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Original Article

Evaluation of dentinal micro-cracks caused by the ProTaper Universal, ProTaper Next and Reciproc rotary file systems used in root canal preparation

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Abstract

Aim: In this study, we compared the occurrence of dentinal micro-cracks after use of the ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper Next (Dentsply Maillefer), and Reciproc (VDW, Munich, Germany) nickel-titanium rotary file systems in root canal preparation.

Methodology: One hundred mandibular anterior teeth were divided into five groups of 20 specimens each. Group 1 served as a control, with no intervention. In group 2, preparation was performed using the step-back technique and K files. In groups 3-5, root canal preparation was performed using the ProTaper Universal, ProTaper Next, and Reciproc file systems, respectively. Following preparation, specimens were sectioned at 3, 6, and 9 mm using a Minitom precision cut-off machine. The sections were evaluated under a stereomicroscope. The following scoring system was used to rate specimens: 1, no micro-crack; 2, incomplete micro-crack; and 3, vertical root fracture. The results were statistically assessed ($p \leq 0.05$).

Results: No micro-crack formation was observed in groups 1 and 2. The highest rate of micro-crack formation was observed in specimens prepared with the ProTaper Universal file system (20%), followed by those prepared with the Reciproc (11.7%) and ProTaper Next (6.7%) file systems. However, no significant difference was detected among groups ($p>0.05$). In the groups ProTaper Universal and Reciproc files were used, 1 vertical root fracture was found in 9 mm sections for each.

Conclusions: Considering the limitations of in vitro studies, we can conclude that all rotary file systems used in this study led to dentinal micro-crack formation in roots. The ProTaper Universal file system caused more dentinal micro-cracking than did the ProTaper Next and Reciproc file systems.

Keywords: Micro-crack, ProTaper Universal, Reciproc, ProTaper Next

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Introduction

In recent years, Nickel-titanium (NiTi) rotary files are increasingly used in root canal preparation. The use of nickel–titanium (Ni-Ti) rotary file systems in root canal treatment has been associated with increased vertical fracture and micro-crack formation rates (1). The rotary file systems used in root canal preparation apply rotational forces to root canals, which may cause dentinal micro-cracking or vertical root fracture. The preparation techniques, turbination angles, blade designs, tip configurations, and motion kinematics (e.g., rotation, reciprocation, adaptive motion) of various root canal filing systems may lead to the creation of dentinal defects (2).

Ni-Ti rotary file systems commonly employ two motions: rotation and reciprocation. Torsion and stretching occurring with rotation during preparation can cause tool breakage. To avoid such damage, clinicians have shown an increased tendency to use reciprocation-based systems (3). The use of reciprocation has been found to reduce the risk of rotational fatigue caused by tension and compression (4, 5).

ProTaper Universal (PTU) (Dentsply Tulsa Dental, Tulsa, USA) is a NiTi rotary system which manufactured with progressive taper over the length of the cutting blades, convex triangular cross sections, and noncutting tips with a nonradial land design for more effective cutting (6).

Recently, ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) instruments have been introduced that have an off-centered rectangular design and progressive and regressive percentage tapers on a single file, which is made from M-Wire technology. It has an off-centered rectangular design and decreases the screw effect, dangerous taper lock, and torque on any given file by minimizing the contact between the file and the dentin (7).

Reciprocating instruments are made of M-Wire alloy and were originally developed for single-file endodontic treatment that subjected to an innovative thermal treatment process to increase flexibility of the instrument. Recently, Reciproc (VDW, Munich, Germany) was introduced that advocated the reciprocation concept which would reduce the risk of cyclic fatigue and the torsional fractures by periodically reversing the rotation (150o counterclockwise, then 30o clockwise rotation) of the file. This reciprocating movement is ultimately increase the lifespan of the instrument. The Reciproc files have an S-shaped cross-section, 2 cutting blades, and a continuous taper over the first 3 mm of their working part followed by a decreasing taper until the shaft (8, 9).

The aim of this study was to investigate dentinal micro-crack formation occurring with the use of the ProTaper Universal, ProTaper Next, and Reciproc (VDW, Munich, Germany) rotary file systems and K files during root canal treatment in the maxillary incisors.

Materials and Methods

One hundred maxillary anterior teeth extracted for periodontal reasons were used in this study. Teeth with inclination angles <5° were selected. Mesio–distal and bucco–lingual radiographs were obtained, and teeth with calcification or multiple canals were excluded. Specimens were assessed under a stereomicroscope (×12) to exclude those with superficial micro-cracks or lack of root development. For standardization, decoronization was performed under water cooling using a diamond disk maintained at 13 mm from the apex in all groups except the control group. This study has been evaluated by the Local Ethics Committee of the Dicle University Dental Faculty.

To embed the specimens, 10-mm molds were prepared from 5-cc injectors. The root surfaces were covered with aluminum foil, and the specimens were embedded in the molds using auto-polymerizing acrylic provisional material (Imicryl, Konya, Turkey). After polymerization, the teeth were removed, and the aluminum foil was stripped away. Then, the teeth were coated with light-body silicone impression material (Speedex; Coltene AG, Altstatten, Switzerland) and re-embedded in the acrylic molds. By this process, in vitro models of the periodontal ligaments were obtained. Twenty specimens served as controls and received no intervention. The remaining 80 specimens were assigned to four groups (n = 20 each).

The working length was set 1 mm short of the apical foramen with a #10 K file. Enlargement was performed at the working length with K files up to #15. The X-Smart Plus endodontic motor (Dentsply Maillefer) was used for preparation, with each file set being used in two specimens. For standardization among groups, irrigation was performed after each file change. After preparation was complete, specimens were treated with 17% EDTA (5 ml) for 1 min. Final irrigation was performed with distilled water.

- **Group 1:** Control group, no intervention.
- **Group 2:** Enlargement performed using the step-back technique and K-file (Master apical file = 25).

- **Group 3:** Enlargement performed using the ProTaper Universal sequence (SX, S1, S2, F1, F2) at 300 rpm. The first three shaping files were used with the Reciproc motion. Then, the F1 and F2 finishing files were used at working length for final shaping.
- **Group 4:** Enlargement performed using the ProTaper Next sequence (SX, S1, S2, F1, F2) at 300 rpm. The files were used with the Reciproc motion, similar to the technique used with the ProTaper Universal system.
- **Group 5:** Enlargement performed with the R25 file at 300 rpm. Canals were cleaned after three instrument movements.

Sectioning and Microscopic Evaluation

Sections of all specimens were obtained at the levels of 3, 6, and 9 mm using the Minitom (Struer, Denmark) precision cut-off machine at low speed under water cooling. The sections were evaluated under a stereomicroscope (Leica Imaging System, Ltd., Cambridge, UK), and images were captured with a digital camera (x-835; Olympus Co., Ltd., Tokyo, Japan) attached to the microscope. The presence / absence of microcracks on the sections was assessed by scoring by two observers. The scoring of the samples was made by taking the scoring done by Monga et al. (10). This finding was not included in the scoring because no linear cracks were observed in the samples in this study. The following scoring system was used to rate specimens (Fig. 1).

- **1:** No micro-cracking. Lack of micro-cracking in the area extending from the root canal space to the dentin–cementum junction.
- **2:** Incomplete micro-crack. Crack extending from the dentin–cementum junction toward the root canal space or vice versa.
- **3:** Vertical root facture. Uninterrupted crack extending from the root canal space to the dentin–cementum junction.

Statistical Analysis

Data were analyzed using SPSS software (Statistical Package for Social Sciences, version 21.0) and the chi-squared test ($p \leq 0.05$). The results are given with 95% confidence intervals.

Results

No micro-crack formation was detected in the control group or in group 2. This lack of micro-cracking differed significantly from the presence of micro-crack formation in the rotary file groups, as indicated by the chi-squared test ($p < 0.05$). Regardless of the section level, the highest rate of micro-crack formation was observed in specimens prepared with the ProTaper Universal file system (20%), followed by those prepared with the Reciproc (11.7%) and ProTaper Next (6.7%) file systems (Table 1). However, no significant difference was detected among groups ($p > 0.05$). The chi-squared test revealed no significant difference in micro-crack formation among section levels ($p > 0.05$). When micro-cracks were evaluated according to section level, regardless of group assignment, the highest rate was observed at 9 mm (11%), followed by 6 mm (7%) and 3 mm (5%; $p = 0.033$) (Table 2). Two vertical root fractures were detected in 9-mm sections from group 3 (ProTaper Universal file system) and group 5 (Reciproc file system), respectively.

Figure 1. Classification of dentinal defects. **A)** No micro-crack, **B)** Incomplete micro-crack, **C)** Vertical root fracture.

Table 1. Evaluation of micro-cracks by group, regardless of section level

Defect	Control	Hand file	ProTaper Universal	ProTaper Next	Reciproc
Negative	60 (100%)	60 (100%)	48 (80%)	56 (93.3%)	53 (88.3%)
Positive	-	-	12 (20%)	4 (6.7%)	7 (11.7%)
Total	60	60	60	60	60

Table 2. Evaluation of micro-cracks according to section level (n = 20 each)

Group	3 mm	6 mm	9 mm	Total
Control	-	-	-	-
Hand file	-	-	-	-
ProTaper Universal	3 (15%)	4 (20%)	5 (25%)	12 (20%)
ProTaper Next	1 (5%)	1 (5%)	2 (10%)	4 (6.7%)
Reciproc	1 (5%)	2 (10%)	4 (20%)	7 (11.7%)
Total	5 (5%)	7 (7%)	11 (11%)	
p value	0.181	0.074	0.033*	0.268

Discussion

In vitro conditions cannot replicate the native structure of the tooth under clinical conditions (11). Despite attempts to mimic clinical practice in laboratory conditions, the confounding effects of extrinsic factors cannot be eliminated (12). Çapar et al. (13) attempted to simulate the periodontal ligament; in this study, we enhanced resistance against extrinsic forces and mimicked stress distribution using a similar technique.

In our study, sections were obtained at low speed under water cooling using a Minitom precision cut-off device. Obviously, sectioning can lead to micro-crack formation. In previous studies, no micro-crack or other defect was observed after sectioning of control specimens that received no intervention (14–17).

In a study investigating the effects of enlargement with Ni-Ti files on vertical root fracture, Kim et al. (1) found that greater stress increased dentin defect formation and that this formation was associated with the transverse section level (apical, middle, and coronal thirds). Versluis et al. (18) showed that sections from the middle and coronal thirds of the root were exposed to three-fold greater stress than were those from the apical third. Similarly, Üstün et al. (14) detected more frequent dentinal defects in the coronal third of roots. In our study, micro-crack rates were 11% in the coronal third, 7% in the middle third, and 5% in the apical third. However, no significant difference was found among section levels ($p > 0.05$). We believe that the increased micro-crack formation rate in the coronal region was the result of exposure to greater stress in this region compared with the apical region. This high stress level may be due to increased contact of the rotary file with the dentin wall in the coronal third compared with the apical third, given the increased tapering of the root toward the coronal region. In addition, the lower micro-crack formation rate in the apical third may be due to the diameters of finishing files used in this region.

In our study, no micro-crack formation was observed in group 2, which was instrumented with hand-operated files. Similarly, Bier et al. (17) and Yoldaş et al. (19) reported no micro-cracking in specimens instrumented with hand-operated files. Micro-cracks have been observed in some studies investigating dentinal micro-crack formation at the root, but coronal enlargement was performed with Gates-Glidden drills in those studies (2, 11). The discrepancy in results may be attributed to this methodological difference.

In our study, the use of the ProTaper Universal system was associated with the highest micro-crack formation rate. ProTaper Universal files reduce debris efflux during enlargement due to their convex triangle shape in the transverse plane. In addition, these files have no radial area, which increases deviation from the center of the root. This characteristic may increase micro-crack formation by exerting more stress on the dentin (20). In a study investigating dentinal micro-crack formation occurring with the use of the ProTaper

Universal, ProTaper Next, and Heroshaper rotary file systems, Shori et al. (21) found the highest micro-crack formation rate in the ProTaper Universal group. Similarly, Liu et al. (22) observed more micro-crack formation with the use of the ProTaper Universal and OneShape systems than with the use of the Reciproc and self-adjusting file systems.

Compared with specimens prepared with the ProTaper Universal system, less micro-crack formation was observed in specimens prepared with Reciproc rotary files in our study. The Reciproc file system is the only system that uses reciprocation for enlargement. The use of a single file during enlargement may reduce micro-crack formation compared with the use of multiple files (20). In a study in which enlargement was performed using the distinct motion kinematics of rotary file systems, Priya et al. (23) found that the ProTaper Universal system caused more micro-cracking than did the Reciproc, in agreement with our results. Liu et al. (24) reported that the use of the R25 file from the Reciproc system caused more micro-cracking than did the use of the whole ProTaper Universal file sequence, including enlargement with the F2 file. However, the authors performed coronal enlargement with a Gates-Glidden drill before using the rotary file systems. We believe that outcomes may differ among studies due to methodological differences.

In our study, the least micro-cracking among specimens prepared with rotary files occurred in the group treated with the ProTaper Next file system. This lower micro-crack formation rate may be due to the lesser degree of tapering of these files. In addition, ProTaper Next files with M-wire technology have a rectangular design outside the center, which reduces the screwing effect, dentin compression, and torque over the file by minimizing contact between the file and dentin.

Conclusions

In our study, defects in root dentin were observed in all groups in which rotary file systems were used. We believe that file systems that do not damage the dentin during root canal preparation are required for successful root canal treatment and long-term tooth retention, given the defects caused by commonly preferred rotary file systems.

Ethical Approval: Ethics committee approval was received for this study from Dicle University (No:2016/12).

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References

1. Kim HC, Lee MH, Yum J, Versluis A, Lee CJ, Kim BM. Potential relationship between design of nickel-titanium rotary instruments and vertical root fracture. J Endod. 2010;36(7):1195-99. (Crossref)
2. Karataş E, Arslan H, Alsancak M, Kırıcı DÖ, Ersoy İ. Incidence of dentinal cracks after root canal preparation with Twisted File Adaptive instruments using different kinematics. J Endod. 2015;41(7):1130-3. (Crossref)
3. Varela-Patiño P, Ibañez-Párraga A, Rivas-Mundiña B, Cantatore G, Otero XL, Martin-Biedma B. Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod. 2010;36(1):157-59. (Crossref)
4. De-Deus G, Brandão MC, Barino B, Di Giorgi K, Fidel RAS, Luna AS. Assessment of apically extruded debris produced by the single-file ProTaper F2 technique under reciprocating movement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;110(3):390-4. (Crossref)
5. Plotino G, Grande N, Testarelli L, Gambarini G. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. Int Endod J. 2012;45(7):614-18. (Crossref)
6. Ruddle CJ. The ProTaper technique. Shaping the future of endodontics. In: Castellucci A, ed. Endodontics, vol II. Florence: Il Tridente; 2005:548 - 63.
7. Ruddle CJ. The ProTaper endodontic system: geometries, features, and guidelines for use. Dent Today 2001;20:60-7.).
8. Varela-Patino P, Ibanez-Parraga A, Rivas-Mundina B, Cantatore G, Otero XL, MartinBiedma B. Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod 2010;36:157-9. (Crossref)
9. De-Deus G, Moreira EJ, Lopes HP, Elias CN. Extended cyclic fatigue life of F2 ProTaper instruments used in reciprocating movement. Int Endod J 2010;43: 1063-8. 10.
10. Monga P, Bajaj N, Mahajan P, Garg S. Comparison of incidence of dentinal defects after root canal preparation with continuous rotation and reciprocating instrumentation. Singapore Dent J 2015;36:29-33. (Crossref)
11. Helvacıoğlu-Yiğit D, Aydemir S, Yılmaz A. Evaluation of dentinal defect formation after root canal preparation with two reciprocating systems and hand instruments: an in vitro study. Biotechnol Biotec EQ. 2015;29(2):368-73. (Crossref)
12. Bürklein S, Tsotsis P, Schäfer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. J Endod. 2013;39(4):501-4. (Crossref)
13. Çapar İD, Arslan H, Akcay M, Uysal B. Effects of ProTaper Universal, ProTaper Next, and HyFlex instruments on crack formation in dentin. J Endod. 2014;40(9):1482-4. (Crossref)
14. Üstün Y, Aslan T, Sağsen B, Kesim B. The effects of different nickel-titanium instruments on dentinal microcrack formations during root canal preparation. Eur J Dent. 2015;9(1):41-6. (Crossref)

15. Shemesh H, Bier C, Wu MK, Tanomaru-Filho M, Wesselink P. The effects of canal preparation and filling on the incidence of dentinal defects. Int Endod J. 2009;42(3):208-13. (Crossref)
16. Adorno CG, Yoshioka T, Suda H. The effect of working length and root canal preparation technique on crack development in the apical root canal wall. Int Endod J. 2010;43(4):321-7.
17. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod. 2009;35(2):236-8. (Crossref)
18. Versluis A, Messer HH, Pintado MR. Changes in compaction stress distributions in roots resulting from canal preparation. Int Endod J. 2006;39(12):931-9. (Crossref)
19. Yoldaş O, Yılmaz Ş, Atakan G, Kuden C, Kasan Z. Dentinal microcrack formation during root canal preparations by different NiTi rotary instruments and the self-adjusting file. J Endod. 2012;38(2):232-5. (Crossref)
20. Karataş E. Farklı kök kanal şekillendirme sistemlerinin dentin çatlağı oluşturmadaki etkilerinin karşılaştırmalı olarak incelenmesi, Atatürk University Institute of Health Sciences Doctorate Thesis, Erzurum, 2014.
21. Shori DD, Shenoi PR, Baig AR, Kubde R, Makade C, Pandey S. Stereomicroscopic evaluation of dentinal defects induced by new rotary system: "ProTaper NEXT". J Conserv Dent. 2015;18(3):210-3. (Crossref)
22. Liu R, Kaiwar A, Shemesh H, Wesselink PR, Hou B, Wu MK. Incidence of apical root cracks and apical dentinal detachments after canal preparation with hand and rotary files at different instrumentation lengths. J Endod. 2013;39(1):129-32. (Crossref)
23. Priya NT, Chandrasekhar V, Anita S, Tummala M, Raj TB, Badami V, et al. "Dentinal microcracks after root canal preparation" a comparative evaluation with hand, rotary and reciprocating instrumentation. J Clin Diagn Res. 2014;8(12):70-2. (Crossref)
24. Liu R, Hou BX, Wesselink PR, Wu MK, Shemesh H. The incidence of root microcracks caused by 3 different single-file systems versus the ProTaper system. J Endod. 2013;39(8):1054-6. (Crossref)