Original Article

Evaluation of apical crack formation associated with root canal preparation with ProTaper Next, ProTaper Gold, and TruNatomy systems

N Neslihan Yilmaz Çirakoglu, Yağiz Özbay

Department of Endodontics, Faculty of Dentistry, Karabük University, Karabük, Turkey

ABSTRACT

Aim: The present study aimed to evaluate and compare the microcrack formation in apical root dentin as a result of root canal preparation with different nickel–titanium (NiTi) rotary systems.

Materials and Methods: Sixty extracted mandibular premolar teeth with single canals were used. Apical 1 mm of roots was flattened perpendicular to the tooth axis. Forty-five teeth were prepared using ProTaper Next (PTN), ProTaper Gold (PTG), or TruNatomy files. Fifteen teeth were left unprepared as the negative control group. Images of apical surfaces of roots were obtained using a stereomicroscope at 20 magnification. The presence of microcracks was noted with the help of the images. The data were analyzed with a Chi-square test using MiniTab 17 Statistical Software.

Results: There was a statistically significant difference between the PTN and TruNatomy groups ($P < 0.05$). There was no statistically significant difference between the PTG group and other groups ($P > 0.05$).

Conclusion: Whereas all rotary files created microcracks in the apical root dentin, TRN caused fewer microcracks than other NiTi rotary systems.

Keywords: Apical microcrack, ProTaper Gold, ProTaper Next, root canal preparation, TruNatomy

INTRODUCTION

The fundamental steps of root canal therapy are shaping the root canals chemomechanical and complete obturation. On the other hand, preparation steps may weaken the tooth structure and induce the creation of crack lines and microcracks.[1] As a result of forces provoked by dental treatments and occlusal loads, these crack bands and microcracks can result in root fractures. Root fractures are clinical difficulties that potentially lead to endodontic treatment failure.[2]

As well as several advantages of nickel–titanium (NiTi) rotary file systems, NiTi files have been demonstrated to have certain disadvantages, such as causing dentinal defects during root canal shaping.[3] Many articles have stated the causative effect of microcrack formation on vertical root fractures and the impact of the preparation with NiTi file systems in creating these microcracks.[4-6]

ProTaper Next (PTN) (Dentsply Maillefer, Ballaigues, Switzerland) NiTi files have an off-centered rectangular conception and progressive and regressive tapers. Variation in tapers minimizes the contact between file and dentin, which reduces the impact of the screw and taper lock.[7] On the other hand, the offset

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Address for correspondence: Dr. N Neslihan Yılmaz Çirakoglu
Department of Endodontics, Faculty of Dentistry, Karabük University, Karabük, Turkey.
E-mail: neslihanyilmazcirakoglu@karabuk.edu.tr

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design provides better debris removal from root canals than a file with a centered mass and axis of rotation.[8]

ProTaper Gold (PTG) (Dentsply Maillefer, Ballaigues, Switzerland) works by continuous rotation motion. It has an alterable advanced taper, rotary motion, and a convex triangular cross-section. It was suggested that PTG has a gradually tapered pattern for more decisive and safer cutting motion and statedly better flexibility and resistance to cyclic fatigue.[9]

Lately, TruNatomy (TRN; Dentsply Maillefer, Ballaigues, Switzerland) was introduced with distinctive slip shaping, allowing for a larger debridement area. The manufacturer declared that TRN instruments have increased flexibility and cyclic fatigue strength by virtue of the characteristic heat procedure with a characteristic pattern. TRN has an off-centered parallelogram cross-section design.[10] It has been argued that TRN instruments maintain the remaining dentine and tooth intactness due to the instrument design, regressive tapers, and the thinned design, along with the heat treatment of the NiTi alloy.[10,11] Microcrack formation in apical dentin after shaping root canals using TruNatomy rotary has not been evaluated yet. Therefore, the purpose of this *in vitro* research was to assess the prevalence of crack formation in apical dentin after root canal preparation using PTN, PTG, and TRN instruments.

MATERIALS AND METHODS

Materials and specimen preparation

Ethical approval for the study was obtained from the Ethics Committee of Non-Interventional Clinical Research (2020/208). A total of 60 freshly extracted human mandibular premolars with single canals were stored. The teeth were decoronated from the cementoenamel junction to determine the root length to 14 mm for all teeth. Teeth with internal or external root resorption, immature roots, calcification, cracks or fractures, previously initiated root canal treatment, deviated apical foramen, or root canal curvature more than 10° were not included in the study. Exclusion criteria were implemented after radiographs were taken in the mesiodistal and buccolingual directions. After removing the root surfaces, samples were immersed and stored in the physiological saline solution until the experiment.

The root surfaces were covered with aluminum foil before immersing in acrylic resin (Imicryl, Konya, Turkey), similarly with the other studies.[12,13] The teeth were removed from the resin after the acrylic resin had hardened. Then, the foils were taken out. The resin blocks were filled with a silicone impression material (Express XT Light Body Quick, 3M ESPE, Seefeld, Germany) to mimic the periodontal ligament, and the specimens were placed back to the resin blocks. To capture images from the apical area, the apical 4 mm of the root was not covered. Apical 1 mm of roots was flattened perpendicular to the tooth axis using abrasive paper and polished using waterproof silicon carbide abrasive paper to ensure a smooth surface for obtaining high-quality images. The apical thirds of the roots were immersed in water during the experiments to avoid dehydration.[14] Randomly 15 teeth were assigned in the negative control group.

Root canal preparation

Forty-five teeth were randomly divided into three experimental groups ($n = 15$) according to the rotary file set. The working length (WL) was set as 1 mm short of the length that the tip of a 10 K-file could be seen from the apical foramen. The root canal preparation of each specimen was completed with 20 mL of 1% NaOCl by a single operator to eliminate biases. Each tooth was prepared with a new set of files.

Group 1: PTN files were used in the sequence of X1 (size 17, 0.04 v) and X2 (size 25, 0.06 v) with a gentle in-and-out brushing motion until resistance was felt in the canal. After withdrawal from the canal, files were cleaned and checked before reuse.

Group 2: PTG Sx (size 19, 0.04 v), S1 (size 18, 0.02 taper), S2 (size 20, 0.04 v), F1 file (size 20, 0.07 v), and F2 file (size 25, 0.08 v) were used with slightly in-and-out movement.

Group 3: TruNatomy Orifice Modifier (size 20, 0.08 v), Glider (size 17, 0.02 v), Small (size 20, 0.04 v), and Prime (size 26, 0.04 v) files were used with 2–3 gentle approximately 2–5 mm length in-and-out motion in the canal. Every file was replaced with the next file upon reaching the length to avoid over-enlargement.

Stereomicroscopic examination

The apical root tip was then evaluated under a stereomicroscope at 20X (OLYMPUS S2 × 12, Tokyo, Japan), and their digital images were captured. Each image was evaluated by two researchers who were blinded to the group assignment. If any lines, microcracks, or fractures were identified, the specimens were defined as "with crack," and "no crack" was defined as the absence of craze lines, microcracks on the external or internal surface of the root [Figure 1].[15]

Statistical analysis

Pearson's Chi-square test was used in the intergroup statistical analysis of the prevalence of dentinal defects. Inter-examiner reliability was calculated by Cohen's kappa

test. The level of statistical significance was set to 5%. All the statistical analyses were performed using MiniTab 17 Statistical Software (Minitab Inc., USA).

RESULTS

The interobserver agreement was 94% for microcrack formation (kappa test). The number of microcracks is shown in Table 1. No apical cracks were observed on baseline images. The highest number of cracks was observed in the PTN group, whereas the lowest number of cracks was observed in the TRN group [Figure 2]. There was a statistically significant difference between the PTN group and the TRN group ($P = 0.025$). There was no statistically significant difference between the PTG group and other groups ($P > 0.05$) [Table 2].

DISCUSSION

The contacts between the instrument and root canal walls can concentrate transient stress in the root dentin during root canal treatment. Hence, importance is laid to ensure minimal iatrogenic harm to the root dentin during endodontic treatment procedures, thus improving the prognosis of the tooth.

The present study investigated the effect of PTN, PTG, and TruNatomy NiTi systems on dentinal apical microcrack formation of mandibular premolars using the stereomicroscopic examination. Our results showed more apical cracks with PTN rotary file systems than PTG and TruNatomy systems. This result was compatible with the studies that demonstrated that PTN rotary files were associated with more apical crack formation than the PTG system.[16,17] Furthermore, TruNatomy system produced the least number of cracks compared to PTN and PTG. However, apical crack formation during the canal preparation phase using TruNatomy has not been studied and compared with other systems. Therefore, the results of our study are not directly comparable with other studies.

Mandibular first premolars were used in our study due to their smaller dimensions and their thin dentinal walls that are more prone to the stress caused by shaping. This approach was applied since the likelihood of microcrack formation with large tapered files is higher in mandibular premolars than in other teeth.[18] Furthermore, in our study, teeth with deviated apical foramen were excluded from having standardized the specimens since it is associated with the crack formation on the apical surface.[19]

Increased incidence of apical delta ramification in apical 1 mm of the root may mimic cracks and affect the interpretation of results; thus, we avoided it by the removal of 1 mm of the apical root. And also, it provided a flat surface for better visualization of cracks under a stereomicroscope and helped in determining the WL accurately.[20]

Higher concentrations of NaOCl irrigation significantly reduce the elastic modulus and torsional resistance of root dentin than lower concentrations and physiologic saline.[21] For this

Table 1: The proportion of microcracks at apical levels of the root canal

Groups	Microcrack incidence/ number of total samples
Group 1 – ProTaper Next	6/15[a]
Group 2 – ProTaper Gold	3/15[a,b]
Group 3 – TruNatomy	1/15[b]

[a,b]Different letters indicate statistically significant difference ($P<0.05$)

Table 2: Binary comparisons between groups in terms of microcracks

Groups	*P*
ProTaper Next–ProTaper Gold	0.229
ProTaper Gold–TruNatomy	0.273
ProTaper Next–TruNatomy	0.025

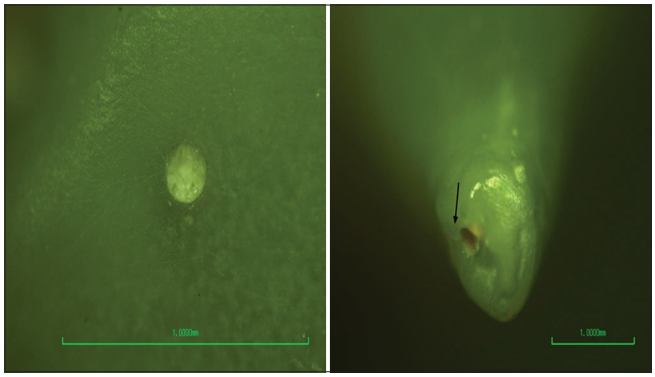

Figure 1: The images of specimens without any microcrack and with a visible microcrack

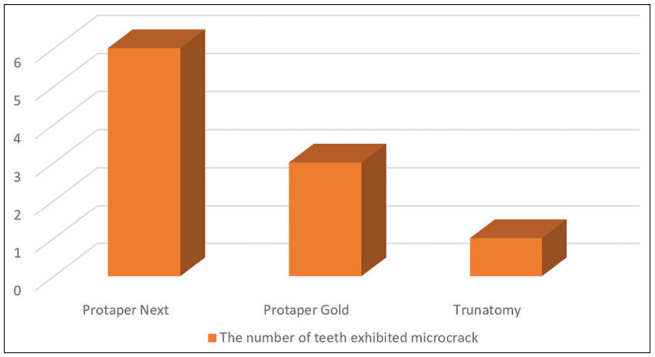

Figure 2: The number of teeth exhibited microcrack after canal preparation with different instrumentation systems

reason, the use of 1% NaOCl solution was considered for irrigation purposes.

Manufacturers recommend discarding the files after several uses in root canals to avoid file fractures. The anatomic variations of canals (such as curvature angle and obliterations) lead to file separation. However, there is no agreement on how many times an endodontic file can be used in the literature.[22,23] The instruments used in our study were recommended for single use by the manufacturers.[12] Therefore, in preparation, a new file set was used for shaping each new tooth.

In the previous studies, the roots were cut perpendicular to the long axis of teeth, and three slices were taken from each specimen.[17,24,25] However, since this cutting process may cause new cracks in the dentin walls, we examined the cracks only in apical portions after flattening without sectioning.

The crack formation is affected by the design and taper of the file due to altered stress degrees provoked by the files on the canal surfaces.[1,26] PTN showed more cracks than PTG because the PTN file system has an offset mass of rotation which leads to dynamics analogous to the resonance stated along with a sinusoidal wave in our study. This results in cutting off a bigger envelope of motion compared to a file with the same size but asymmetrical mass and axis of rotation. Moreover, PTG has the most recent metallurgical characteristic making it more flexible than PTN. These results are compatible with Nishad and Shivamurthy's study results.[16] Furthermore, in our study, the TruNatomy system caused significantly less apical cracks than the PTN and PTG systems. Previously, it has been shown that file taper influences dentinal crack formation.[1,26] TRN files (Glider, Small, and Prime) have less taper (0.02 v, 0.04 v, and 0.04 v) than PTN (0.04 v, 0.06 v) and PTG (0.04 v, 0.02 v, 0.04 v, 0.07 v, and 0.08 v). Lower dentinal crack incidence in the TRN group may be attributed to the taper differences between TRN and the other groups. It has been argued that TRN instruments are less destructive for root canal system due to the regressive tapers and the heat treatment of the NiTi alloy.[12] The slenderized pattern might have caused relatively fewer apical cracks in the TruNatomy system.

Contrary to our results, De-Deus *et al*. concluded that there is a lack of correlation between root canal preparation and dentinal microcrack formation.[27,28] The researchers conducted their studies with micro-CT imaging which might be one of the reasons why their study demonstrated that new microcracks were not observed in the sections.

Postextraction extrinsic parameters, for example, storage conditions of teeth until the analysis, might have influenced the consequences of our study despite the efforts to mimic the clinical conditions.[6] Another limitation of our study was the standardization of the apical pressure performed by the operator during the preparation, and nonstandardization could have affected the results.

CONCLUSION

Within the limitations of the present *in vitro* study, it was concluded that TRN caused statistically significantly fewer dentinal damage than PTN systems. Furthermore, PTG caused fewer microcracks than PTN, and TRN caused fewer microcracks than PTG, but there was no significant difference among the PTN-PTG and PTG-TRN groups. Moreover, all rotary files led to microcracks in the apical root dentin.

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Conflicts of interest
There are no conflicts of interest.

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