Incidence of Dentinal Defects after Root Canal Preparation: Reciprocating versus Rotary Instrumentation

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Abstract

Introduction: The purpose of this study was to evaluate the incidence of dentinal defects after root canal preparation with reciprocating instruments (Reciproc and WaveOne) and rotary instruments. **Methods:** One hundred human central mandibular incisors were randomly assigned to 5 groups (n = 20 teeth per group). The root canals were instrumented by using the reciprocating single-file systems Reciproc and WaveOne and the full-sequence rotary Mtwo and ProTaper instruments. One group was left unprepared as control. Roots were sectioned horizontally at 3, 6, and 9 mm from the apex and evaluated under a microscope by using 25-fold magnification. The presence of dentinal defects (complete/incomplete cracks and craze lines) was noted and analyzed by using the chi-square test. **Results:** No defects were observed in the controls. All canal preparation created dentinal defects. Overall, instrumentation with Reciproc was associated with more complete cracks than the full-sequence files (P = .021). Although both reciprocating files produced more incomplete cracks apically (3 mm) compared with the rotary files (P = .001), no statistically significant differences were obtained concerning the summarized values of all cross sections (P > .05). **Conclusions:** Under the conditions of this study, root canal preparation with both rotary and reciprocating instruments resulted in dentinal defects. At the apical level of the canals, reciprocating files produced significantly more incomplete dentinal cracks than full-sequence rotary systems (P < .05). *(J Endod 2013;39:501–504)*

Key Words

Dentinal defects, M-wire, nickel-titanium, reciprocating, single-file systems

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The primary aims of chemomechanical root canal preparation include the preservation of the original course of the canal and cleaning of the entire root canal system. One common complication associated with mechanical canal preparation is vertical root fracture (VRF), which usually leads to tooth loss (1, 2). Various nickel-titanium instruments with different designs have been introduced, but the use of probably all of them results in dentinal defects like incomplete cracks or even VRF (3–6). It is still unknown whether even minor dentinal defects may lead to root fractures (2, 7); therefore, currently the consensus is that such defects should be prevented (5–7). Furthermore, some other cofactors that promote VRF have been discussed such as the use of high concentrations of sodium hypochlorite (8), the tooth anatomy (9), the placement of prosthetic posts (10, 11), and different obturation techniques (3).

The recently introduced single-file nickel-titanium systems Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) are able to prepare canals with only 1 instrument, thereby requiring less time than rotary full-sequence systems (12). These files are made of a special nickel-titanium alloy called M-wire (13). This M-wire alloy provides increased flexibility and improved resistance to cyclic fatigue of the instruments (14, 15).

The reciprocating movement is claimed to relieve stress on the instrument by special counterclockwise (cutting action) and clockwise (release of the instrument) movements, and it is assumed that this movement reduces the risk of cyclic fatigue caused by tension and compression (16–18).

It might be speculated that when using only 1 instrument for complete preparation, more stress will be generated during mechanical instrumentation compared with canal instrumentation by using full-sequence systems. Thus, it might be assumed that the incidence of dentinal defects might be increased compared with preparations by using full-sequence rotary systems. Currently, no data are available to prove or disprove this assumption. Therefore, the aim of this investigation was to compare the incidence of dentinal defects after preparation with reciprocating (Reciproc and WaveOne) and full-sequence rotary Mtwo and ProTaper instruments.

Materials and Methods

A total of 100 freshly extracted human mandibular central incisors with mature apices and straight root canals (<5°) were selected (19). All roots were observed with a stereomicroscope under ×20 magnification (Expert DN; Müller Optronic, Erfurt, Germany) to exclude cracks. Only single-rooted teeth with a single canal and a single apical foramen were included. This was verified by viewing their buccal and proximal radiographs. Coronal access was achieved by using diamond burs, and the canals were controlled for apical patency with a size 15 K-file (VDW). The canal width near the apex was approximately compatible with size 20. This was checked with silver points sizes 15–25 (VDW). On the basis of the distance between the cementoenamel junction and the apex, the teeth were allocated into 5 identical groups. The homogeneity of the 5 groups with respect to this parameter was assessed by using analysis of variance (P = 1.0). The working length was obtained by measuring the length of the initial instrument (size 15) at the apical foramen minus 1 mm.

After each instrument or after 3 pecks by using the reciprocating files, 2 mL NaOCl was used as irrigant. The irrigation needle (NaviTip 31-gauge needle; Ultradent, South

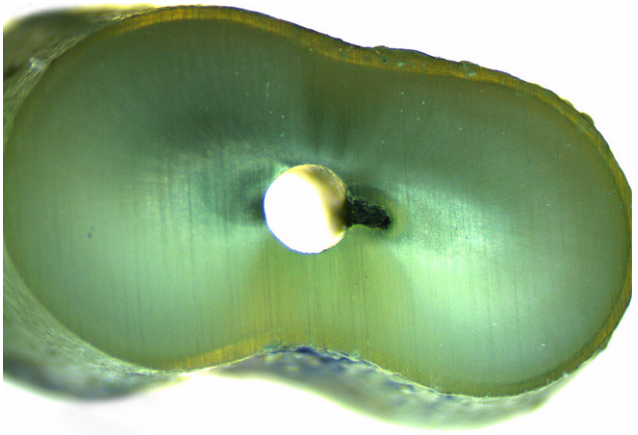

Figure 1. Cross section at the 6-mm level without any dentinal defects.

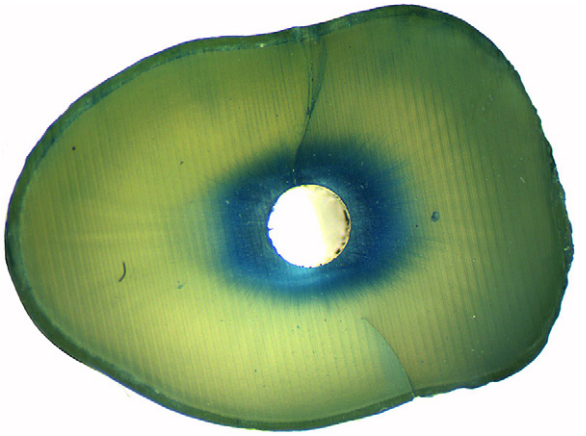

Figure 2. Cross section at the 6-mm level showing a complete and a partial dentinal crack.

Jordan, UT) was placed as deep as possible into the canal without binding to the canal wall but not deeper as the predetermined working length minus 1 mm.

All instruments were set into rotation with a 6:1 reduction handpiece (Sirona, Bensheim, Germany) powered by a torque-limited electric motor (VDW Silver Reciproc motor, VDW). For each file the individual torque limit and rotational speed programmed in the file library of the motor were used, whereas Reciproc and WaveOne were used in a reciprocating working motion generated by the motor.

In group A, all Mtwo instruments were used to the full length of the canals by using a gentle in-and-out motion. The instrumentation sequence was 10.04, 15.05, 20.06, 25.06, 30.05, 35.04, and 40.04.

In group B, ProTaper instruments were used in a modified crown-down manner by using a gentle in-and-out motion. The instrumentation sequence was SX instrument at two-thirds of working length, S1 and S2 at working length − 1 mm, and then F1 (20.07), F2 (25.08), F3 (30.09), and F4 (40.06) at working length.

In group C, a R40 Reciproc file with size 40 at the tip and taper of 0.06 over the first 3 mm was used in a reciprocating, slow in-and-out pecking motion. The flutes of the instrument were cleaned after 3 in-and-out-movements (pecks).

In group D, a large reciprocating WaveOne file with size 40 and taper of 0.08 was used in a reciprocating, slow in-and-out pecking motion. The flutes of the instrument were cleaned after 3 pecks.

No glide path was created before instrumentation with the R40 and the WaveOne file because the initial size of all canals was equal to size 20.

In each of these groups, 20 canals were enlarged. Thus, a total of 80 canals were prepared. Instruments were used to prepare 4 canals only. The last group (20 teeth) served as control group.

All root canal preparations were completed by one operator (S.B.), and the assessments of the cross sections were performed by 2 other examiners who were blinded in respect to all experimental groups.

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. The teeth were horizontally sectioned at 3, 6, and 9 mm from the apex with a 0.1-mm low-speed saw (Leitz, Wetzlar, Germany) under water-cooling. To avoid any artifacts by dehydration, the teeth were kept moist in purified filtered water throughout all experimental procedures.

All slices were observed under a digital stereomicroscope (Expert DN) at ×25 magnification by using a cold light source, and pictures were taken. In cases of discrepancy in the observations of the 2 examiners, the slices were inspected again and discussed until a consensus was reached. Fractures, incomplete cracks, and craze lines as well as the relative and absolute length of the defects were recorded by using the ImageJ software (National Institutes of Health, public domain). The incidences of the different defects were analyzed by using the chi-square test at a significance level of $P < .05$.

Definitions of the Defects

No defect is root dentin without any lines or cracks on the external or the internal surface of the root (Fig. 1).

Incomplete crack is a line extending from the canal wall into the dentin without reaching the outer surface.

Complete crack is a line extending from the root canal wall to the outer surface of the root (Fig. 2).

Craze lines are all other lines that did not reach any surface of the root or extend from the outer surface into the dentin but did not reach the canal wall.

Results

The distribution of the different defects is summarized in Table 1.

Overall, instrumentation with Reciproc files was associated with significantly more complete cracks compared with Mtwo and ProTaper ($P = .021$), but no significant differences were obtained between Reciproc and WaveOne ($P > .05$). Regarding the different sections (3, 6, and 9 mm), no significant difference was found between the 4 2file systems ($P > .05$).

Only in the apical section (3 mm), Reciproc and WaveOne produced significantly more incomplete cracks than Mtwo and ProTaper ($P = .001$). Concerning the length of the incomplete cracks, the data were not distributed normally (Kolmogorov-Smirnov test). The Kruskal-Wallis test revealed no significant differences between the groups ($P > .05$).

Craze lines were detected in all groups, without any statistical difference between the 5 groups ($P > .05$).

Discussion

This study revealed that dentinal defects occurred independent of the type of instruments used (rotary full-sequence systems or reciprocating instruments). In the apical part of the canals the reciprocating files produced significantly more incomplete cracks compared with the rotary instruments ($P < .05$). Previous studies showed that dentinal defects can be related to instrumentation techniques and obturation

TABLE 1. Number of Cracks in the Different Cross-section Slices (n = 60 in each group) and Percentage of Sections in Which Defects Were Present

	Absolute number of complete cracks/percentage of specimens with complete cracks				Absolute number of incomplete cracks/percentage of specimens with incomplete cracks			
	3 mm	6 mm	9 mm	Total	3 mm	6 mm	9 mm	Total
Control	0/0%	0/0%	0/0%	0/0%	0/0%	0/0%	0/0%	0/0%
Mtwo	0/0%	1/5%	1/5%	2[a]/3.3%[a]	7[a]/25%[a]	6/20%	5/10%	18/15%
ProTaper	2/10%	1/5%	0/0%	3[a]/5%[a]	8[a]/30%[a]	9/35%	3/5%	20/23.3%
Reciproc	4/20%	5/25%	2/10%	11[b]/18.3%[b]	17[b]/60%[b]	10/35%	2/10%	29/33.3%
WaveOne	1/5%	5/25%	1/5%	7[a,b]/11.7%[b]	16[b]/55%[b]	8/30%	3/10%	27/30%
P value	.140	.99	.551	.021	.001	.614	.627	.114

Note that more than 1 crack per slice was possible.

Values with the same superscript letter were not statistically different at $P = .05$; *P* values are given for the absolute number of defects.

methods, and currently no method is able to completely avoid such defects (5, 6).

The differences between the instruments tested regarding the incidence of dentinal defects may be due to the preparation technique and the cross-sectional design of the instruments. Both Mtwo and Reciproc have an identical S-shaped cross-sectional design with sharp cutting edges, whereas ProTaper and WaveOne are characterized by a triangular or modified triangular cross section that results in a lower cutting efficiency and less chip space (12). An increased cutting ability is usually associated with an improved cleaning efficacy (20, 21). The reciprocal motion seems to enhance debris transportation toward the apex (22) and may increase torsional forces. It should be evaluated in further studies whether these increased torsional forces in combination with sharp cutting edges, as found in Reciproc instruments, are in general associated with an increased risk of creating dentinal defects.

Overall, Reciproc instruments caused significantly more complete cracks than the full-sequence rotary instruments ($P = .026$). Hitherto, no definitive conclusion can be made regarding the clinical implication of these dentinal defects on long-term follow-up (23, 24). It is yet unclear whether craze lines and incomplete cracks may propagate into complete cracks and fractures after completion of the root canal treatment. In addition, following treatment procedures such as post-space preparation or retreatment (2) or simply masticatory forces and occlusal loading (25) are discussed as cofactors for the development of dentinal defects or fractures. However, even teeth without any root canal treatment may fracture. Currently, there is an evident lack of correlation between the results obtained in this type of studies and the clinical situation. Despite efforts to reproduce the clinical conditions in the laboratory setting, it is impossible to eliminate discrepancy between the 2 situations and to eliminate possible influence of external factors on the results. Storage of the specimens before, during, and after the preparation may affect results, especially when mechanical properties of the specimens are investigated.

The sectioning method used in the present study allowed the evaluation of the effect of root canal treatment procedures on the root dentin by direct inspection of the roots and is in agreement with a methodology described in a previous study (5). However, numerous other methods have been described such as stress distribution measurements, observations of the presence of defects in tooth sections, and resistance of the root canal–treated tooth to fracture (26–29). The latter method applies an external force until the root fractures (30). Hence, the method in the present study differed from that approach because no external forces were applied, and the influence of root canal preparation on the root canal walls and the adjacent dentin was observed directly. In addition, resistance to fracture does only provide information on VRF, but the occurrence of dentinal defects cannot be detected.

Dentinal defects not connecting directly with the pulp space or the root canal wall were defined as craze lines. It is still unclear whether these defects may be caused by the stresses generated during mechanical instrumentation exceeding the tensile strength of the collagen matrix (2). In the present study, craze lines were also observed in unprepared teeth. Although this finding is contradictory to previous studies (2, 3, 5), it was assumed that they may be a result of forces induced during extraction procedures. Hence, these defects were classified as artifacts, although it has been claimed that fractures observed in one section could communicate with the canal space in an adjacent section (3). This supposition was recently supported by nondestructive observations of VRF induced in extracted teeth and assessed by using optical coherence tomography (7).

Further clinical studies are required to assess the benefits of reciprocal root canal instrumentation concerning its probably immanent risk factors and its impact on treatment outcome.

Acknowledgments

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

References

1. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod 1999;25:506–8.
2. 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.
3. 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.
4. Sathorn C, Palamara JE, 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.
5. Bier CA, Shemesh H, Tanomaru-Filho M, et al. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod 2009;35:236–8.
6. Shemesh H, Bier CA, Wu MK, et al. The effects of canal preparation and filling on the incidence of dentinal defects. Int Endod J 2009;42:208–13.
7. Shemesh H, van Soest G, Wu MK, Wesselink PR. Diagnosis of vertical root fractures with optical coherence tomography. J Endod 2008;34:739–42.
8. Sim TP, Knowles JC, Ng YL, et al. Effect of sodium hypochlorite on mechanical properties of dentine and tooth surface strain. Int Endod J 2001;34:120–32.
9. Wu MK, van der Sluis LW, Wesselink PR. Comparison of mandibular premolars and canines with respect to their resistance to vertical root fracture. J Dent 2004;32:265–8.
10. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. Endodontic Topics 2006;13:57–83.
11. Kishen A, Kumar GV, Chen N. Stress–strain response in human dentine: rethinking fracture predilection in postcore restored teeth. Dent Traumatol 2004;20:90–100.
12. Bürklein S, Hinschitza K, Dammaschke T, Schäfer E. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. Int Endod J 2012;45:449–61.
13. Gutmann JL, Gao Y. Alteration in the inherent metallic and surface properties of nickel-titanium root canal instruments to enhance performance, durability and safety: a focused review. Int Endod J 2012;45:113–28.
14. Alapati SB, Brantley WA, Iijima M, et al. Metallurgical characterization of a new nickel-titanium wire for rotary endodontic instruments. J Endod 2009;35:1589–93.

15. Al-Hadlaq SM, Aljarbou FA, AlThumairy RI. Evaluation of cyclic flexural fatigue of M-wire nickel-titanium rotary instruments. J Endod 2010;36:305–7.
16. De-Deus G, Brandão MC, Barino B, et al. 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;110:390–4.
17. Varela-Patiño P, Ibañez-Párraga A, Rivas-Mundiña B, et al. Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod 2010;36: 157–9.
18. Plotino G, Grande NM, Testarelli L, Gambarini G. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. Int Endod J 2012;45:614–8.
19. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271–5.
20. Schäfer E, Vlassis M. Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe—part 2: cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 2004;37:239–48.
21. Bonaccorso A, Cantatore G, Condorelli GG, et al. Shaping ability of four nickel-titanium rotary instruments in simulated S-shaped canals. J Endod 2009; 35:883–6.
22. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012;38:850–2.
23. Tamse A. Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management. Endodontic Topics 2006;13:84–94.
24. Meister F Jr, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surg Oral Med Oral Pathol 1980;49:243–53.
25. Assif D, Nissan J, Gafni Y, Gordon M. Assessment of the resistance to fracture of endodontically treated molars restored with amalgam. J Prosthet Dent 2003;89:462–5.
26. Obermayr G, Walton RE, Leary JM, Krell KV. Vertical root fracture and relative deformation during obturation and post cementation. J Prosthet Dent 1991;66:181–7.
27. Saw LH, Messer HH. Root strains associated with different obturation techniques. J Endod 1995;21:314–20.
28. Lertchirakarn V, Palamara JE, Messer HH. Load and strain during lateral condensation and vertical root fracture. J Endod 1999;25:99–104.
29. Mayhew JT, Eleazer PD, Hnat WP. Stress analysis of human tooth root using various root canal instruments. J Endod 2000;26:523–4.
30. Ribeiro FC, Souza-Gabriel AE, Marchesan MA, et al. Influence of different endodontic filling materials on root fracture susceptibility. J Dent 2008;36:69–73.