In-vitro Comparison of NiTi Tee, RaCe and Protaper Instruments in Dentinal Crack Formation

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Abstract

Background and Aim: Root canal preparation with rotary instruments may cause dentinal cracks leading to tooth fracture. The aim of this study was to compare three different rotary systems ProTaper, RaCe and Niti Tee on formation of dentinal cracks following root canal preparation. **Materials and Methods:** In this experimental study, 50 extracted mandibular first molars were selected. Teeth having roots with previous cracks and defects were excluded from the study. The crowns and distal roots of teeth were cut. Silicon impression material was used to simulate tooth PDL. The mesial roots were randomly prepared using ProTaper (up to F3) RaCe and Niti Tee systems (up to ≠30/0.06) in three groups of 15. Five teeth remained unprepared as the control group. The specimens were then sectioned horizontally in 3, 5 and 9 mm distances from the apex. Cracks exploration was done by digital stereomicroscope. The occurrence of dentinal cracks with different systems were statistically analyzed by chi-square test. **Results:** Dentinal defects were observed in 3 (20%), 4 (26.7%) and 2 (13.3) of root canals following the preparation with ProTaper, Niti Tee and RaCe files, respectively. Two of the 3 defects in protaper group were as complete crack. The overall incidence of crack among the rotary files was 20%. No significant differences were found in defect formation between the three rotary systems (P>0.05). **Conclusion:** Under the condituion of this study Dentinal cracks were observed in all systems. The overall incidence of crack among the rotary files was 20%. Although more cracks were observed in NTiTee group, the differences were not significant.

Key words: Dentinal crack, root canal preparation, rotary instrumentation system, NiTi Tee, Protaper, RaCe.

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Introduction

Endodontic procedures require adequate cleansing and shaping and an acceptable three dimensional obturation of root canal systems. Vertical root fracture and cracks may appear after canal enlargement, filling especially lateral compaction , post space preparation, retreatment and ultrasonic instruments (1).

These consequences have seen during and after root canal therapies and may finally lead to treatment failures or even tooth loss (1). Therefore, early diagnosis of predisposing factors and efforts to reduce their incidence is necessary. Numerous studies have reported that root canal preparation with nickel-titanium (NiTi) rotary instruments leads to crack formation in root dentin(2-4). Rundquist showed that cracks originate from the apical third (5).

Cracks or craze lines may initiate from the external surface of root without extending into the root canal lumen, or they may extend from inside the canal toward the outer surface, without reaching it. Alternatively, they may extend from the most inner to the most outer surface and make a connection between pulp and periodontal ligament (6). Occurrence of such lesions should be prevented as far as possible.

ProTaper files are well known rotary instruments with Convex Triangular *Cross Section* that performed well in different studies with regard to shaping ability (9, 10).

RaCe instruments with a triangular cross-sectional design and alternating cutting edges (straight sector varies with twisted sector) are claimed to prevent from screwing the instrument into the root canal thus reducing intraoperative torque values (11).

Because of their increased tapering, their active cutting movements are facilitated and thus more dentin is removed in coronal areas in comparison to other rotary systems and maintained the original canal curvature more than ProTaper (12).

NiTi Tee instruments consist of six Ni-Ti files (Coronal Shaper, K-type and five files with a modified S-profile) with varying tapers for use with the crown down method. Like most rotary instruments is a rounded noncutting tip with S-type flute design that is characterized by two 90° cutting edges with no radial lands. Flutes at base are twice the size of flutes at the tip.

This three NiTi root canal instruments represent three different cross-sectional designs with large variations in the depth of the flute; apply in crown down technique (13).

Hyeon-Cheol Kim showed that stiffer file designs generated higher stress concentrations in the apical root dentin during preparation of the curved canal, which increases the risk of dentinal defects. Thus, stress levels during shaping and fracture susceptibility after shaping vary with instrument design (14).

Also the final apical preparation size is an important factor in root canal cleanliness. However, enlargement of the apical region with larger instruments may cause excessive crack formation and root canal transportation. There is currently no consensus on the optimum final apical preparation size (15) Several studies have examined and compared the crack formation in various Rotary, Recircal and Hand preparation systems (3, 8, 9, 16, 17). They claimed that the tip design, cross-section geometry, constant or progressive taper type, constant or variable pitch, and flute form might also contributed to defect formation. Yoldas et al reported the fracture rates up to 60%. The relatively low flexibility of the rotary files and repeated instrumentation of the roots reported the two reasons for the high degree of crack formation in this study (8).

To our knowledge, no studies have been performed to evaluate dentinal cracks that may cause by three multi rotary files with the same number of files and the same application method but various cross sections. Thus the aim of this study was to compare the Niti Tee, RaCe and Protaper instruments on dentinal crack formation after root canal preparation of mesial roots of mandibular molars.

Material and methods

In this in vitro study, 50 extracted first mandibular molars were selected.

The inclusion criteria were mandibular molars with roots of 0-20 degrees of curvature. The teeth were examined radiographically and molars with previous dental treatment, open apex or root resorption and severe anatomic variation were excluded from the study.

Root surfaces were cleaned from calculus and tissue remnants and disinfected in NaOCl 2.5% (Bojneh Co. Iran) by 1 minute immersion. After disinfection, the teeth were kept in normal saline.

The distal roots of the specimen were cut at a 11mm distance from the apex by a low speed saw (Isomet, Buehler, Ltd, Evanston: IL, USA) accompanied by water spray as coolant. The roots were observed by stereomicroscopy and light transmission by 12-fold magnification to detect any possible cracks or defects. Defective teeth were excluded from the study and replaced by sound molar roots.

The working length was determined by a K-file #15 (Dentsply, Maillefer, Switzerland) . The file was introduced into the canal until the tip could be seen through the apical foramen. Working length was established by 1mm reduction from the acquired length.

To simulate PDL, the silicon impresion material (Colten Whaledent AG Altsatten Switzerland) was used

so that 10 mm of the roots were placed in 5 × 5 puty blocks (Altsatten Switzerland).

The roots were randomly divided into three experimental groups of 15 and one control group of 5 teeth.

In group 1, the roots were prepared by ProTaper universal rotary system (Densply Maillefer. ballaigous. Switzerland) coupled with reduction gear rotary handpiece driven by electric torque device (VDW co, Munich, Germany) according to manufacturer's instruction up to F3 (30/0.09) file. Sx file and then S1 and S2 were initially used with 300 rpm and 3 N/cm torque for flaring the coronal portion. Then, F1, F2 and F3 were used to the working length with a gentle apical pressure. Each file was used for preparation of 3 canals.

In group 2, roots were prepared with RaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland) rotary system using an electric motor with torque control (VDWco, Munich, Germany) according to the manufacturer's instructions with 600 rpm and 2N/cm as follow: ≠10/0.04, ≠35/0.08, ≠25/0.06, ≠25/0.04, ≠25/0.06 and ≠30/0.06. Each file was used for preparation of three canals.

In Group 3, mesial roots were prepared by NiTi ee (Sjöding Sendoline, Kista, Sweden) file system according to manufacure's instruction with 300 rpm and 2N/cm torque as follow; first #30/0.08 used for preflaring of the coronal and middle of the canal and creating a straight line access, Then #30/0.06 to 2/3 of working length, #30/0.04 to apical one-third, #25/0.04 to the working length, and then #20/0.04, #25/0.04 and #30/0.04 and finally #30/0.06 were used for apical enlargement. Each file was used for preparation of three canals.

In group 4 (control group) the tooth left unprepared.

During preparation, each canal were intermittently cleansed by sodium hypochlorite 2.5% (Bojneh Co. Iran), with a 27 gauge needle.

As final irrigation in all experimental groups (1, 2 and 3) 1 ml of EDTA 17% (Ariadent, Tehran, Iran) for 30 seconds and 5.25% sodium hypochlorite were used for removal of smear layer.

After instrumentation, the teeth were removed from the simulated block and washed with tap water. The Samples were cut horizontally At 3, 5 and 9 mm distances from the apex using a low spead saw (Isomet:BuehlerLtd.Lake Bluff.IL) of 0.13 mm thickness and water spray as coolant. After cleansing the surface, the samples were examined with a digtal stereomicroscope (BX43, Olympus) at a 40X magnification and the images were taken. Samples were evaluated by 2 observers to assess presence of any microcracks.

The samples were placed in "no crack" group, in the lack of any craze lines or microcracks either at the external surface of the root or at the internal surface of the root canal wall toward dentin. ''crack group'' was defined if any craze lines, microcracks, or fractures were present in root dentin.

All 50 specimens were assessed and the incidence of cracks on dentin was reported in number and percentage. The operators were blind to the grouping of samples. In cases of disagreement between observers, the samples were re-evaluated so that consensus was acquired.

Chi-Square test was used to find significant differences in crack incidence between the study groups.

Results

In this study, 50 teeth were prepared by Protaper, RaCe and NiTiTee rotary systems in equal groups of 15. Cross sections were evaluated for presence of microcracks. Also, in each system, 45 cuts were evaluated in 15 teeth at 3 mm, 5 mm and 9 mm distance from the apical region. No crack was observed in the control group. There was no defect in any of the groups at 3 mm sections in this study.

Dentinal defects were observed in 3 samples (20%) of Protaper group that two cases of them were as complete crack (figure 1), 2 samples (13.3%) of RaCe group and 4 samples (26.7%) of NiTi Tee group.

Chi-square and Kruskal Wallis test showed no significant differences in the frequency of cracks at 3, 5 and 9 mm sections from apex between three experimental groups (P=0.76). Of total of 135 sections in three rotary systems, the defects were observed in 9 samples (20 %).

Comparisons between Protaper, RaCe and NiTiTee rotary systems in producing dentinal defects are shown in table 1.

Figure 1. Microscopic view of complete crack in the dentinal wall

Table 1. Distribution of dentinal defects in different root canal preparation systems

System / defect	Protaper	RaCe	NiTiTee	Total	Kruskal-Wallis
Without defect	12 (80%)	13(86.7%)	11(73.3%)	36(80%)	
With defect	3 *(0, 1,2)	2 *(0,0,2)	4 *(0,2,2)	9(20%)	P Value= 0.76
total	15(33.3%)	15(33.3%)	15(33.3%)	45(100%)	

***** The numbers in parenthesis denote the number of teeth with cracks in 3, 5 and 9-mm sections, respectively

Discussion

In this in vitro study the occurrence of dentin defect created by three rotary preparation systems were compared. Cutting techniques as an inexpensive and easy method used in the present study provided the opportunity to evaluate the effects of root canal preparation on root dentin through direct observation under magnification. These techniques have been adopted in previous studies (3, 18). Other methods such as CBCT, a noninvasive method that capable of providing clear imaging of cracks including information on penetration depth in clinical condition and the calculation of stress distribution, and resistance of endodontically treated teeth to fracture in ex vivo enviroment, have also been used for this purpose (19-21), Ultrasound that is capable of imaging cracks in simulated tooth structure could pose an important diagnostic aid in the future (22).

According to the present study, occurrence of microcracks was observed in all preparation systems. There was no relationship between frequency of cracks and the type of preparation systems. Dentinal defects were observed in 3 (20 %), 2 (13.3%) and 4(26.7%) specimens of Protaper, RaCe and NiTi Tee systems, respectively. Despite the higher number of microcracks in NiTi Tee system, there were no significant differences between groups in terms of frequency. Also, the pattern of defects in 2 of 3 in protaper group was as complete crack.

The study by Salem Milani *et al* , showed that the number of defects and also the frequency of surface cracks of Protaper and Hand instrumentation do not have significant differences and dentinal defects were reported in the 21% protaper (9) This finding is consistent with the present study

Similarly, Burklein *et al* did not find any significant differences in incidence of dentinal defects after root canal preparation by Rotary and Reciprocal motion in any of the sections (3).

Previous studies have shown that dentinal defects may be related to the type of preparation systems and methods of sealing the root canals; so far, there has been no way to prevent these types of defects (18, 23).

The differences between root canal preparation instruments in creating dentinal defects may be related to preparation techniques and the cross-sectional design of the files. RaCe system has a triangular and NiTi Tee has S-shaped cross sectional design and both systems have extremely sharp cut end. While Protaper files have a convex triangular cross section with less cutting efficacy and smaller space for accumulation of dentin debris (24).

Due to the grater taper in the tip region and more friction with the canal walls of protaper system, there is possible that more force is imposed on dentinal wall and larger amount of dentin removes that causes weakness of the tooth structure. In the study by Yoldas *et al*, no significant differences were observed in number of defects in dentin after preparation with 4 rotary systems, HERO shaper, Revo-S, Twisted File and Protaper (60%, 25%, 40% and 30% respectively) (8).

In a study by Bier *et al*, the ability of nickel-titanium rotary instruments to make dentinal damage was reviewed. This study showed that the crack lines and microcracks occurred in 4% of cases following use of Protaper systems(18) while in the present study, the total incidence of crack is 20%

The reason for this difference can be attributed to the selection of premolar teeth in mentioned study which intrinsically have wide canals and the file is less involved with the canal walls.

Studies that compared rotary and manual files found that total fracture in rotary systems are more than manual systems (16, 17).

This higher incidence could be related to the higher taper of rotary systems, which is greater than manual files, and can therefore be a factor in the occurrence of dentin fractures; Furthermore, significantly more rotations in the canal which are necessary to complete the preparation with rotary NiTi files as compared with hand files, which may be a promoting factor for crack formation (18, 24).

The occurrence of microcracks in Liu et al. study were reported 50% for Protaper, 35% for OneShape, and 5% for Reciproc (25) Unlike the present study the differences were statistically significant. Liu et al, in another study Reported that apical dentinal detachment

developed in 2.5% with hand files and 21.9% with rotary files. Significantly, less cracks and detachments occurred when instrumentation with rotary files was terminated short of AF, as compared with that terminated at or beyond AF (17).

Burklein reported that the total incidence of complete and incomplete cracks with 4 rotary and reciprocal systems was 25.4%. Mandibular incisors were used in the mentioned Study and master files ≠ R40 with a 0.06% taper in Reciproc system and F4 in Protaper system and 40/04 in Mtwo system were used. Clearly, greater apical preparation imposes more stress to root canal walls and this may explain the higher incidence of dentinal defects. Similarly, in the present study apical preparation of apical foramen was F3 (30/0.09) for protaper and ≠30/0.06 for RaCe and NiTi Tee systems in mesial mandibular roots, increasing the apical size of the canal especially in protaper system can impact on creation and extension of dentinal defects.

Because of the greater apical tapering of finishing files in this study, much more stress is imposed to dentinal walls (18). Sathorn et al. concluded that by maintaining the canal size as small as practical, a reduction in fracture susceptibility could be expected (26).

The incidence of dentinal defects in addition to the apical size may depends on the preparation techniques and the cross-sectional design of the instruments.

All rotary files in the present study were applied with the crown-down technique. The results of some studies showed an increase in the crack propagation in crown-down preparation technique (23, 27). However, the effect of single length preparation technique in occurrence of cracks still remains unknown.

No reasonable association has been found between the results of in-vitro studies and clinical conditions regarding microcrack formation. Despite the efforts made to simulate the clinical conditions in in-vitro studies, complete elimination of differences seems impossible as the cracks may exist in areas between the section cuts. Hence, the effects of external factors on the results of several studies still continue to exist. Forces induced during extraction procedures, storage conditions, dentin thickness and number of the samples may also affect the results; in particular, the mechanical properties of the samples that is the subject of debate.

The uniformed tapered preparation and the same number of files was attempted in all groups. Molar teeth were used in this study because of the higher incidence of longitudinal root fracture of these teeth (28) as reported in previous studies. Formerly, single rooted teeth were often used for the study of dentinal defects. In this study, the mesial roots of the lower first molar were used. These roots, anatomically have the higher risk of strip perforation. Also, the mentioned teeth were identified to be more prone to fracture (28).

Under the condition of this study, the incidence of microcracks with protaper, RaCe and NiTi Tee rotary systems are relatively high and have no significant differences in different systems. Further studies are still needed to evaluate the effects of different apical preparation size, reciprocating motion during root canal preparation, and confounding factors in this area to the outcome of treatment.

Conclusion

Dentinal cracks were observed in different preparation systems and at different distances from the anatomic apex. Despite the higher frequency of dentinal cracks in NiTi Tee system, there were no significant differences between different systems or various distances from the apex.

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