

Original Article

The Effect of Different Rotary Systems on Creating Intracanal Dentinal Defects: An *Ex Vivo* Study

Abbas Abbaszadegan¹, DDS, Msc; Alireza Adl², DDS, Msc; Fateme Nemati³, DMD Student; Nikta Ranjbar⁴, DDS;

¹ Dept. of Endodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

² Dept. of Endodontics, Biomaterials Research Center, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

³ Undergraduate Students, Shiraz University of Medical Sciences, Shiraz, Iran.

⁴ Private Practice, Shiraz, Iran.

KEY WORDS

Dentine;
Root canal preparation;
Instrumentation;
Tooth fracture;

Received:
Revised:
Accepted:

ABSTRACT

Background: The creation of intracanal dentinal defects during root canal preparation is a concern in endodontic treatment; as such defects can compromise the integrity of the tooth and potentially lead to fractures or failure of the treatment. Rotary systems, commonly used for shaping root canals, vary in their design, material, and cutting mechanisms, which may influence the extent of dentinal defects they induce. However, the comparative impact of different rotary systems on the formation of these defects remains unclear.

Purpose: The aim of this *ex vivo* study was to compare the effects of four rotary systems (One-curve, One-shape, Neolix, and ProTaper Universal) on the creation of intracanal dentinal defects in extracted human teeth.

Materials and Method: In this *ex vivo* study, seventy extracted human mandibular incisor teeth with straight roots and no extra canals or existing dentinal defects were selected and randomly divided into five groups, including one control group and four experimental groups. In the control group (n=10), no instrumentation was performed. In the experimental groups (n=15 each), instrumentation was done using the rotary systems ProTaper Universal, Neolix, One-shape, and One-curve, respectively. All groups received the same amount of irrigation: 12mL of 2% sodium hypochlorite followed by 3mL of sterile saline. The roots were then horizontally sectioned at 3, 6, and 9 mm from the apex and evaluated under a stereomicroscope for the presence of intracanal defects. Data were analyzed using Chi-square test.

Results: The lowest and highest rates of dentinal cracks were observed in the One-curve and One-shape groups, respectively. No significant differences were observed among the experimental groups (*p* Value=0.46).

Conclusion: All tested rotary systems induced dentinal defects. The lowest and highest incidence of dentinal defects occurred in teeth prepared using the One-curve (26%) and One-shape (53%) rotary instruments, respectively.

Corresponding author: Adl A. Dept. of Endodontics, Shiraz University of Medical Sciences, Shiraz, Iran.
Tel: +987136263194 Email: adla@sums.ac.ir

Cite this article as:

Introduction

One of the most unfavorable consequences of endodontic treatments, which may arise during root canal preparation, is the creation of dentinal cracks and craze lines. These defects can lead to vertical root fractures, impacting the outcome of root canal therapy and the prognosis of treatment [1].

Several factors contribute to the formation of incomplete dentinal fractures, craze lines, and micro-cracks. These include the use of nickel-titanium (Ni-Ti) rotary instruments for root canal preparation, dentine dehydration, and irrigation solutions, particularly high-concentration sodium hypochlorite (NaOCl) [2-6].

Specific parameters of each rotary system may in-

fluence the formation of dentinal defects, such as blade design, the number of cutting edges, file taper, cross-sectional shape, and rake angle [2, 5]. Rotary files create higher stress on dentin compared to hand files due to their greater taper and the increased rotations required inside the lumen [7-8].

Recently, single-file rotary systems have gained popularity due to their advantages, including reduced working time, lower cross-contamination, and improved safety during shaping procedures [9]. However, using only one file for the preparation process may increase the risk of dentinal defects due to stress concentration in the lumen [10].

The first rotary single-file system, One Shape (Micro Mega, France), was introduced to the dental market in 2011. It features a continuous clockwise motion and requires endodontic motors [11]. One Shape files have a safe, non-cutting tip and three different cross-sections along the active length: a triangular or modified triangular cross-section with three sharp cutting edges in the middle and apical thirds, and an S-shaped cross-section with two cutting edges near the shaft [11-12]. The One-Curve rotary system (Micro Mega, France), another single-file system from the same company introduced in 2018, also has varying cross-sectional designs along the shaft, enabling effective cutting ability [13].

Neolix (Neolix, Châtres-la-Forêt, France) is also a single-file rotary system [14] with continuous motion. These files have a non-cutting tip to prevent transportation and ensure safe instrumentation [15]. They are manufactured using a wire-cut electrical discharge machining process, which creates a rough surface with abrasive properties, resulting in faster root canal preparation. Additionally, they are heat-treated to enhance flexibility [16].

The ProTaper Universal system (Dentsply/Maillefer, Ballaigues, Switzerland) is a widely used rotary instrument made from conventional super-elastic NiTi wire. It has a convex triangular cross-sectional design with a progressive taper along the file length and an aggressive cutting action, which removes relatively more dentin coronally [17]. The Protaper system is commonly utilized across numerous countries and is included in the curricula of undergraduate dental programs. Furthermore, it has been extensively investigated in the literature, making it a suitable standard for use in the present study [3, 18].

To the best of our knowledge, there are limited stud-

ies comparing the effects of different single-file rotary systems on the formation of dentinal defects. Therefore, this study was designed to assess the potential for dentinal defects induced by the ProTaper, One Shape, One Curve, and Neolix rotary systems.

Materials and Method

This study received approval from the ethics committee of Shiraz University of Medical Sciences (IR.SUMS.DENTAL.REC.1399.086).

The sample size was calculated based on at least a moderate difference between the groups (effect size $w=0.30$), type I error rate $\alpha=0.05$, and type II error rate $\beta=0.20$. Therefore, the sample size was calculated to be 15 teeth in each experimental group. Seventy extracted single-canal mandibular incisors were selected for this study. These teeth had been extracted as a result of orthodontic treatment or periodontal diseases. The selected teeth were washed, soft tissue and calculus were removed and were then stored in distilled water until use. Teeth with curved roots, calcifications, root decay, and other defects were excluded. To exclude teeth with external root cracks, all samples were evaluated using a stereomicroscope (BestScope, BS-3060C, China) with 20× magnification.

Teeth were radiographically examined in both mesiodistal and buccolingual directions to exclude any extra canals. All teeth were decoronated using a high-speed diamond bur (Tizkavan, Iran) with water spray to reach a standard root length of 13mm. Aluminum layers were wrapped around each tooth to mimic the periodontal area, and the teeth were mounted in silicone impression material (Heavy Body, Coltene, Germany) in square-shaped bottles. After setting, the impression materials were removed from the bottles, and the aluminum foils were taken out. Then, the free spaces were filled with light body silicone impression material (Coltene, Germany). Samples were randomly divided into four experimental groups ($n=15$ each) and one control group ($n=10$). In the control group, no instrumentation was performed; only irrigation was done. In ProTaper Universal group, files from S1 to F2 were used (S1, and S2, 300 rpm and 3 Ncm; F1 and F2, 300 rpm and 2 Ncm). In the single files groups, One Curve rotary file (25/06, 300 rpm, 2.5 Ncm), One Shape single rotary file (25/06, 400rpm, 4Ncm), and Neolix rotary system (25/06, 400rpm, 1.5Ncm) were

used. In all groups, a manual glide path was established using K-files #10 and #15. An electronic motor (NSK, Endo-Mate DI, Model NE, Japan) was used for preparation according to the manufacturer's instructions for each rotary system. Irrigation was done similarly for all groups using 12mL of 2% NaOCl (Cerkamed, Poland) followed by 3mL of sterile saline as final irrigation, using a #27 needle gauge (Ava, Iran). After root canal preparation, the roots were removed from their molds and horizontally sectioned at 3, 6, and 9mm from the apex using a saw (Mecatome T180, Presi SA, Angonnes, France) with water cooling. All the segments were soaked in methylene blue to increase the accuracy of crack line detection. The segments were then evaluated by two expert operators, who were blinded to the study, using a stereomicroscope with 25× magnification. If there was a disagreement between the two observers, they checked the samples together to reach an agreement.

If in any section of a root, an incomplete crack originating from inside the canal or a complete crack was observed, that root was considered as "cracked" [19]. Statistical analysis was done using Chi-square with SPSS 23 (SPSS Inc, Chicago, Illinois, USA). Level of significance was set at 0.05.

Results

The number and percentage of intra-canal cracks in different groups are shown in Table 1 and Figure 1. No cracks were found in the control group. Among the experimental groups, the lowest and highest rates of dentinal cracks were observed in the One-curve and One-shape groups, respectively. According to the Chi-square test, there was no significant difference in the number of dentinal cracks among the experimental groups ($p=0.46$).

Discussion

An important drawback of NiTi rotary systems is the possibility of dentinal crack formation during root canal preparation, despite their advantages such as time-saving, flexibility, and reduced clinician fatigue [20]. This study

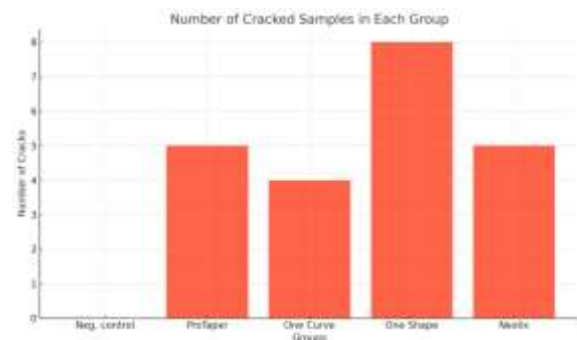


Figure 1: Distribution of cracks in different groups

aimed to compare four rotary systems (ProTaper Universal, One-curve, One-shape, and Neolix) regarding their ability to induce intracanal dentinal defects. Results indicated that all rotary systems were capable of causing dentinal defects. The highest dentinal crack rate occurred with the use of One-shape single rotary files, while the lowest rate was observed with One-curve rotary files.

We selected mandibular incisors for this study, consistent with previous research, as they are more prone to dentinal cracks due to their smaller proportions [4, 6].

Notably, the absence of cracks in the negative control group in our study is consistent with literature findings, suggesting that the sectioning procedure does not produce dentinal defects [21-22].

In this current *ex vivo* study, the PDL was reconstructed using a light body silicone-based impression material, allowing the teeth to have limited movement and preventing external reinforcements [21]. The role of the periodontal ligament (PDL) in receiving and distributing stress and strain on teeth due to its viscoelastic characteristics is crucial. However, some studies have neglected to reconstruct the PDL in the methods of their study [3, 21].

Onnink *et al.* [23] were the first to identify that canal preparation methods can lead to dentinal defects. Excessive cleaning and shaping can reduce intra-canal dentin thickness and weaken root structure. Additionally, rotary files generate different degrees of rotational forces on dentinal walls, potentially resulting in microcracks or craze lines [5]. We observed a 53% crack formation rate with One-Shape rotary files, higher than the 29% reported by Shantiaee *et al.* [24]. However, Pedullà *et al.* [25] reported a 75% crack formation rate with the One-shape system, although they did not establish a glide path in their study. These discrepancies may stem from differences in glide path establishment methods, as well as variations in speed and torque settings.

The reported percentage of crack formation varies in

Table 1: The number and percentage of intra-canal cracks in different groups

Groups	Number	+ crack	- crack	% crack
Neg. control	10	0	10	0
ProTaper	15	5	10	33
One-curve	15	4	11	26
One-shape	15	8	7	53
Neolix	15	5	10	33

previous investigations [3-5] involving the use of ProTaper Universal. Our study found a 33% crack formation rate, whereas Liu *et al.* [4] reported 50% when using mandibular incisors. Additionally, Yoldas *et al.* [5] observed 30% crack formation in mesial roots of mandibular molars, and Bier *et al.* [3] reported 16% crack formation in mandibular premolars. These discrepancies are likely due to differences in the teeth studied.

Instrument design plays a role in dentinal defect formation [11, 26]. The S-shape cross-sectional design of the One-shape rotary system, with its two cutting edges, may reduce the screwing effect and influence dentinal defects. Our study revealed a higher but not significant likelihood of dentinal defects with One-shape instruments, consistent with findings by Burklein *et al.* [11] and Gergi *et al.* [26], indicating that the S-shape design is more prone to creating defects than modified triangular or triangular cross-sections.

Similar to findings by Ozlek *et al.* [27], we observed fewer dentinal defects with the One-curve rotary system, likely due to its manufacturing design. The One-curve rotary file, made from a heat-treated Ni-Ti alloy (C-Wire), features shape memory, increased flexibility with a triangular cross-section, and variable shape designs [13]. In this study, Neolix rotary systems demonstrated 33% crack rates which was similar to Protaper rotary group. It is speculated that the manufacturing process of Neolix files, combined with their rectangular cross-section, provides them with higher flexibility, increased cutting efficiency, and reduced intra-canal stress. However, Priya *et al.* [28] found that Neolix single files induced more dentinal cracks compared to the ProTaper system, contrary to our results.

The influence of the number of instruments in a rotary system and instrument motion used for canal preparation on crack incidence remains a debated topic. Although we did not directly investigate the influence of these factors on crack formation, our findings align with previous research suggesting that rotary instrumentation can induce various dentinal defects [11, 21, 28]. Several studies [4, 21, 29] have reported significantly higher dentinal crack rates with continuous motion compared to reciprocating motion. However, some researchers have found higher crack rates with rotary systems utilizing reciprocating motion [11, 26]. As mentioned earlier, there are a large number of discrepancies in the litera-

ture regarding the incidence of crack formation with different rotary files. Therefore, performing meta-analysis studies is suggested to shed light on this topic.

Conclusion

Within the limitations of this study, we found that all experimented rotary systems resulted in the development of dentinal cracks. Although no significant difference was observed between the experimental groups, the fewer crack in one-curve group may make it a safer choice for clinical use.

Acknowledgment

The authors of this paper would like to appreciate the Vice-Chancellery of Shiraz University of Medical Sciences for supporting this study (Grant: #98-01-03-21871). This manuscript is based on the thesis by Dr. Fateme Nemati.

Conflicts of Interest

The authors declare that they have no conflict of interest.

References

- [1] Hin ES, Wu MK, Wesselink PR, Shemesh H. Effects of self-adjusting file, Mtwo, and ProTaper on the root canal wall. *J Endo.* 2013; 39: 262-264.
- [2] Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. *J Endo.* 2004; 30: 559-567.
- [3] Bier CAS, 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 Endo.* 2009; 35: 236-238.
- [4] 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 Endo.* 2013; 39: 1054-1056.
- [5] 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 Endo.* 2012; 38: 232-235.
- [6] Adorno CG, Yoshioka T, Suda H. Crack initiation on the apical root surface caused by three different nickel-titanium rotary files at different working lengths. *J Endo.* 2011; 37: 522-525.
- [7] Pasqualini D, Scotti N, Tamagnone L, Ellena F, Berutti E.

- Hand-operated and rotary ProTaper instruments: a comparison of working time and number of rotations in simulated root canals. *J Endo*. 2008; 34: 314-317.
- [8] Milani AS, Froughreyhani M, Rahimi S, Jafarabadi MA, Paksefat S. The effect of root canal preparation on the development of dentin cracks. *Iranian Endo J*. 2012; 7: 177.
- [9] Selvan PS, Aparajitha R, Ahamed AS, Bhavani S, Rajaraman G. Comparative evaluation of shaping ability of sequential rotary, single rotary, and single reciprocating file systems in simulated curved canals using cone-beam computed tomography: An in vitro study. *Endodontology*. 2022; 34: 55-60.
- [10] Elnaghy AM, Elsaka SE. Cyclic fatigue resistance of One Curve, 2Shape, ProFile Vortex, Vortex Blue, and RaCe nickel-titanium rotary instruments in single and double curvature canals. *J Endo*. 2018; 44: 1725-1730.
- [11] Bürklein S, Tsotsis P, Schäfer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. *J Endo*. 2013; 39: 501-504.
- [12] Santa-Rosa J, de Sousa-Neto MD, Versiani MA, Nevares G, Xavier F, Romeiro K, et al. Shaping ability of single-file systems with different movements: a micro-computed tomographic study. *Iranian Endo J*. 2016; 11: 228.
- [13] Serafin M, De Biasi M, Franco V, Angerame D. In vitro comparison of cyclic fatigue resistance of two rotary single-file endodontic systems: One Curve versus One-Shape. *Odontology*. 2019; 107: 196-201.
- [14] Khoshbin E, Donyavi Z, Atibeh EA, Roshanaei G, Amani F. The effect of canal preparation with four different rotary systems on formation of dentinal cracks: An in vitro evaluation. *Iranian Endo J*. 2018; 13: 163.
- [15] Gergi R, Sabbagh C. Effectiveness of two nickel-titanium rotary instruments and a hand file for removing gutta-percha in severely curved root canals during retreatment: an ex vivo study. *Int Endo J*. 2007; 40: 532-537.
- [16] Moazzami F, Khojastepour L, Nabavizadeh M, Habashi MS. Cone-beam computed tomography assessment of root canal transportation by neoniti and reciproc single-file systems. *Iranian Endo J*. 2016; 11: 96.
- [17] Pereira E, Peixoto I, Viana A, Oliveira I, Gonzalez B, Buono V, Bahia M. Physical and mechanical properties of a thermomechanically treated NiTi wire used in the manufacture of rotary endodontic instruments. *Int Endo J*. 2012; 45: 469-474.
- [18] Shemesh H, Bier C, Wu MK, Tanomaru-Filho M, Weselink P. The effects of canal preparation and filling on the incidence of dentinal defects. *Int Endo J*. 2009; 42: 208-213.
- [19] Adl A, Sedigh-Shams M, Majd M. The effect of using RC prep during root canal preparation on the incidence of dentinal defects. *J Endo*. 2015; 41: 376-379.
- [20] Ossareh A. Role of dentin compositional changes and structural loss on fracture predilection in endodontically treated teeth: University of Toronto (Canada); 2015.
- [21] Kansal R, Rajput A, Talwar S, Roongta R, Verma M. Assessment of dentinal damage during canal preparation using reciprocating and rotary files. *J Endo*. 2014; 40: 1443-1446.
- [22] Bhagyashree B, Rao D, Panwar S, Kothari N, Gupta S. An in vitro comparative evaluation of dentinal crack formation caused by three different nickel-titanium rotary file systems in primary anterior teeth. *J Indian Soc Pedo Prev Dent*. 2022; 40: 188-194.
- [23] Onnink PA, Davis RD, Wayman BE. An in vitro comparison of incomplete root fractures associated with three obturation techniques. *J Endo*. 1994; 20: 32-37.
- [24] Shantiaee Y, Dianat O, Mosayebi G, Namdari M, Tordik P. Effect of root canal preparation techniques on crack formation in root dentin. *J Endo*. 2019; 45: 447-452.
- [25] Pedullà E, Genovesi F, Rapisarda S, La Rosa GR, Grande NM, Plotino G, Adorno CG. Effects of 6 single-file systems on dentinal crack formation. *J Endo*. 2017; 43: 456-461.
- [26] Gergi RM, Osta NE, Naaman AS. Dentinal crack formation during root canal preparations by the twisted file adaptive, Reciproc and WaveOne instruments. *Europ J Dent*. 2015; 9: 508-512.
- [27] Ozlek E, Gunduz H. The effect of heat-treated single-file systems on dentinal crack formation. *Nigerian J Clin Pract*. 2021; 24: 418-424.
- [28] Priya NT, Chandrasekhar V, Anita S, Tummala M, Raj TP, Badami V, et al. Dentinal microcracks after root canal preparation, a comparative evaluation with hand, rotary and reciprocating instrumentation. *J Clin Diagnos Research (JCDR)*. 2014; 8: ZC70.
- [29] Wardoyo MP, Artiningsih DANP, Usman M, Nazar K, Wiranatakusumah ST. Rotary Continuous and Reciprocating Single-File Nickel-Titanium Instruments in the Induction of Dentinal Cracks. *J Inte Dent Medical Res*. 2020; 13: 922-927.