A Scanning Electron Microscopy Evaluation of Microfractures, Deformation and Separation in EndoSequence and Profile Nickel-Titanium Rotary Files Using an Extracted Molar Tooth Model

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Abstract

The development of microfractures in the EndoSequence nickel-titanium rotary (NTR) file (Brassler USA, Savannah, GA) and Profile NTR file was evaluated by using scanning electron microscopy (SEM). Seventy-three maxillary buccal roots and 53 mandibular mesial roots with an average canal curvature of 37° were randomly assigned to one of three groups and prepared with 21-mm .06 taper NTR files as follows: (1) EndoSequence at 300 rpm, (2) EndoSequence at 600 rpm, and (3) ProFile at 300 rpm. File sizes .45 to .20 were used in a crown-down technique to a master apical file (MAF) size of .35/.06. The MAF instruments were evaluated by SEM before use, after completion of 7 canals, and after completion of 14 canals. All EndoSequence instruments developed microfractures by the seven-canal evaluation. The ProFile instruments showed no microfractures at the 7- or 14-canal evaluations. EndoSequence files separated at a higher rate than ProFile instruments. Under the conditions of this study, unique file design and electropolishing did not inhibit the development of microfractures in EndoSequence NTR. *(J Endod 2007;33:712–714)*

Key Words

Electropolishing, file separation, nickel-titanium rotary file, root canal preparation

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Endodontic instruments used in this study were donated by Brasseler USA and Tulsa Dental/Dentsply.

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Nickel-titanium rotary (NTR) instruments have gained widespread acceptance for use in root canal therapy in the past decade, although the influence of many instrument design variables is not completely understood (1). EndoSequence is a new NTR file developed by Brassler USA (Savannah, GA). The file is a reamer-like design and incorporates alternate contact point geometry. The developers state that removing radial lands increases cutting efficiency, increases flexibility, and reduces "drag," therefore lowering the torque requirements of the files (2, 3). They claim the alternate contact point geometry, precision tip, and excellent flexibility results in no canal transportation. The usual machining process of NTR files creates imperfections such as grooves, pits, and metal fold-over on the cutting edges (4). Electropolishing removes many of the machining defects found on NTR files and is claimed to inhibit crack propagation. EndoSequence NTR files have an electropolished surface and Profile NTR files (Dentsply Tulsa Dental Specialties, Tulsa, OK) do not. Several studies have shown that surface treatment of a NTR file may improve durability (5–7). In an evaluation of ProFile NTR file microstructure, Kuhn et al. (8) proposed that crack nucleation is facilitated by surface defects and that fatigue failure (cyclic fatigue) is largely a crack propagation process. Our hypothesis is that the electropolishing procedure used in the manufacture of the EndoSequence NTR files will inhibit the development of microfractures in comparison to the untreated surface of the Profile NTR file.

The purpose of this study was to evaluate the development of microfractures by scanning electron microscopy (SEM) in a clinically simulated extracted molar tooth model with EndoSequence NTR at 300 rpm, EndoSequence NTR at 600 rpm, and ProFile NTR at 300 rpm. The following data were collected: the presence of microfractures after preparation of 7 canals and 14 canals, file deformation, and file separation.

Materials and Methods

Sixty-six extracted molar teeth were placed in 10% buffered formalin mixture for 24 hours. Teeth were then soaked in 5.25% sodium hypochlorite (NaOCl) for 5 minutes and placed in sterile water for storage. Only buccal canals of maxillary molars and mesial canals of mandibular molars were selected. Access cavities were prepared by using a #4 round carbide bur (Brassler USA) and refined with an Endo-Z bur (Dentsply/Maillefer, Tulsa, OK) in a high-speed handpiece. One hundred and twenty-six roots were used out of a possible 132 due to two canals with an open apex and 4 canals that were non-negotiable. Length determination was accomplished by manipulation of a #10 stainless steel (SS) hand file (Dentsply/Tulsa Dental, Tulsa, OK) coated in RC-Prep (Premier Products Co, Plymouth Meeting, PA) through the apical foramen as determined by visualization of the file with an operating microscope (Global Inc, St Louis, MO) at 10× magnification and then subtracting 0.5 mm. The crowns were reduced with a 0816 diamond bur (Brassler USA) to working lengths of 21 mm, 19 mm, or 17 mm to avoid complete decoronation. All files were lubricated preinsertion with RC-prep. Canals were passively enlarged by using a watch-winding technique and alternating #8, 10, and 15 SS hand files. The creation of a manual glide path with SS instruments before the use of NTR files is believed to decrease the risk of instrument separtion (9). When a #15 SS reached working length, roots were numbered, and a radiograph was made with #15 SS at WL. The angle of curvature was determined by using the method described by Schneider (10). The average angle of curvature was 37° and ranged from 10° to 95°. To ensure that groups received an equal number of the 50 mandibular mesial roots and 76 maxillary buccal roots in each test group, they were divided into four groups: mesial buccal (MB) and distal buccal (DB) maxillary roots and mesial buccal (MB) and mesial lingual (ML) mandibular roots. These four groups were separately randomized and assigned to one of nine sets of rotary instruments by using a program provided by Random.org for a total of 14 roots per set of rotary instruments. There were three sets of .06 rotary files .20 to .45 in each group of EndoSequence 300 rpm, EndoSequence 600 rpm, and Profile 300 rpm for a total of nine sets.

Coronal preflaring was accomplished by using low-speed Gates Glidden burs #4, 3, and 2 (Densply/Tulsa Dental) in a crown-down technique. Coronal preflaring was considered complete when a Gates Glidden #2 bur reached within 6 mm of the apex. To enssure a level of competency with both instrument systems, the primary investigator completed 30 molar root canal treatments with each instrument system before the study. The same investigator (KSH) instrumented all 126 roots.

Each group, EndoSequence at 300 rpm, EndoSequence at 600 rpm, and ProFile at 300 rpm, included three sets of new files with a taper of .06 and tip diameters of .45, .40, .35, .30, .25, and .20. Before instrumentation, all canals were irrigated with 5.25% NaOCl. All phases of nickel titanium instrumentation were completed through a reservoir of 5.25% NaOCl in the pulp chamber. An Aseptico ITR electric motor (Aseptico Inc, Woodinville, WA) with the torque control in the off position was used for rotary instrumentation. The files were used in a crown-down technique beginning with file .45/.06. A light up and down motion was used to advance each file to two or three engagements of dentin. No files were left in the canal for longer than 2 to 3 seconds. The procedure was repeated with the next smaller instrument. The instrumentation was considered complete when a .35/.06 file reached working length. If this goal was not achieved, the canals were irrigated, patency was established with a #10 SS, and the crown-down procedure was repeated beginning at a .45/.06 until the .35/.06 reached working length. All rotary files were coated with RC prep before insertion into the canal and cleaned after every pass by repeated insertion into an endo sponge (Jordco Inc, Beaverton, OR). Rotary files were evaluated after every use for distortion or separation.

Scanning Electron Microscopy

A .35/.06 NTR file from each group was imaged by using SEM before use, after 7 canals, and finally after 14 canals to visualize the presence of microfractures, pitting, or fretting. All files were placed in an ultrasonic bath for 25 minutes, autoclaved, wiped with gauze soaked in 70% alcohol, and allowed to dry. Files were mounted on 23-mm SEM specimen mount stubs using double-sided carbon tape. In an attempt to evaluate the same area of a file on multiple examinations, a line was drawn in permanent ink on the handle of the first side of the file evaluated. All files were evaluated at known distances from the tip including 0, 1, 2, 3, and 5 mm. Files were imaged at three magnifications: 500×, and 1,000×, 2,000×.

Results

Instrument Separation and Deformation

A total of 36 NTR files deformed or separated during instrumentation of 126 canals (Table 1). EndoSequence NTR files (groups 1 and 2) were used in 48 maxillary buccal roots and 36 mandibular mesial roots for a total of 84 roots. Eight EndoSequence files separated while instrumenting maxillary roots, and five EndoSequence files separated while instrumenting mandibular roots. The ratio of maxillary to mandibular roots instrumented was 8:6, and the ratio of maxillary to mandibular separated files was 8:5. Seven files were separated in the mesial buccal root of maxillary molars compared with a total of 6 separated files in all other roots combined (Table 2). Separated instruments occurred in canals with an average curvature of 47.8° compared with the average of 36.8° for all canals. In group 1 (EndoSequence at 300 rpm), 4 files separated and 10 files showed plastic deformation. In group 2 (EndoSequence at 600 rpm), nine files separated and four files showed plastic deformation. ProFile NTR files (group 3) were used in 24 maxillary and 18 mandibular roots for a total of 42 roots. No Profile instruments separated, and 9 showed plastic deformation. Using chi-square analysis, there was a statistically significant difference ($p = 0.005$) in number of instruments separated between EndoSequence NTR files at 600 rpm (group 2) and Profile NTR files at 300 rpm (group 3). Differences between other groups were not statistically significant.

TABLE 1. Incidence of File Separation and Deformation During Canal Instrumentation of Extracted Molar Teeth Using EndoSequence and Profile NTR files

	File Separation	File Deformation
EndoSequence 300 rpm Group 1 (n = 42)	4	10
EndoSequence 600 rpm Group 2 (n = 42)	9	4
Profile 300 rpm Group 3 (n = 42)	0	9

Scanning Electron Microscopy Evaluation

SEM examination of new EndoSequence files revealed that the surface was smooth with no visible microfractures (Fig. 1A). SEM examination of new ProFile files (group 3) revealed machining grooves, some pitting, and slight metal fold over at edges with no visible microfractures (Fig. 1D). After instrumenting seven canals, every EndoSequence 35/.06 file exhibited microfractures regardless of rpm (Figs. 1B, C). One EndoSequence instrument exhibited 2 mm of sheared-off cutting flutes or fretting. ProFile files exhibited an increase in visible pitting, but no microfractures were seen at any level (Fig. 1E). Small cracks were noted in the fold-over metal that covers the two edges of the land area, but they never continued into the cutting flute or the body of the file so they were not identified as microfractures (Fig. 1F). After completion of 14 canals, ProFile instruments exhibited defects similar to those observed after instrumentation of 7 canals.

Discussion

The primary focus of this study was to test the hypothesis that the electropolishing of NTR files would decrease the incidence of microfractures and subsequent file separation. The development of microfractures is related to cyclic fatigue and leads to greater risk of instrument separation (8, 11, 12). Electropolishing is a surface treatment commonly used on surgical instruments. SEM images of new EndoSequence files revealed a well-polished surface that was free from visible defects. After instrumentation of seven canals, SEM images showed microfractures on all EndoSequence files. These results are in contrast to

TABLE 2. Relationship Between Canal Type and File Separation

	Separated File
Maxillary MB canal	7
Maxillary DB canal	1
Mandibular MB canal	2
Mandibular ML canal	3

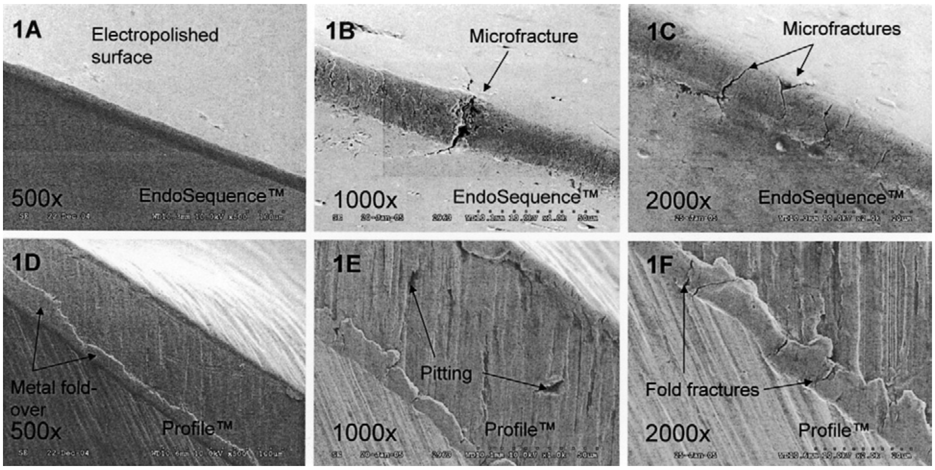

Figure 1. SEM images of NTR files. (A) New EndoSequence file, (B) Endosequence file after use in 7 canals, (C) EndoSequence file after 14 canals, (D) New Profile, (E) Profile after use in 7 canals, and (F) Profile after use in 14 canals.

the findings of the developers of the files who claim that electropolishing should reduce the potential for microfracture development and propagation (2, 3). ProFile NTR files were chosen as the control instrument because these files are not electropolished, and previous studies have suggested that machining defects and surface treatment may affect the durability of these instruments (4–8, 13, 14).

Two rotation speeds, 300 rpm and 600 rpm, were selected for instrumentation. Real World Endo recommends 450 to 600 rpm for use of EndoSequence NTR instruments (2, 3). Dentsply Tulsa Dental Specialties recommends 300 rpm for the use of ProFile NTR files. When used at 600 rpm, nine EndoSequence NTR files separated and four showed plastic deformation. When used at 300 rpm, 4 EndoSequence NTR files separated, and 10 showed plastic deformation. ProFile NTR files at 300 rpm only experienced plastic deformation failures. In an extracted molar tooth model, Yared et al. (15) concluded that ProFiles at 350 rpm in the hands of experienced operators are safe but recommended lower rpm for inexperienced operators. Several studies have shown that NTR files are less likely to fracture when used at lower speeds (15–17). These findings are consistent with our results. When using the EndoSequence NTR instruments, we found that higher speed leads to a higher rate of separation, whereas lower speed results in less separation and a higher rate of plastic deformation. Two explanations may account for these findings. First, more file revolutions around a curvature increases cyclic fatigue (12, 18); therefore, time to failure is decreased as the rotational speeds increase (19). Second, at a slower rpm, torsion or brittle type fractures may be avoided by tactile sensation of binding and therefore allowing removal of a file from a canal before reaching the elastic limit of the alloy. Operator experience and knowledge of dental anatomy are probably more significant variables in predicting risk of instrument separation than file design (20, 21). The differences between these file systems was not explained by a difference in canal curvature between groups because the average angle of canal curvature was 37° in the EndoSequence groups and 36° in the ProFile group.

In conclusion, under the conditions of this study, electropolishing did not inhibit the development of microfractures in EndoSequence .06 NTR files. All EndoSequence .06 NTR files developed microfractures by the seven-canal instrumentation stage. Nevertheless, although file separation during clinical use is an undesirable outcome, clinicians who only use NTR files for one or two cases may not experience a clinically important difference in incidence of file separation between the two NTR files studied in this project.

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