

Comparison of Dentinal Crack Formation With Reciproc, Mtwo and ProTaper Root Canal Preparation Systems

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Abstract

Background: Instrumentation with rotary instruments could potentially cause dentinal cracks possibly leading to tooth fracture. Reciproc files require a single file to finalize the root canal preparation and the effect of this procedure has not been compared with other systems.

Objectives: The aim of this study was to compare the incidence of dentinal micro-cracks following root canal preparations with ProTaper, Mtwo and Reciproc files.

Materials and Methods: In an experimental in vitro trial, 80 maxillary and mandibular first molars were selected and their crowns and distal roots were cut. The roots were then examined to remove any previous cracks and defects. An impression polyether material was used to simulate teeth periodontal ligament (PDL). The teeth were divided to four experimental groups (n=20) and prepared using Reciproc, Mtwo and ProTaper or remained unprepared as a control group. The specimens were then sectioned horizontally on 3, 5 and 9 mm from the apex and number of micro-cracks was determined by stereomicroscope. The incidence of dentinal cracks on different systems or sections were statistically analyzed by means of the chi-square test.

Results: Dentinal defects on 3-mm, 5-mm and 9-mm sections from the apex were noted in 10 (5.6%); 7 (3.9%) and 9 (5.0%) samples of all, respectively. Following canal preparation using Reciproc, ProTaper and Mtwo systems, the defects were observed in 7 (3.9%), 12 (6.7%) and 7 (3.9%) the sections, respectively. No significant differences were observed regarding the defect incidence on the studied instrumentation files or sections.

Conclusions: Regarding the study limitations, dentinal cracks were observed in all files and distances from the apex. Although there was more crack incidence in ProTaper files, no significant differences were noted regarding the studied systems and sections from the apex.

Keywords: Dentinal Cracks, Canal Preparation Systems, ProTaper, Mtwo, Reciproc File Rotary System

1. Background

Root canal treatment consists of proper cleaning and shaping of the canal and a three-dimensional obturation. In these phases, there is the possibility of vertical fracture of the root or development of cracks due to the use of rotational or ultrasonic instruments and particularly when using lateral compaction as an obturation technique (1). These complications are seen during and after endodontic treatment processes. Because root cracks have various types and their development can lead to failure in endodontic treatment or loss of the tooth, it is necessary to diagnose factors involved in its development and efforts should be made to reduce its abundance (2). There is no definitive perspective on whether small dentinal cracks can lead to root fracture (3); however, these damages must

be prevented as much as possible (4-6). Recent studies have shown that there is always a chance of crack formation in the root following the use of Nickel-Titanium (Ni-Ti) rotary files, and its incidence varies between 12% and 60% (7, 8). Recently, an increasing number of rotary (Ni-Ti) instruments have been used for the preparation of root canals during root canal therapy, and despite their numerous benefits compared with hand instruments, they can produce greater stress within the canal (9). This stress is produced due to greater rotation of the instrument within the canal in order to terminate the preparations (4, 10). Considering these factors, it seems there will be more dentinal cracks with the use of these files (4, 11).

ProTaper universal (Dentsply, Maillefer, Switzerland) rotary files are popular files for endodontic treatment with increased taper, thus they have active cutting motion and

ultimately remove more dentin of coronal areas compared to other systems (12). It seems that ProTaper rotary files make more dentinal damages compared to rotary instruments (4).

The Mtwo (VDW Munich: Germany) system was introduced to the market in the recent years. Unlike the majority of other rotary instruments, it is used with a single length method. This file has an S-shaped cross-section with a safe tip. In addition, the Mtwo instruments pitch length increases from the tip of the instrument towards the handle, which has the following functions: avoids screwing in effect and reduces engagement in continuous rotations and reduces the push of debris towards the apex (13).

Recently, preparation of the root canal by a Reciproc file (VDM Munich: Germany) has been raised, which prepares canals with reciprocating motions. In this method, canal preparation is performed by an instrument and so the preparation time will be reduced in comparison with rotary files (14). These files are made from particular Ni-Ti alloys named M-wire that have more flexibility and cyclic fatigue resistance (15-17). Since the motions of these files are 150 degrees in a counterclockwise direction and 30 degrees in the clockwise direction, there is also the possibility of cracks forming by these files. It seems that by using these files, the remaining stress on the tool is released and its reciprocating motion reduces the risk of cyclic fatigue caused by compression and tension (18-20). At the same time, it is possible that during the use of an instrument in full preparation of a canal, there will be more stress during the mechanical preparation compared to preparation of canals by the full sequence protocol. Therefore, dentin damages such as cracks are increased compared to conventional systems, although all these conclusions need further investigation.

2. Objectives

This study aimed to compare the frequency of crack formation after canal preparation with the following three systems, Reciproc, ProTaper and Mtwo.

3. Materials and Methods

In this experimental study the sample size was determined according to related studies (7, 11, 14, 21); 80 mandibular and maxillary first molars of human extracted teeth were selected. Teeth with fracture lines, open apices, anatomic irregularities and previous root treatment were excluded. The selected teeth had curvature in the range of 20 to 30 degrees (according to the Schneider method) and had 4-6 mm and 3-4 mm width in buccolingual and

mesiodistal dimensions in their cemento-enamel junction (CEJ) level, respectively. These teeth were kept in distilled water after selection. After selecting the teeth, the root surfaces were cleaned and specimens were placed in sodium hypochlorite 2.5% for 10 minutes for disinfection.

Distal roots were dissected at 11 mm length using a low speed saw (Isomet, Buehler, Ltd, Evanston: IL, USA) with copious water and inspected under a stereo-microscope and light transmission microscopy at 12x magnification in order to discover and identify any crack or craze line fracture. Working length was determined by placing a size 15 k-type file (Dentsply, Maillefer, Switzerland) within the canal so that its tip can be seen in the area of the apical foramen using 4 x magnifications (Zeiss Stemi SV6, Carl Zeiss, Jena, Germany). Working length was determined by subtraction of 1 mm from its length. The teeth were placed in molten wax at a 10-mm distance of root and after wax cooling teeth were placed in $2 \times 2 \times 2$ cm blocks filled with gypsum (Moldano Blue Heraeus Kulzer, Harau, TM, Germany) in order to simulate the periodontal support. After setting, the teeth were removed and their wax was cleaned and socket washed with warm water and filled with polyether impression material using a syringe (Impregum, Soft, 3M ESPE, Seefeld, Germany). The teeth were placed back in the artificial socket. The excess of impression material was cut with a razor. The teeth were randomly divided to three experimental groups and one control group. In Group 1 ($n = 20$), teeth were prepared by ProTaper Universal (Dentsply, Maillefer, Switzerland) rotary system according to the manufacturer's instructions up to F2 file and using the engine with controlled torque silver (VDW Munich, Germany). Coronal enlargements were done by Sx files, followed by the S1, S2, F1 and F2 files. Each file was used to prepare five Canals. In group 2 ($20 = n$), the teeth were prepared using Mtwo (VDWco, Munich, Germany) rotary system and the same electric motor as Group 1, according to the manufacturer's instructions and up to files 25/ 0.06, and also each file was used to prepare five canals.

In Group 3 ($n = 20$), the teeth were prepared with a single file Reciproc (VDWco, Munich, Germany) system with file 25/0.08 and engine with controlled torque (VDWco, Munich, Germany) silver. Each file was used for three canals. In the teeth of group 4 ($n = 20$), or the control group no preparation was performed on any of the teeth.

In all experimental groups (1, 2 and 3), each canal was irrigated with 1 mL of EDTA 17% (Ariadent, Tehran, Iran) as the final irrigator for 30 seconds. Each canal using 2 mL of diluted 1.5% NaOCl (Bojneh co, Iran) was irrigated between each instrument by using a 27-gauge syringe.

After instrumentation, teeth were taken out of the socket and were washed by current water. Specimens were

sectioned horizontally at 3, 5 and 9 mm from apex using a 0.13-mm saw under water as a coolant (Exact300d, Exact Aparatban, Narderstock, Germany). After cleaning the surfaces, the specimens were analyzed under a stereomicroscope at 40x (Dx50, Olympus).

Each specimen was evaluated by two observers, to check for any cracks. In case of a lack of craze line on root dentin in the internal or external surfaces of the root or root canal wall surfaces, the specimen was categorized in the 'no crack' group. Moreover, if craze lines were detected in the root canal dentin, the specimens were categorized in 'with crack' groups. All 60 specimens of tooth section in different groups were evaluated and frequency of incidence of cracks in different areas was reported as numbers and percentages. The operators were blind to the specimens, and specimens were re-evaluated if they disagreed. Data were analyzed by the SPSS-16 software. With different systems and in different coronal, middle and apical cuts from the anatomic apex of the tooth, the number and percentage of dentinal cracks in the preparation was determined and reported. The difference in the frequency of incidence of cracks in different groups from a variety of preparation systems and different sections of the apex were statistically analyzed using the chi-square test. Also, in each preparation system, two by two comparisons between the apical, median and coronal sections, and also in each of the cuts, two by two comparisons between the ProTaper, Reciproc and Mtwo preparation systems were carried out with the chi-square test. Type I error rate in this study was determined as 0.05.

4. Results

In this study, 20 teeth (60 sections) using Reciproc, 20 teeth (60 sections) with ProTaper system and 20 teeth (60 sections) using Mtwo system were prepared and evaluated for the presence of micro-cracks. Also, in each of the systems, 20 sections at 3 mm from apex, 20 sections at 5 mm from apex and 20 samples at 9 mm from tooth apex were evaluated. According to the research results, dentine cracks were seen at 3-mm apical sections in ten samples (5.6%), at 5-mm median sections in seven samples (3.9%) and at 9-mm sections in coronal of nine samples (5%) and no crack was found in 50 (27.8%), 53 (29.4%) and 51 (28.3%) sections, respectively (Table 1). Chi-square tests showed no significant differences in the frequency of cracks at 3, 5 and 9 mm sections from apex ($P = 0.73$). Overall, 180 prepared sections were studied by three systems; 26 (4/14%) were cracked and 154 (6/85%) were not.

In the Reciproc, ProTaper and Mtwo files, dentinal crack was observed in seven (3.9%), twelve (6.7%) and seven (3.9%) sections, respectively. In these groups cracks were

not observed in 53 (29.4%), 48 (26.7%) and 53 (29.4%) sections, respectively (Table 2). Chi-square test showed that there was no significant difference in terms of dentinal crack incidence based on the type of preparation systems ($P = 0.32$). However, with regards to the control group, significant differences were observed for the incidence of cracks in different groups ($P < 0.05$).

In the study of joint relationship between systems of preparation and different sectioning types of the apex using Logistic test, Reciproc system and 3-mm apical sections from apex were considered as a reference and the other groups were compared with them (Table 3). According to Logistic test results, there was no significant association between the incidence of cracks and preparation systems with different sectioning, in other words, the detection position of the apex ($43/0 = P$, $67/0 = OR$) and the type of preparation ($25/0 = P$, $89/1 = OR$) has no effect on the anticipation of incidence of cracks.

Comparison of the results of dentin defects in two by two preparation systems at various stages is provided in Tables 4-6. No significant differences were observed in none of the comparisons in terms of crack incidence when comparing two by two of systems in the apical, median and coronal sections.

5. Discussion

According to the results of this study, the incidence of cracks was observed in all studied preparation systems and in apical, median and coronal sections from the apex, with no relationship with the anatomical location of the apex or the system. Overall, in the groups of Reciproc, ProTaper and Mtwo files, dentinal crack was observed in seven (9/3%), twelve (7/6%) and seven (9/3%) roots, respectively. Despite the larger number of dentinal crack incidence in ProTaper preparation system, there was no significant difference. On the other hand, dentinal cracks were observed in 3, 5 and 9 mm apical, middle and coronal sections from the anatomic apex, and in 6.5%, 9.3% and 5% of the specimens. In the study of Milani *et al.* (2012) the number of damages in 3 and 6 mm sections and the frequency of surface cracks in these sections had no obvious difference, thus this report is consistent with the results of our study, despite the fact that in the current study, sections were created at 6 mm from apex (8). In addition, Burklein *et al.* (2013) investigated the incidence of dentin cracks after root canal preparation by rotary files and Reciproc, and observed no significant difference in the incidence of damage in various sections (3, 6 and 9 mm) (21). Previous studies have shown that dentinal crack can be associated with system of preparation and canals filling method, and currently there is no complete prevention of these types of damages (4,

Table 1. Distribution of Dentinal Cracks in 3- (Apical), 5- (Median) and 9-mm (Coronal) Sections From the Apex in All Samples^a

Crack	Sections			
	3-mm Apical	5-mm Median	9-mm Coronal	Total
Absence of cracks	50 (27.8)	53 (29.4)	51 (28.3)	154 (85.6)
Presence of crack	10 (5.6)	7 (3.9)	9 (5)	26 (14.4)
Total	60 (33.3)	60 (33.3)	60 (33.3)	180 (100)

^aValues are presented as NO. (%).

Table 2. Distribution of Dentinal Cracks in Reciproc, ProTaper, Mtwo Preparation Systems and Control Group^a

Crack	Cuts				Total
	Recipro	ProTaper	Mtwo	Control	
Absence of cracks	53 (29.4)	48 (26.7)	53 (29.4)	30 (14.3)	184 (87.6)
Presence of crack	7 (3.9)	12 (6.7)	7 (3.9)	0	26 (12.4)
Total	60 (33.3)	60 (33.3)	60 (33.3)	30 (14.3)	210 (100)

^aValues are presented as NO. (%).

Table 3. Logistic Test Results in the Investigation of Dentinal Crack Incidence in Different Systems and Sections

	B	S.E	Wald	df	P Value	Odds Ratio (OR)	CI 95% for OR	
							Down	Up
3 mm apical			0.632	2	0.729			
5 mm median	-0.42	0.534	0.619	1	0.432	0.657	0.231	1.871
9 mm coronal	-0.127	0.504	0.063	1	0.801	0.881	0.328	2.366
Recipro system			2.208	2	0.332			
ProTaper system	0.641	0.517	1.537	1	0.215	1.897	0.689	5.223
Mtwo system	0	0.57	0	1	1	1	0.327	3.054
Constant coefficient	-1.854	0.487	14.49	1	0	0.157		

5). The difference between the various root canal preparation instruments in terms of dentinal cracks can be associated with preparation techniques and the cross sectional design of files. Mtwo and Reciproc preparation systems have S-shaped cross-sectional design and their cutting tips are extremely sharp, while the ProTaper system has a triangular cross-section and lower cutting performance and also it has limited filings space (14). High cutting ability is usually associated with increased cleaning efficiency (22, 23). Reciprocating motions can also increase the movement of debris towards the apex (24), and there is a possibility of increasing torsional forces following these motions. It seems that the effects of increased torsional forces along the sharp tips, as with reciproc files, can be effective in the formation of dentinal cracks. Bier et al. (2009) investigated the ability of Ni-Ti rotary instruments in cracks

formation in the root canal preparation process (4). In the study of Yoldas et al. (2012), as well as the current study, no significant differences were observed regarding the number of dentinal cracks following preparation with four rotary files, including Twisted File, Revo-S, HERO shaper and ProTaper (60%, 25%, 40% and 30%) (7). In this study, molar teeth were used, as like our study PDL was simulated but performed with a different method.

In one study, Burklein and colleagues (2013) showed that preparation with the Reciproc files led to more complete cracks compared to Mtwo and Reciproc files, and at apical surfaces (3mm), reciprocating instruments led to more incomplete cracks compared to Mtwo and ProTaper rotary files; thus cracks were not considered as complete or incomplete (21). In the study of Burklein, unlike the present study, central mandibular teeth were used and

Table 4. Comparison of the Distribution Frequency of Dentinal Cracks Two by Two in the Reciproc, ProTaper and Mtwo Preparation Systems in 3-mm Apical Sections From the Apex^a

System	Crack		P Value
	Absence of Cracks	Presence of Crack	
Reciproc	18 (45)	2 (5)	0.11
ProTaper	14 (35)	6 (15)	
Reciproc	18 (45)	2 (5)	1
Mtwo	18 (45)	2 (5)	
ProTaper	14 (35)	6 (15)	0.11
Mtwo	18 (45)	2 (5)	

^aValues are presented as NO. (%).

Table 5. Comparison of Two by Two Distribution Frequency of the Dentinal Cracks in Reciproc, ProTaper and Mtwo Preparation Systems With 5-mm Median Sections^a

System	Crack		P Value
	Absence of cracks	Presence of crack	
Reciproc	18 (45)	2 (5)	0.63
ProTaper	17 (42.5)	3 (7.5)	
Reciproc	18 (45)	2 (5)	1
Mtwo	18 (45)	2 (5)	
ProTaper	17 (42.5)	3 (7.5)	0.63
Mtwo	18 (45)	2 (5)	

^aValues are presented as NO. (%).

Table 6. Comparison of Two by Two Distribution Frequency of Dentinal Cracks in Reciproc, ProTaper and Mtwo Preparation Systems With 9-mm Coronal Sections^a

System	Crack		P Value
	Absence of Cracks	Presence of Crack	
Reciproc	17 (42.5)	3 (7.5)	1
ProTaper	17 (42.5)	3 (7.5)	
Reciproc	17 (42.5)	3 (7.5)	1
Mtwo	17 (42.5)	3 (7.5)	
ProTaper	17 (42.5)	3 (7.5)	1
Mtwo	17 (42.5)	3 (7.5)	

^aValues are presented as NO. (%).

master apical file was also different from the present study, so that in the Reciproc file, the master file was R40, which had 0.06 convergence, in ProTaper f4 file convergence was 06/0, and in Mtwo 40.04 was used as a master apical file, which obviously produces more stress on the root canal and this may explain the difference between these results and those of the current study. On the other hand, Liu and colleagues (2013), compared the frequency of cracks

incidence following the use of three single-file OneShape, Reciproc and SAF systems with the ProTaper system and the reported incidence of cracks in the ProTaper was 50%, OneShape 35% and Reciproc 5% (25). In a recent study, the experimental group difference was significant in this regard thus the findings were not consistent with the current study. The only similarity between the present study and this recent study was finding more dentin damage fre-

quency in preparation with the ProTaper system. Liu and colleagues (2013) reported that 25% of cracks forming in the roots were prepared with the ProTaper system in apical regions (26). Jalali et al. (2015) in a similar study concluded that the frequency of crack incidence following preparation with Mtwo and ProTaper files is significantly higher than the prepared tooth with Reciproc files, however this study was conducted on mandibular premolars, which can be a reason for the differences in results between this study and the present study (27). In the study of Ustun and colleagues (2015), the incidence of dentinal crack was compared between handmade K file, ProTaper universal, ProTaper next, and Reciproc systems. In this study ProTaper universal and ProTaper next systems caused more cracks than Reciproc systems, which corresponds with the data of this study (28).

Reviewing of various studies indicates that the ProTaper system causes more dentinal damage. In the ProTaper system, finishing files have been used to prepare the apical areas and due to larger taper of apical finishing files in this system (up to about 0.09 mm), more stress is generated on the canal dentinal walls compared to other system (4) that may cause a crack. Although today many rotary systems are used with the crown-down method, ProTaper files have been used with single length techniques (29) and at the same time, some research results have shown increased crack incidence following preparation with the crown-down technique in the rotary system (5, 11, 30). However, the effects of single length preparation techniques in the development of dentinal cracks still remain unknown.

There are no definitive conclusions about the clinical outcomes of dentine damages during long-term periods (31, 32). Also, it is not clear if incomplete cracks or craze lines can lead to complete cracks and vertical fractures of the root following root canal treatments. In addition, the role of therapeutic processes such as canal preparation or second treatments (3), and applying masticatory forces, as well as occlusal loading (33), as factors involved in dentinal cracks or fracture forming, still have not been investigated. Obviously, fractures can develop in teeth even without having root canal treatment (1). Also, no reasonable relationship was observed between the obtained results in experimental studies and clinical conditions for the incidence of cracks. Despite the efforts made under laboratory conditions to make the situation similar to clinical conditions, yet elimination of the differences and discrepancies in the two groups seem to be impossible as cracks may be out of section areas. Hence, external conditions still affect the findings of various researches. Specimens maintenance and the number of samples before, during and after preparation may also be effective on the results, especially when the mechanical properties of the specimens are examined.

Sectioning techniques used in present study allowed us to investigate the effects of root canal treatment on dentin by direct observation. These processes have been adopted in previous studies (4, 21). However, other methods such as computation of distributed stresses, direct observation of damages in teeth sections and resistance of teeth with root therapy have been used for this purpose (34-37). Regarding the method used in this study, no external force was applied and the effects of the preparation of root canal at canal walls and adjacent dentin were observed directly. In the present study, the roots were sectioned 3 mm, 5 mm and 9 mm from the anatomic apex and dentin crack incidence was assessed in them. The reason for 5-mm sections in this study was that the canal curve usually starts at 5 mm from apex (1). On the other hand, in present study molars were used, which was because of more linear fractures of roots in these teeth (1, 38). In previous research, mostly single-rooted teeth were used for evaluation of dentin damages. In the present study, multi-root teeth, especially the mesial root of lower first molar and maxillary mesiobuccal root were used, which are at a higher risk of strip perforation due to the anatomical issues. Also it has been suggested that most teeth with fracture development, are mandible and maxilla first molars (38). Periodontal ligament because of its viscoelastic properties plays a major role in distributing stress in the teeth. Therefore, PDL simulation has always been considered in studies that examined the effects of applied forces in crack forming and fracture strength, including the present study. In the present study, the polyether impression material was used to simulate the periodontal ligament (8, 39). Despite previous research, further studies are still needed to evaluate the results of reciprocating motions during root canal preparation and evaluation of factors involved in this field of treatment outcomes.

5.1. Conclusion

According to the limitation of this in vitro study and its confiding factors, dentin cracks have been found in preparations with different systems and at different distances from the anatomic apex and despite their higher frequency with the ProTaper system, in this regard there was no significant differences between these systems or different sections of the anatomic apex.

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