA Amsterdam, The Netherlands. E-mail address: hshemesh@acta.nl.

0099-2399/$0 - see front matter

doi:10.1016/j.joen.2008.10.021

The goals of endodontic instrumentation are to completely remove microorganisms, debris, and tissue by enlarging the canal diameter and create a canal form that allows a proper seal. Complications such as transportation, ledge formation, and perforation are well documented (1, 2). However, preparation procedures could also damage the root dentin resulting in fractures or craze lines (3). Wilcox et al. (3) examined teeth after hand preparation and lateral compaction of gutta-percha and sealer. Teeth not presenting vertical root fractures (VRFs) were retreated by removing the root canal filling and further enlarging the canal. No VRFs were observed after the initial preparation, whereas numerous fractures had occurred after further enlargement. All roots that eventually fractured had previously shown craze lines. They concluded that the more dentin removed the more chance for a fracture. The observation that all teeth presented craze lines led the authors to speculate that these could later propagate into VRF if the tooth is subjected to repeated stresses from endodontic or restorative procedures. Indeed, evidence of recent years concentrate on the findings that VRFs are probably caused by a propagation of smaller, less pronounced defects and not by the force practiced during preparation or obturation (4, 5).

An increasing number of rotary nickel-titanium (NiTi) file systems have been marketed by various manufacturers. These systems differ from one another in the design of the cutting blades, body taper, and tip configuration. Despite the obvious clinical advantages of these techniques over hand instrumentation, the influence of the design of the cutting blades is still controversial (6, 7) and could generate increased friction and stresses within the root canal (8). Rotary instrumentation requires less time to prepare canals as compared with hand instrumentation but result in significantly more rotations of the instruments inside the canal (9). This may cause more friction between the files and the canal walls.

The goal of this ex vivo study was to compare the damage observed in the root dentin after endodontic preparations with different NiTi rotary files systems.

Materials and Methods

Two hundred sixty extracted lower premolars were selected and stored in purified filtered water. This storage medium causes the smallest changes in dentin over time and was previously recommended for investigations of human dentin (10). The coronal portion of all teeth was removed by using an Isomet 11–1180 low-speed saw (Buehler Ltd, Evanston, IL) with water cooling, leaving roots approximately 16 mm in length. All roots were observed with a stereomicroscope under 12× magnification (Zeiss Stemi SV6, Jena, Germany) to exclude cracks. Forty teeth were left unprepared and served as control group A. Twenty teeth were prepared with hand files (K-Flexofiles; Dentsply-Maillefer, Ballaigues, Switzerland) using balance force crown down to file 40 and step-back 1-mm increments with Flexofiles #45 to 80 (Dentsply-Maillefer), resulting in a preparation with a taper of about 0.05. These teeth formed control group B. The remaining 200 teeth were randomly divided into four groups of 50 teeth each. Canal patency was established with a #20 K-Flexofile (Dentsply Maillefer). Thereafter, canal preparation followed with rotary files according to the relevant group (1–4) using a torque-control motor (ATR; Technika, Pistoia, Italy) and at the torque and speed recommended by the manufacturer for the specific system used.

In group 1, the following sequence of ProTaper rotary files (Dentsply Maillefer) was used at 300 rpm to prepare the canals; an SX file was used to enlarge the coronal portion of the canal, and then all files were used to working length: S1→ S2→F1→F2→F3. The last file used was F4, which corresponds to file 40 with a taper 0.06 at the apical area.

In group 2, canal preparation with SystemGT files (Dentsply Maillefer) at 300 rpm using a crown-down technique. Files 50/0.12 and 35/0.12 were used to enlarge the canal opening, and GT series 30 and 40 taper 0.1, 0.08, 0.06, 0.04 were used consequently to prepare the canal till GT file 40/0.06 reached 1 mm short of the apical foramen.

In group 3, ProFile rotary NiTi files (Dentsply Maillefer) at 300 rpm were used in a crown-down sequence. ProFile Orifice shapers 2 and 3 were used to preflare the canal opening, and the preparation ended when a 40/0.06 file reached 1 mm short of the apex.

In group 4, S-ApeX rotary files (FKG Dentaire, La Chaux-de-Fonds, Switzerland) sizes 15 to 60 were used at a speed of 600 rpm. The manufacturer's instructions were followed using the full sequence of 6 files available at the working length. This system has an inverted taper, and the preparation may result in a nontapered form.

In all experimental and control groups, each canal was irrigated with a freshly prepared 2% solution of sodium hypochlorite (NaOCl) between each instrument during the preparation procedure using a syringe and a 27-G needle. Twelve milliliters of NaOCl solution was used for each root. After the completion of instrumentation, passive ultrasonic irrigation was performed with an Irrisafe 20/21 file (Satelec, Merinac Cedex, France) in order to efficiently clean the canals and remove any debris still present (11). After completion of the procedure, canals were rinsed with 2 mL distilled water. All roots were kept moist in distilled water throughout the experimental procedures.

Sectioning and Microscopic Observations

All roots were cut horizontally at 3, 6, and 9 mm from the apex with a low-speed saw under water cooling (Leica SP1600, Wetzlar, Germany). Slices were then viewed through a stereomicroscope (Zeiss Stemi SV6, Carl Zeiss, Jena, Germany) using a cold light source (KL 2500 LCD, Carl Zeiss). The appearance of dentinal defects was registered by the author (CASB), after which pictures were taken with a camera (Axio Cam, Carl Zeiss) at a magnification of ×12. The pictures were then blindly inspected by the second author (HS). In four cases out of a total of 780 slices (0.5%), there was a discrepancy in the observations, and a consensus was reached after inspecting the slices again. In order to avoid confusing definitions of root fractures, three distinguished categories were made: "no defect," "fracture," and "other defects" (12). "No defect" was defined as root dentin devoid of any lines or cracks where both the external surface of the root and the internal root canal wall did not present any evident defects. "Fracture" was defined as a line extending from the root canal space all the way to the outer surface of the root (3). "Other defects" were defined as all other lines observed that did not seem to extend from the root canal to the outer root surface (eg, a craze line, a line extending from the outer surface into the dentin but does not reach the canal lumen (3), or a partial crack, a line extending from the canal walls into the dentin without reaching the outer surface).

Statistical Analysis

Roots were classified as "defected" if at least one of three sections showed either a craze line, partial crack, or a fracture. Results were expressed as the number and percentage of defected roots in each group. A chi-square test was performed to compare the appearance of defected roots between the experimental groups by using the SPSS/PC version 15 (SPSS Inc, Chicago, IL). The level of significance was set at $\alpha = 0.05$.

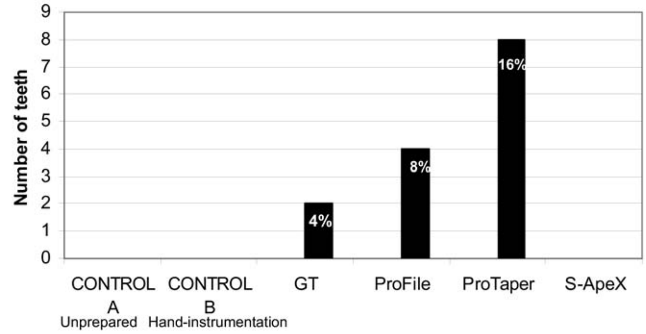

Figure 1. The number of teeth and percentage showing defect.

Results

No complete fractures were observed in any of the samples. Control groups A (unprepared canals) and B (hand preparation) showed no defected roots. Craze lines and partial cracks ("other defects") were found in the SystemGT, ProFile, and ProTaper groups, whereas no defects were observed in canals prepared with S-Apex files (Fig. 1). The difference between the experimental groups in the appearance of defects was significant (chi-square test, $p = 0.001$).

Discussion

Recent ex vivo studies suggest that VRF is probably not an instant phenomenon but rather a result of gradual diminution of root structure (4, 5) .The current results could confirm that fractures did not occur immediately after canal preparation. However, craze lines occurred in 4% to 16%, and these may develop into fractures during retreatment or after long-term functional stresses like chewing (3). This is in agreement with Onnink et al. (13), who were the first to report dentinal defects as a consequence of canal preparation but only found small defects entirely within dentin that did not communicate with the canal wall. Less pronounced dentinal defects like craze lines were observed in the current study. Considering the crucial clinical importance of VRF and its determinant effect on tooth survival, even a small percentage of damaged teeth could be of clinical importance.

Ultrasonic irrigation was used in order to effectively clean the canal walls (11). However, ultrasonic action can also result in rough canal walls (14) and cause fractures after root-end preparations (15). In the current experiment, ultrasonic irrigation was performed in all groups (11). Because all teeth were irrigated following the same protocol and roots prepared with hand files and S-ApeX files did not show any dentinal defects, the conclusion that the ultrasonic irrigation performed in this study did not contribute to the appearance of dentinal defects seems justified.

Sawing action could also result in dentinal defects. However, because both the controls and the S-ApeX groups did not show any defect, we may conclude that the defects seen were a result of preparation procedures.

The only rotary file system among those used in this study that did not show any dentin damage is S-ApeX. A literature search revealed no previous studies regarding this file system. It is the only system available with an inverted taper (Fig. 2) and may result in a parallel preparation similar to the previously described LightSpeed system (LightSpeed Technology, Inc, San Antonio, TX) (16).

The taper of the preparation and the files could be a contributing factor in the generation of dentinal defects. Wilcox et al. (3) concluded that the more root dentin that is removed the more likely a root is to fracture. However, in the present study, a uniformed tapered preparation (0.05–0.06) was attempted in all groups except for the S-ApeX

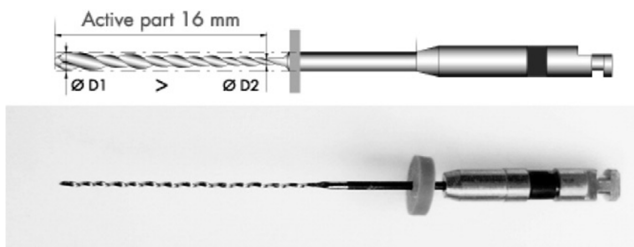

Figure 2. The S-Apex file has an inverted taper.

preparation, which is not tapered at all. The observation that all groups prepared with rotary NiTi files showed various degrees of damage except for the nontapered group supports the idea that tapered files may generate an increased stress on the dentin wall. This observation is supported by Sathorn et al. (17) who concluded that by maintaining the canal size as small as practical, a reduction in fracture susceptibility could be expected.

The amount of material removed from the root canal depends on the shape of the rotary instrument and the penetration depth in the canal. Because the roots prepared with rotary files that had a taper of at least 0.06 in this study showed defects, it should be realized that these instruments remove more apical dentin as compared with hand files that have a taper of 0.02. It is noteworthy that ProTaper file F3 has a large apical taper of 0.09 (18), which could explain the higher incidence of damage observed in the ProTaper group as compared with the other tapered rotary files. Furthermore, significantly more rotations in the canal are necessary to complete a preparation with rotary NiTi files as compared with hand files (9). This, in itself, may contribute to the formation of dentinal defects.

Some of the defects seen did not connect with the pulp space. Wilcox et al. (3) speculated that the stresses generated from inside the root canal are transmitted through the root to the surface where they overcome the bonds holding the dentin together. Onnink et al. (13) speculated that a fracture contained within the dentin in one section could communicate with the canal space in an adjacent section. This was recently supported by nondestructive observations of dentinal defects induced in extracted teeth and viewed with optical coherence tomography (5).

Under the tested conditions and within the limitations of this ex vivo investigation, it may be concluded that the use of some rotary NiTi instruments could result in an increased chance for dentinal defects.

Acknowledgments

The authors thank Wim van der Borden, DDS, Department of Cariology Endodontology Pedodontology, Academic Centre of Dentistry Amsterdam, The Netherlands, for his clinical expertise with S-ApeX files.

References

1. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;18:269–96.
2. Pettiette MT, Metzger Z, Phillips C, Trope M. Endodontic complications of root canal therapy performed by dental students with stainless-steel K-files and nickel-titanium hand files. J Endod 1999;25:230–4.
3. Wilcox LR, Roskelley C, Sutton T. The relationship of root canal enlargement to finger-spreader induced vertical root fracture. J Endod 1997;23:533–4.
4. Soros C, Zinelis S, Lambrianidis T, Palaghias G. Spreader load required for vertical root fracture during lateral compaction ex vivo: evaluation of periodontal simulation and fracture load information. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:e64–70.
5. Shemesh H, van Soest G, Wu MK, Wesselink PR. Diagnosis of vertical root fractures with optical coherence tomography. J Endod 2008;34:739–42.
6. Peters OA.Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004;30:559–67.
7. Bergmans L, Van Cleynenbreugel J, Beullens M, Wevers M, Van Meerbeek B, Lambrechts P. Smooth flexible versus active tapered shaft design using NiTi rotary instruments. Int Endod J 2002;35:820–8.
8. Blum JY, Machtou P, Ruddle C, Micallef JP.Analysis of mechanical preparations in extracted teeth using ProTaper rotary instruments: value of the safety quotient. J Endod 2003;29:567–75.
9. Pasqualini D, Scotti N, Tamagnone L, Ellena F, Berutti E. Hand-operated and rotary ProTaper instruments: a comparison of working time and number of rotations in simulated root canals. J Endod 2008;34:314–7.
10. Strawn SE, White JM, Marshall GW, Gee L, Goodis HE, Marshall SJ. Spectroscopic changes in human dentine exposed to various storage solutions-short term. J Dent 1996;24:417–23.
11. van der Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J 2007;40:415–26.
12. Shemesh H, Bier CA, Wu MK, Tanomaru Filho M, Wesselink PR. The effects of root preparation and obturation on the incidence of dentinal defects. Int Endod J (in press).
13. Onnink PA, Davis RD, Wayman BE. An in vitro comparison of incomplete root fractures associated with three obturation techniques. J Endod 1994;20:32–7.
14. Stock CJ. Current status of the use of ultrasound in endodontics. Int Dent J 1991;41:175–82.
15. Navarre SW, Steiman HR. Root-end fracture during retropreparation: a comparison between zirconium nitride-coated and stainless steel microsurgical ultrasonic instruments. J Endod 2002;28:330–2.
16. Thompson SA, Dummer PM. Shaping ability of Lightspeed rotary nickel-titanium instruments in simulated root canals. Part 1. J Endod 1997;23:698–702.
17. Sathorn C, Palamara, Messer HH. A comparison of the effects of two canal preparation techniques on root fracture susceptibility and fracture pattern. J Endod 2005;31:283–7.
18. West JD. Introduction of a new rotary endodontic system: progressively tapering files. Dent Today 2001;20:50–2, 54–7.