IEJ Iranian Endodontic Journal

Incidence of Dentinal Crack Formation Using ProTaper Universal and WaveOne Systems in Straight and Curved Root Canals

Nahid Mohammadzade Akhlaghi [a,b], Abbas Delvarani [b], Vanousheh Norouzi [c], Pooneh Mohebbi [b], Naghmeh Meraji [d*]

a Craniomaxillofacial Research Center, Dental Branch, Islamic Azad University, Tehran, Iran; b Department of Endodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran; c Private Practice, Tehran Iran; d Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Article Type:
Original Article

Received: 29 Jun 2018
Revised: 13 Sep 2018
Accepted: 16 Sep 2018
Doi: *10.22037/iej.v13i4.21114*

**Corresponding author*: Naghmeh Meraji, Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

Tel: +98-21 88351173
E-mail: meraji_n@yahoo.com

ABSTRACT

Introduction: This study aimed to compare dentinal micro crack formation following root canal instrumentation with ProTaper Universal (PTU) and WaveOne (WO) rotary systems in straight and curved root canals. **Methods and Materials:** One hundred mesiobuccal (MB) straight and curved canals of mandibular molars meeting inclusion criteria were divided into two control (n=10) and four experimental groups (n=20). After mounting the teeth and simulating the periodontal ligament, all the MB canals were coronally flared using Gates-Glidden drills #3 and 2 respectively. Then, in the experimental groups, the canals were instrumented with either PTU files (S_x, S_1, S_2, F_1, F_2), or Primary WO (25/0.08). Afterwards, roots were horizontally sectioned at 2, 4, and 6 mm from the apices, and evaluated under a microscope under 20× magnification. Data were analyzed with the *Chi*-Square and Kruskal-Wallis tests. The significance level was set at 0.05. **Results:** The control groups showed no cracks. There was no significant difference between the two systems in the straight root canals (P>0.05). But in the curved root canals, PTU produced significantly more cracks (P<0.05) with the complete crack type which was dominant (P=0.013) compared to WO. **Conclusions**: This *in vitro* study showed that in curved root canals, instrumentation with reciprocal WO system may be safer than full rotational PTU instruments regarding crack formation.

Keywords: Crack; Dentin; Instrumentation; Reciprocating; Root Canal Preparation

Introduction

Biomechanical preparation of the canal can cause crack formation [1]. Distribution of occlusal forces might further extend the formed micro cracks or craze lines leading to root fracture and consequently tooth extraction [2]. Researchers have shown that both hand and rotary instruments are able to induce dentinal cracks [3, 4]. Nevertheless, rotary systems may contribute to more defects in the dentinal structure of the root [5]. In the last decades, numerous nickel-titanium (NiTi) rotary systems have been introduced to reduce operator fatigue, chair time and minimize the procedural mishaps [6, 7]. However, some of their functions such as their cleaning ability, maintenance of the original canal shape, maintenance of the apical foramen position and ability to sufficiently prepare oval canals are still in debate.

The prevalence of dentinal crack formation using various rotary systems for cleaning and shaping of the canals is influenced by multiple factors, including the file design, metal composition, motion, and torque [5, 6]. Most commonly used NiTi instruments have two types of movements: continuous full rotation and reciprocation.

Instrumentation systems using reciprocating motion claim to reduce the risks associated with full rotation motions, namely dentinal crack formation [8]. Repeated torsion and flexion occurs in instrumentation systems using continuous full rotation which can lead to instrument fatigue failure [9]. However, in single file reciprocating systems it might be speculated that when using only one instrument, more stress will be generated during instrumentation, increasing the frequency of dentinal defects [10]. Kansal *et al.* [11] reported less cracks after using reciprocal instrumentation systems compared to those using full rotation.

Figure 1. Cross-sections at the 6-mm level: *A)* Without crack; *B)* Complete crack; *C)* Incomplete crack

However, Burklein *et al.* [12] reported a higher incidence of incomplete dentinal cracks at the apical level when using reciprocal systems. Controversy remains in this matter.

WaveOne (WO) (Dentsply, Maillefer, Ballaigues, Switzerland) is a NiTi single file instrumentation system. It is designed to work in a reverse balanced force reciprocal motion using a preprogrammed device. As WO utilizes a greater counter clock wise (CCW) movement than clockwise (CW), it is claimed that it requires less apical pressure on each instrument for advancement to the working length of the root canal [13].

To the best of our knowledge, controversy remains on the effect of instrument motions on dentinal crack formation in curved canals compare with straight ones. Hence, this study aimed to evaluate the incidence of dentinal cracks formation following preparation of straight and curved root canals using WO (reciprocating motion) and ProTaper Universal (PTU) (continuous rotating motion) rotary systems (Dentsply, Maillefer, Ballaigues, Switzerland). The null hypothesis was that no difference will be seen between the crack formation of full rotation and reciprocating instruments regardless of canal curvature.

Materials and Methods

A total of 223 recently extracted mandibular human molars due to periodontal problems, with separate distal and mesial roots were collected and immersed in chloramine-T. Then all the roots were evaluated with a stereomicroscope under 20× magnification (Nikon Co, Tokyo, Japan) to detect the initial cracks. Afterwards, parallel radiographic images were taken. Teeth with root caries, cervical, apical or internal resorptions, previous root canal treatment, open apices, cracks or fractures, reduced pulpal space, pulp stones, calcified canals and hypercementosis were excluded.

After access cavity preparation, a #8 or #10 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) was inserted into the mesial canals to check the patency and to make sure of the presence of two separate canals. The canals should have apical stop during insertion of a # 15 K-file into the mesiobuccal (MB) canal. The teeth with root canal curvature less than 5° and between 20°-35° (according to Schneider's method) were considered as straight and curved canals, respectively. The teeth were decoronated at the cemento-enamel junction. Distal roots were also cut and only mesial roots with 14-15 mm length remained. A total of 100 teeth met the criteria and were included in the study. Each root was covered with a single layer of aluminum foil, and then embedded in acrylic resin. Subsequently, the root was removed from the set acrylic tube, the foil was peeled off, and impression of the root was made with hydrophilic Vinyl Polysiloxane (Provil Novo, Heraeus Kulzer GmbH, Hanau, Germany) to replace the empty space to simulate the periodontal ligament. Then, 3 mm apical portion of the roots were exposed and sank in water during instrumentation. The coronal 2-3 mm of each canal was pre flared with #3 and #2 Gates-Glidden drills (Dentsply, Maillefer, Ballaigues, Switzerland), respectively and a #8 and 10 K-file was used for canal patency during canal preparation. All the canals were prepared up to a #15 hand K-file to the working length (WL). The WL was set at 1 mm short of the anatomic apex. Then the samples were randomly allocated into two control groups (*n*=10) without any instrumentation, and 4 experimental (*n*=20). Group 1; straight canals with PTU (Dentsply, Maillefer, Ballaigues, Switzerland), group 2; curved canals with PTU, group 3; straight canals with WO (Dentsply, Maillefer, Ballaigues, Switzerland) and group 4; curved canals with WO.

In all groups, instruments were used according to the manufacturer's instructions with X-Smart Plus electric motor (Dentsply, Maillefer, Ballaigues, Switzerland). In PTU groups, F_2 were used to the WL as final apical file. In WO groups, a primary file 25/0.08 were used in a reciprocating motion, gradually to the WL.

All instruments were dipped in RC prep (MetaBiomed Co., Seoul, Korea) before use to facilitate their movements and avoid fracture. One skilled operator performed all the instrumentations. Each file was used for a total of 2 straight and 2 curved root canals. During the instrumentation and after each file, the canals were irrigated with 2 mL of 2.5% NaOCl using 28-gauge side ended needle (Max-i-probe). The smear layer was removed by 17% EDTA (MetaBiomed Co., Seoul, Korea) followed by 5.25% NaOCl, and the canals were finally rinsed with 10 mL of distilled water. The flutes of every instrument were cleaned after three pecking motions.

Sectioning and microscopic observation

All the specimens while were mounted and fixed in acrylic resin, were sectioned perpendicular to the long axis at 2, 4, and 6 mm from the root apices using a low-speed saw (D&Z, Wellington, New Zealand) with 0.02 mm thickness under water-cooling. Slices were viewed under the stereomicroscope (Nikon SMZ1500, Nikon Corporation, Tokyo, Japan) under 20× magnification and the images were recorded using the attached camera (Nikon SMZ1500, Nikon Corporation, Tokyo, Japan). All the sections have been evaluated separately by two experienced Endodontists (k=0.8). In case of discrepancy, a third Endodontist evaluated the sections and each of two agreed opinions was considered as the final agreement.

Statistical analysis

Findings were expressed as the number of cracks in the cross-sectional slices (300 sections) and the crack percentage. Incidence of cracks were analyzed using the *Chi*-Square and Kruskal-Wallis tests at a significance level of 0.05. All statistical analysis was performed using the SPSS software version 22 (SPSS Inc., Chicago, IL, USA).

Results

Table 1 represents the distribution of straight and curved canals among experimental groups. Kolmogrov Smirnov test showed there was normality between the groups with straight and curved canals, and ANOVA test showed that there were no significant differences between the groups ($P \leq 0.05$). The number of complete and incomplete cracks in the cross-sectional slices and the crack percentage in straight and curved canals are shown in Tables 2 and 3, respectively.

No crack was found in the control groups and in other groups, most of the specimens did not show any cracks. Among the ones with cracks, most were observed at the level of 6 mm from the apex, especially in curved canals.

In straight canals, there was no significant difference between the two experimental groups at different section levels. However, ProTaper produced significantly more cracks in curved canals compared with WaveOne ($P \leq 0.05$). Moreover, the number of complete cracks generated by ProTaper was significantly higher than that of WaveOne ($P=0.013$). After instrumentation with WaveOne, more incomplete cracks were observed than complete ones.

Discussion

In this *in vitro* study, dentinal crack formation in straight and curved canals after instrumentation with PTU and WO were evaluated. The results showed that there was no difference between PTU and WO in straight canals; however, PTU generated more cracks in curved canals, and, created more complete cracks when compared with WO.

The sectioning method used in the study allowed evaluation of the impact of root canal treatment procedures on dentin root by direct inspection. This method is in agreement with a methodology described in a previous study [14]. However, there are different methods to evaluate the cracks formed in the root dentin following

Table 1. Distribution of straight and curved canals among groups

	Curvature (<5°)			**Curvature (20°-35°)**		
Group (N)	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**
ProTaper Universal (20)	4.35 (1.08)	3	6	28.1 (4.25)	21	35
WaveOne (20)	4.45 (1.14)	3	7	30.1 (3.30)	25	34
Control (20)	4.3 (.94)	3	6	30 (3.16)	25	34
***P*-value**	0.927			0.193		

Table 2. Number of cracks in the different cross-section slices (*n*=60 in each group) and the crack percentage in straight canals

Absolute number of cracks (percentage)						
	Complete cracks			**Incomplete cracks**		
Group (N)	**2 mm**	**4 mm**	**6 mm**	**2 mm**	**4 mm**	**6 mm**
ProTaper Universal (20)	0	0	4 (%83.3)	0	0	1 (%16.7)
WaveOne (20)	0	0	1 (%33.3)	0	1 (%100)	2 (%66.7)
Control (20)	0	0	0	0	0	0
***P*-value**	0.013			0.567		

Table 3. Number of cracks in the different cross-section slices (*n*=60 in each group) and the crack percentage in curved canal

Absolute number of cracks (percentage)						
	Complete cracks			**Incomplete cracks**		
Group (N)	**2 mm**	**4 mm**	**6 mm**	**2 mm**	**4 mm**	**6 mm**
ProTaper Universal (20)	0	1 (%50)	6 (%83.3)	1 (%100)	1 (%50)	1 (%16.7)
WaveOne (20)	0	0	1 (%33.3)	1 (%100)	0	2 (%66.7)
Control (20)	0	0	0	0	0	0
***P*-value**	0.013			0.527		

instrumentation, such as stress distribution measures, observations of the presence of cracks in tooth sections using methylene blue, resistance of the root canal treated tooth to fracture and Optical Coherence Tomography or Infrared Thermography [14-18]. These methods eliminate sectioning procedures, but has some limitations due to the equipment sizing [15].

The different incidence of dentinal cracks in the current study may be due to the dissimilarities of metal compositions and movement kinematics between the instruments tested. In this study, there was no significant difference between the two motions regarding dentinal crack formation in straight canals, nevertheless, reciprocating motion outperformed full rotation sequence in curved canals. The superior safety of canal preparation with reciprocating motion over continuous rotation has been shown in previous studies [7, 10].

WO is a single-instrument rotary file system produced with a special NiTi alloy (M-wire) subjected to a special thermal treatment process, and, have more flexibility than those made from conventional NiTi wires [19]. These specially designed files work in a reverse balance force action in a back and forth motion, which is claimed to require less apical pressure for its penetration into the canal and induce less stress on the instrument and minimize fracture stemming from cyclic fatigue [7, 10]. Their counterclockwise motion disengages the instrument blades, so, the torsional and flexural stresses on dentin are reduced [16]. On the contrary, some researches were not in accordance with the present findings. Bürklein *et al.* [12] stated that single-file reciprocal systems generated more dentin defects than multi-file systems with full rotational movements. The discrepancy may be attributed to difference in tooth type, taper and final size of apical preparation, and probably not simulating the periodontal ligament, as compared with the present study.

Meanwhile, it has been speculated that dentin thickness in association with canal curvature and external root morphology are factors potentially influencing fracture susceptibility [20]. The thinner the dentin, the greater is the likelihood of tooth fracture [21]. In a study performed by Katz *et al.* [22], it was reported that in roots with less mesiodistal dimension than the buccolingual, such as maxillary and mandibular premolars, mesial roots of mandibular molars and mandibular incisors, the risk of fracture due to root canal and post space preparation is greater.

In the present study, for standardization of samples, all were assessed under stereomicroscope to exclude any specimen with pre-existed crack or fracture [12, 16]; and, for better simulation of the clinical condition, we used hydrophilic vinyl polysiloxane for mimicking the periodontal ligament [2, 10]. It is stated that using elastomeric impression materials are not appropriate due to the collapse and direct contact between the tooth and the experimental socket made by acryl [17].

Root canal procedures, either treatment or retreatment, and post space preparations are considered as factors for developing dentinal defects in the form of craze line, incomplete or complete crack, and, finally fracture [18]. However, even teeth with no or least dental treatments may lead to formation of crack and fracture [12], which can be attributed to external forces such as, normal or excessive masticatory and occlusal loadings [16]. Following additional forces, complete cracks can propagate into vertical root fractures more readily than incomplete ones [12]; so, in this study we classified the cracks into complete and incomplete.

The taper of the file used for preparation could be contributive to the formation of dentinal cracks [23]. The more removal of the tooth structure, the more possibility for root fracture [18]. Therefore, in order to reduce the effect of this factor, we tried to create an identical taper by using WO Primary file and PTU F_2 file, both having taper of 0.08 and tip diameter of 0.25 mm.

In the present study, both WO and PTU systems induced significantly more cracks at 6 mm level from the apex, which was in agreement with the study done by Li *et al.* [16]. They speculated that the PTU and WO systems induced significantly more complete cracks in the 2 mm above the most curved plan compared with either of the 2 other plans. The instruments can get stuck in the curved root canals, which can make the instrumentation much difficult. If the clinician keeps working, excessive torque will be generated that can increase the risk of intra canal fracture, that can be the case in ProTaper groups [24]. Nevertheless, more studies are to be done to conclude such a definite statement.

Dane *et al.* [25] reported that the canal preparation with PTU system resulted in more crack formation at high-torque setting compare to low-torque one. In the present study the low-torque was set for canal preparation with PTU system.

Due to the nature of these kinds of studies, no definitive conclusion can be made regarding the clinical implication of these dentinal defects on long term follow up.

Conclusion

Under the limits of this study, there was no significant difference between PTU and WO in straight root canals; however, PTU, with full rotation motion, generated more cracks in curved canals, and created more complete cracks than reciprocating movement.

Acknowledgement

The authors thank Dr Nasrin Akhoundi for her valuable statistical analysis.

Conflict of Interest: 'None declared'.

References

1. 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.
2. Yoldas O, Yilmaz S, 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.
3. Kumari MR, Krishnaswamy MM. Comparative Analysis of Crack Propagation in Roots with Hand and Rotary Instrumentation of the Root Canal -An Ex-vivo Study. J Clin Diagn Res. 2016;10(7):Zc16-9.
4. Soni D, Raisingani D, Mathur R, Madan N, Visnoi S. Incidence of Apical Crack Initiation during Canal Preparation using Hand Stainless Steel (K-File) and Hand NiTi (Protaper) Files. Int J Clin Pediatr Dent. 2016;9(4):303-7.
5. 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.
6. 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):1195-9.
7. 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.
8. Ruddle CJ. Canal preparation: single-file shaping technique. Dent Today. 2012;31(1):124, 6-9.
9. Varela-Patino P, Ibanez-Parraga A, Rivas-Mundina 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):157-9.
10. 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.
11. Kansal R, Rajput A, Talwar S, Roongta R, Verma M. Assessment of dentinal damage during canal preparation using reciprocating and rotary files. J Endod. 2014;40(9):1443-6.
12. Burklein S, Tsotsis P, Schafer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. J Endod. 2013;39(4):501-4.
13. Webber J, Machtou P, Pertot W, Kuttler S, Ruddle C, West J. The WaveOne single-file reciprocating system. Roots. 2011;1(1):28-33.
14. Karatas E, Arslan H, Alsancak M, Kirici DO, Ersoy I. Incidence of Dentinal Cracks after Root Canal Preparation with Twisted File Adaptive Instruments Using Different Kinematics. J Endod. 2015;41(7):1130-3.
15. Matsushita-Tokugawa M, Miura J, Iwami Y, Sakagami T, Izumi Y, Mori N, Hayashi M, Imazato S, Takeshige F, Ebisu S. Detection of dentinal microcracks using infrared thermography. J Endod. 2013;39(1):88-91.
16. Li SH, Lu Y, Song D, Zhou X, Zheng QH, Gao Y, Huang DM. Occurrence of Dentinal Microcracks in Severely Curved Root Canals with ProTaper Universal, WaveOne, and ProTaper Next File Systems. J Endod. 2015;41(11):1875-9.
17. 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(2):e64-70.
18. Wilcox LR, Roskelley C, Sutton T. The relationship of root canal enlargement to finger-spreader induced vertical root fracture. J Endod. 1997;23(8):533-4.
19. Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, Castellucci A, Pasqualini D. Canal shaping with WaveOne Primary reciprocating files and ProTaper system: a comparative study. J Endod. 2012;38(4):505-9.
20. Lertchirakarn V, Palamara JE, Messer HH. Patterns of vertical root fracture: factors affecting stress distribution in the root canal. J Endod. 2003;29(8):523-8.
21. Ganesh A, Venkateshbabu N, John A, Deenadhayalan G, Kandaswamy D. A comparative assessment of fracture resistance of endodontically treated and re-treated teeth: An in vitro study. J Conserv Dent. 2014;17(1):61-4.
22. Katz A, Tamse A. A combined radiographic and computerized scanning method to evaluate remaining dentine thickness in mandibular incisors after various intracanal procedures. Int Endod J. 2003;36(10):682-6.
23. 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.
24. Gambarini G. Rationale for the use of low-torque endodontic motors in root canal instrumentation. Endod Dent Traumatol. 2000;16(3):95-100.
25. Dane A, Capar ID, Arslan H, Akcay M, Uysal B. Effect of Different Torque Settings on Crack Formation in Root Dentin. J Endod. 2016;42(2):304-6.

***Please cite this paper as*:** Mohammadzade Akhlaghi N, Delvarani A, Norouzi V, Mohebbi P, Meraji N. Incidence of Dentinal Crack Formation Using ProTaper Universal and WaveOne Systems in Straight and Curved Root Canals. Iran Endod J. 2018;13(4):549-53. *Doi: 10.22037/iej.v13i4.21114*.