

The effects of different nickel-titanium instruments on dentinal microcrack formations during root canal preparation

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ABSTRACT

Objective: The aim of the present study was to investigate the incidence of dentinal microcracks caused by different preparation techniques. **Materials and Methods:** 120 extracted human mandibular incisor teeth were divided into five experimental groups and one control group ($n = 20$): Group 1: Hand preparation with balanced force technique up to #25 K-file. Group 2: Preparation with only ProTaper F2 instrument in a reciprocating movement. Group 3: Preparation with Reciproc R25 instrument in a reciprocating movement. Group 4: Preparation with ProTaper instruments up to F2 instrument. Group 5: Preparation with ProTaper Next instruments up to X2 instrument. No procedure was applied to control group. The roots were sectioned horizontally at 3, 6 and 9 mm from the apex and examined. Absence or presence of dentinal microcracks was noted. **Results:** The Chi-square test was performed to compare the appearance of cracked roots between all groups. There were no significant differences among the groups ($P > 0.05$). **Conclusions:** In conclusion, except the hand file and control group, all experimental groups showed microcrack formations.

Key words: Dentinal microcrack, ProTaper, Reciproc

INTRODUCTION

The major purpose of root canal therapy is to reduce intracanal microorganisms. Chemomechanical preparation is an essential and indispensable step for disinfection of the root canal system.^[1] During endodontic treatment, roots are susceptible to have dentinal damage. Quantity of dentinal damages can be effected by various factors like physical properties of teeth,^[2] preparation technique or various endodontic instruments that used, etc., Thus, each preparation technique can damage root dentin.^[3]

Besides stainless steel hand files, several rotary nickel-titanium (Ni-Ti) file systems have been introduced for the preparation of root canals. Ni-Ti instruments provide many advantages compared to conventional files. Increased flexibility, and shortened working time are the major advantages of Ni-Ti files,^[4,5] due to the different tip design, taper, and

cutting blade configuration of these systems, stress on the root canal walls may arise^[6] and these can result as microcracks or craze lines,^[3] because of the repeated stress application by occlusal forces these microcracks and craze lines may develop into fractures.^[3,7]

It is claimed that when using Reciproc (VDW, Munich, Germany) Ni-Ti files, complete preparation and cleaning of root canals can be accomplished with only one instrument. These files are used in a reciprocating movement that requires special automated devices.^[8] The reciprocating movement relieves stress on the instrument,^[8] and it is conceivable that they could relieve stress on root canal walls as well. It is stated that the reciprocating root canal preparation is an evolution of a balanced force technique.^[8,9]

A different approach to the use of the ProTaper F2 instrument (Dentsply Maillefer, Ballaigues, Switzerland) in a reciprocating movement has been

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reported.^[10-13] The advantages of using a single Ni-Ti instrument are: Simple preparation of the entire root canal, greater cost-effectiveness than the conventional multi-file Ni-Ti rotary systems, reduction of instrument fatigue and possible cross-contamination, and they are less time-consuming than rotational movement with multiple instruments^[10,12,14,15]

ProTaper Next (Dentsply Tulsa Dental Specialties, Johnson City, TN, USA) is a newly introduced Ni-Ti rotary system manufactured using M-wire Ni-Ti alloy (Sportswire, Langley, OK). The ProTaper Next system has variable tapers and an off-centered rectangular cross section design and requires working with a rotational movement. This off-centered rectangular cross section design is intended to reduce torsional stress on the instrument (www.tulsadentalspecialties.com).

This study investigated the incidence of dentinal microcracks that may occur during preparation of root canals, using different preparation techniques with different systems. The tested the null hypothesis that there are no significant differences among the groups in dentinal microcrack formations.

MATERIALS AND METHODS

Selection of the specimens

For this *in vitro* investigation, 200 human mandibular incisor teeth with straight roots (<5°) that had been extracted for periodontal reasons were selected. Teeth were stored in purified water. Teeth with approximately the same root length were chosen and inspected with an operating microscope (Zeiss Opmi Pico; Carl Zeiss, Jena, Germany) at ×10 to detect visible cracks or fractures on the teeth. 24 teeth were excluded from the study. The remaining 176 teeth were adjusted to 16 mm in length from the apex to standardize the specimens, and the access cavities were prepared. Subsequently, teeth were re-evaluated with an operating microscope at ×10 magnification for detection of cracks or fractures, and 7 teeth with crack lines were eliminated from the study. Teeth with single canals were selected, and mesiodistal radiographs were taken to verify the canal configuration. Teeth with accessory canals were excluded, and finally, 120 teeth that met the conditions were included in this study. Each root was wrapped with a single layer of aluminum foil and embedded in acrylic resin (Imicryl, Konya, Turkey) set in an acrylic tube. The root was then removed from the tube, and the aluminum foil peeled off. A hydrophilic vinyl polysiloxane

impression material (Oranwash; Zhermack SpA, Rovigo, Italy) that replaced the space created by the foil represented a simulated periodontal ligament, and the root was immediately repositioned.^[16]

Root canal preparation

The patency and working length (WL) of each canal was determined by passing the size 8 K-file (Mani, Inc., Tochigi, Japan) to the anatomic foramen. This length was recorded, and the final WL was established 0.5 mm short. Before root canal instrumentation procedures, all root canals were prepared with #8 and #10 K-files to establish a glide path. Between the use of each instrument, root canals were irrigated with 2 ml of 2.5% NaOCl. Then, the specimens were divided into the following five experimental groups ($n = 20$) according to the root canal shaping procedure:

Group 1: Stainless steel hand K-files (2% taper) (Mani, Inc., Tochigi, Japan) were used to enlarge the root canals to size 25 using the Balanced Force technique.^[8] Files were inserted by a quarter-turn clockwise (CW) rotation of 90° with no apical pressure and cutting was accomplished by counter-clockwise (CCW) rotation of 120° applying sufficient apical pressure. Then WL was incrementally reduced by 1 mm beginning from #30 to #60 K-file instrument. Irrigation was performed with 2.5% sodium hypochlorite. For each canal, a new set of K-file was used.

Group 2: Root canals were prepared with the ProTaper F2 instrument using an endodontic micromotor (ATR Technika Digital motor Motor, Pistoia, Italy) that allows the user to modify and set the reciprocating angles in both CW and CCW directions with a 16:1 reduction handpiece. The CW and the CCW rotations are set on the motor at ~1310° and ~578°, respectively.^[17] The rotational speed is set at 400 rpm.^[10] The instruments were used with slow in-and-out pecking motions (3–4 motions) until it reach the WL. For each root canal, a new ProTaper F2 instrument was used.

Group 3: Root canals were prepared with the Reciproc R25 instrument in a reciprocating movement with 3 slow in-and-out pecking motions. The instrument was used with “Reciproc all” mode of the endodontic micromotor (VDW Silver, Munich, Germany). For each root canal, a new Reciproc instrument was used.

Group 4: Root canals were prepared with ProTaper instruments in a rotary movement with slow in-and-out pecking motions using an endodontic micromotor which has adjusted ProTaper Universal (PTU) mode

for instruments (VDW Silver, Munich, Germany) according to manufacturer rpm (revolutions/min) and torque instructions. All instruments were used with 300 rpm rotational speed and recommended torque values (1.5 Ncm for S2; 2.0 Ncm for F1; 3.0 Ncm for SX, S1, F2, and F3; respectively). The instrument sequence was: (1) SX instrument at two-thirds of the WL, (2) S1, S2, F1, F2 instruments at WL. For each root canal, a new set of ProTaper instruments was used.

Group 5: Root canals were prepared with ProTaper Next instruments in a rotary movement with three slow in-and-out pecking motions using an endodontic micromotor (VDW Silver, Munich, Germany), at 300 rpm and 2 N/cm torque settings. The instrument sequence was: X1 instrument at WL and X2 instrument at WL. For each root canal, a new set of ProTaper Next instruments was used.

Control group: No procedure was applied to the 20 roots in this group.

Composite resin was used to fix rubber stoppers of instruments to control the instrumentation length.^[16] During the instrumentation, 2.5% sodium hypochlorite was used. In total, 10 ml of NaOCl was used for irrigation of root canals in all experimental groups. The root canals were then dried with paper points.

Microscopic evaluation

After preparation, only the crowns of the teeth were embedded in resin (Technovit; Heraeus-Kulzer, Wehrheim, Germany) so that no shrinking forces influenced the roots. All roots were sectioned horizontally at 3, 6, and 9 mm from the apex with a low-speed saw under water cooling (Minitom, Struer, Denmark). To prevent artifacts from dehydration in the samples, the teeth were kept moist in distilled water throughout all experimental procedures. The slices were then examined through a stereomicroscope (Leica DM750, Germany), and pictures were taken with a digital camera (Leica D-Lu × 3, Germany) attached to the stereomicroscope at a magnification of 8x. Two experienced investigators controlled and scored each image until there was consensus between them. Defects were classified according to three types:^[18]

- No defect was root dentin devoid of any lines or cracks and where both the external surface of the root and the internal root canal wall had no defects
- Incomplete defects were all other lines observed that did not extend from the root canal to the outer root surface (e.g. a craze line, a line extending from the outer surface into the dentin but that did not reach the canal lumen; or a partial crack, a line extending from the canal wall into the dentin without reaching the outer surface);

extending from the canal wall into the dentin without reaching the outer surface)

- Fracture was a line extending from the root canal space to the outer surface of the root^[3] [Figure1].

Statistical analysis

After both investigators reached complete consensus on the evaluations of the specimens, the data were subjected to statistical interpretation using the Chi-square test for analysis of differences between the groups at a 95% confidence level ($P < 0.05$).

RESULTS

The no preparation (control) group and hand preparation group presented no defects at all three levels. Defects were found in roots instrumented with ProTaper rotary files, single file ProTaper F2, Reciproc R25, and ProTaper NEXT rotary files. In all groups ($n = 20$) each tooth that has three sections, and this coronal, middle, and apical sections were examined. The incidence of crack formation in sections was recorded, and each crack stereotypes classified according to 3 different types. According to dentinal defects (no defects, complete fracture, and incomplete defects), no significant differences were found among the groups ($P > 0.05$) [Table 1]. Hence, the null hypothesis was accepted. Except for the control group and hand instrumentation group, all groups showed microcrack formations.

DISCUSSION

Several authors have questioned dentinal microcrack formations after root canal preparations with

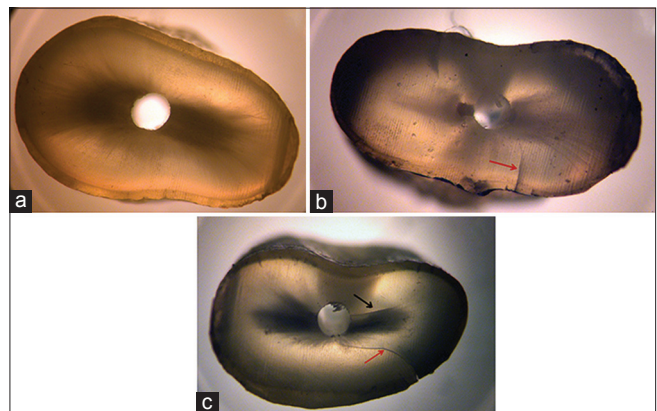


Figure 1: Representative microscopic images from each experimental group. Arrows point at dentinal defects. (a) No defect (devoid of any lines or cracks) (b) incomplete defects (e.g., a craze line, a line extending from the outer surface into the dentin but that did not reach the canal lumen; or a partial crack, a line extending from the canal wall into the dentin without reaching the outer surface). (c) Fracture (a line extending from the root canal space to the outer surface of the root)

Table 1: The quantity of each microcrack type for each group at each root thirds

Groups (n=20)	Root thirds								
	Coronal section			Middle section			Apical section		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
ProTaper	17	2	2	17	3	-	19	1	-
F2 - only	17	3	-	17	3	-	20	-	-
Reciproc	19	1	-	19	1	-	20	-	-
ProTaper next	16	4	-	17	2	1	20	-	-
Hand instrumentation	20	-	-	20	-	-	20	-	-
Control	20	-	-	20	-	-	20	-	-

T1, T2, T3 are the acronyms for microcrack types: Type 1, Type 2, Type 3 as respectively. T1 represents no defect, T2 represents incomplete defects; craze line or microcrack that not extend from root canal surface to the outer surface of the root and T3 means fracture

Ni-Ti rotary instruments.^[18-21] The formation of the microcracks may be caused by rotational forces that were applied to the root canal walls and this may be related to instrument features like tip design, cross-sectional geometry, taper, pitch design, and flute form.^[20]

Reciprocating motion has been shown to have many advantages: Extending the durability of Ni-Ti rotary instruments and increasing the resistance of Ni-Ti files to cyclic fatigue compared to continuous rotational motion.^[10,15,22] Root canal instrument can work with the reciprocation movement in root canal with more centered position.^[23] And owing to the nature of reciprocation motion that contains CW and CCW rotation consequently and repeatedly, file can release when it is engaged in the inner surface of the root canal during the preparation process.^[10] On the other hand, Bürklein and Schäfer stated that debris transportation toward the apex enhances with reciprocal motion,^[24] thus torsional forces may increase.^[25] Due to these advantages and limitations that required further researches, many authors have investigated complete canal shaping with a single file using a reciprocal movement^[11-13,15] Although the manufacturers do not recommend using the single F2 file in a reciprocating motion, in the present study it is included to evaluate the effects of different kinematics on dentinal microcrack formations.

Bürklein *et al.*^[25] stated that Reciproc R40 files created more complete cracks than the full sequence ProTaper (up to F4) system. In the present study, there were no significant differences among the systems in terms of microcrack formations. The instruments used in the present study were at smaller sizes (Reciproc

R25, ProTaper F2). Furthermore, Bürklein *et al.*^[25] did not use a method that simulate the periodontal ligament. Therefore, different results could be related to different methodologies. Liu *et al.*^[16] stated that Reciproc R25 files created fewer microcrack formations than the full sequence ProTaper (up to F2) system, but they observed the apical surface at 2, 4 and 6 mm sections. In the present study, we observed 3, 6, and 9 mm surfaces. Also Liu *et al.*^[16] used Gates Glidden no. 2 instruments to enlarge all root canal orifices and this might have reduced the stresses occurred on the root canal walls. In the present study, no coronal flaring procedure was applied to the roots. The differences of methodologies could create different results.

Kansal *et al.*^[26] investigated the dentinal microcrack formations occurred in mandibular premolars during the use of full sequence ProTaper (up to F2), Waveone 25 and ProTaper F2 with reciprocal movement. They found that full sequence ProTaper created more microcracks than the other systems. The methodology used in the study of Kansal *et al.*^[26] was similar to the methodology used in the present study except the teeth selection. Mandibular incisors were used in the present study, and there were no significant differences among the systems. The root canals of the mandibular incisors vary greatly in their cross-sectional anatomy,^[27] and the microcrack formations may be influenced by the root canal morphology.

Çapar *et al.*^[28] investigated the effects of ProTaper next, PTU and HyFlex instruments on crack formation in dentin and found that ProTaper Next and Hyflex instruments caused less microcracks than PTU. They used mandibular premolar teeth and instrumented up to ProTaper F4, ProTaper Next X4, HyFle × 40/04. In the present study, mandibular incisors were selected, and instrumentations were performed with full sequence ProTaper and ProTaper Next instruments up to F2, X2 instruments, and also ProTaper F2 instruments were used in reciprocation motion. The differences of results could be related to different methodologies and teeth selections.

Versluis *et al.*^[29] stated that during the instrumentation procedure, the stresses generated at the middle, and coronal thirds were three times more prevalent than at the apical level.^[21] In the present study, the occurrence of microcrack formations in the coronal thirds was 10.7%, 11.7% in the middle thirds, and 1.9% in the apical thirds. Our findings could be related to the study of Versluis *et al.*^[29] in terms of stress related to

microcrack formations. In the present study, only the control and hand file instrumentation groups showed no microcrack formations and our findings were similar with Bier *et al.*^[19] who reported that they did not observe any microcrack formations in the hand file group.

Fewer microcrack formations occurred in apical thirds than middle and coronal thirds. All rotary systems used in the study have a similar apical taper design (25/08 for ProTaper F2 and Reciproc R25 and 25/06 for ProTaper Next X2), and this could be the reason for the similar results in apical thirds. Furthermore, lack of microcrack formation in apical thirds could be associated with the size of the final apical instruments.

Cracks after canal instrumentation were detected either in horizontal sections at different levels along the roots^[15,16,18,19] or the apical root surface.^[15,25,29] As in the studies of many other authors,^[16,18-20] we investigated the microcrack formations via horizontal sectioning along the different lengths of the root to see the entire condition of the root at different root thirds. The sawing action and forces applied during the extraction could also result in dentinal microcracks.^[18,19] However, no microcrack formations were observed in the control group. Therefore, the observed microcracks were likely a result of the preparation procedures.

One of the most important limitation of previous studies is there is no chance of evaluating preexisting defects by current methodology. (root sectioning and direct observation by optical microscopy) micro-computed tomography (CT) imaging has a much higher definition than stereomicroscopy, and a large number of sections can be analyzed per tooth without creating defects. De-Deus *et al.*^[30] reported that micro-CT image technology was accurate and a nondestructive method that allows the assessment of specimens before instrumentation.

Within the limitations of the present study, with the exception of the hand file and control groups, all experimental groups showed microcrack formations. Although, ProTaper Next files showed more crack formations, there was no significant statistical difference, and all systems and motions did not affect the microcrack formations.

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