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Original research

Comparison of newly formed microcracks after instrumentation using Protaper Next, Reciproc and Self-Adjusting File systems

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Purpose
The purpose of the present study is to assess the rate of newly formed microcracks comparatively during root canal instrumentation by using ProTaper Next, Reciproc, and Self-Adjusting File systems using micro-computed tomography.

Subjects and Methods
Thirty mesial roots of mandibular molars were randomly assigned to 3 experimental groups (n = 10) as follows, ProTaper Next, Reciproc and Self-Adjusting File system. Preoperative and postoperative scans were obtained at the isotropic resolution of 13.68 μm. Cross-section images were examined to identify the presence of newly formed dentinal microcracks.

Results
The Self-Adjusting File and Reciproc systems caused a higher rate of new microcrack formation than the ProTaper Next group ($p < 0.001$). There were also significant differences in the new microcrack formation between Reciproc and Self-Adjusting File groups ($p < 0.001$).

Conclusion
Reciproc and Self-Adjusting File systems caused a higher rate of newly formed microcraks compared to ProTaper Next system.

Keywords: *Dentinal microcracks; micro–computed tomography; Protaper Next; Reciproc; Self-Adjusting File*

Introduction

The microcracks that occur during root canal shaping procedures can propagate repetitious occlusal forces, be exposed to stresses caused by root canal obturation and retreatment, and result in vertical root fracture (1,2). Numerous studies reported that the use of rotary instrumentation causes microcracks in root dentin (3,4).

In the ProTaper NEXT System (PTN) (Dentsply Tulsa Dental Specialties, Johnson City, TN, USA), which is made by M-wire technology, conventional continuous rotation motion is used. This system has an off centre rectangular cross section with regressive and progressive percentage tapers on a single file. Off-centred rectangular structure provides the file a snake-like, swaggering motion, minimizes the contact between the dentin and file, thus reduces the screw effect (5).

In Reciproc (VDW, Munich, Germany) system, a single file is used with a reciprocating motion. According to the manufacturer, in this system there are 1500 counter clockwise and 300 clockwise movements in the reciprocating motion. Thereby, following three reciprocating motions it enables 3600 preparation after three reciprocating motions. Special

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clockwise and counter clockwise movements of this motion diminish the stress on the instrument (4).

The self-adjusting file (SAF) (ReDent Nova, Ra'anana, Israel) system is a NiTi file and has a hollow cylindrical instrument designed as a thin nickel-titanium lattice with compressible walls. When root canal is prepared, the compressible walls inserted into a narrow root canal allow the instrument to adapt to the root canal shape both along the cross section and longitudinally. Consequently, the SAF instrument three-dimensionally conforms to the root canal with circular and oval cross sections getting maintenance in the original canal shape. In addition, the lattice design of the SAF allows the irrigation solution to flow continuously through the hollow file (6,7).

Recently, micro computed tomography (micro-CT) has been used in assessing dentinal microcracks (8,9). Micro-CT provides reproducible data in all three dimensions and compares the data on each tooth before and after the root canal preparation. However, there is conflicting results between the studies in which the newly microcrack formation was evaluated. De-Deus et al. (8) and De-Deus et al. (9) reported that mechanical enlargement processes can not be related to the formation of new microcracks. However, in another micro-CT study by Ceyhanli et al. (10) the evaluated instrumentation systems increased the number of microcracks when compared to preoperative images. Thus, the aim of this study is to assess newly formed microcracks comparatively during root canal instrumentation by using ProTaper Next, Reciproc, and self-adjusting file systems using micro-CT.

Subjects and Methods

Study sample

After the approval by the ethics committee of University of Ordu (17.04.2014-2014/02), human mandibular first and second molars were collected. The reason for extraction of the teeth was unrelated to this study. The residues were removed by cleaning the outer surfaces of the teeth, and they were stored in purified filtered water until they were used. The roots were investigated by a stereomicroscopy under 25× magnification to exclude roots having cracks or craze lines. The selected teeth having similar lengths were decoronated, and the distal roots were separated with a diamond-coated bur using water cooling. The mesial roots were left at approximately 11 mm to obtain a standardized length. Canal patencies of both mesiobuccal and mesiolingual canals were established with a #15 K-file (Mani, Inc., Tochigi, Japan). The exclusion criteria were obstructed in root canals, having two or more apical foramen, curvature angle under 10º and upper 20º, pre-operative canal size greater than ISO size 15 and pre-existing craze lines or cracks.

As a result, 30 mesial roots were included the study. Digital radiographs were taken buccolingually for evaluating canal curvatures and radii. The roots were randomly assigned to three groups (n=10). One-way ANOVA, revealed no significant difference among the groups in terms of the canal curvatures and radii ($p > 0.05$).

In order to simulate the periodontal ligament, the cement surfaces of roots were coated with a silicone impression material. The roots were then embedded in acrylic blocs as described by Liu et al. (11).

Preoperative Micro-CT Analysis

The test specimens were scanned with a commercially available high-resolution micro-CT system (SkyScan 1172; Bruker micro-CT, Kontich, Belgium). The X-ray tube was operated at 100 μA and 100 kV with a 0.5 mm Al filter, which has a resolution of 13.68 μm pixels. The scanning process was carried out by a 180° rotation around the vertical axis with a camera exposure time of 1550 ms, a frame average of 3, a rotation step of 0.4°, and a random movement of 20. The samples were scanned for approximately 60 minutes. The axial cross sections were reconstructed using the resulting two-dimensional images (8-bit TIFF). NRecon v.1.6.3 (Bruker micro-CT, Kontich, Belgium) was used to reconstruct the axial cross sections of the inner structure of the specimen with a smoothing of 2, a beam hardening correction of 50%, and an attenuation co-efficient range of 0-0.73.

Canal instrumentation

With PTN, Root canals were prepared with a K-file until #20 at the working length (WL). Then the PTN instruments were implemented using an electric motor at 300 rpm at 2 N/cm torque (X-Smart; Dentsply Tulsa Dental, Tulsa, OK). The X1 file (17.04) was used with a slow in-and-out pecking motions until WL was reached. Root canals were then rinsed using 10 ml 5.25% sodium hypochlorite (NaOCl) (Wizard, Istanbul, Turkey), and a #15 K-file was used to confirm patency. Same operations were accomplished with the X2, X3, and X4 files. When using Reciproc, Root canals were prepared with a K-file until #20 at the WL. The RECIPROC instrument was then operated using the "RECIPROC all" mode of the electric motor (VDW Gold, Munich, Germany). The R40 Reciproc file (40/0.06) was used with three slow in-and-out pecking motions and a reciprocating movement until WL was obtained. Root canals were prepared with SAF by using a K-file until #20 at the WL. Then, the SAF 2.0-mm file was applied using an in-and-out vibrating hand piece head (RDT3; ReDent Nova, Ra'anana, Israel) at at 5,000 vibrations per minute and at amplitude of 0.4 mm, as described by Metzger Z et al. [7]. The instrument was used at the WL in each canal with a packing motion for 4 minutes. During the preparation, the canal was irrigated with a pump (Vatea ReDent Nova, Ra'anana, Israel) and 5 ml 5.25% NaOCl per minute.

For all groups, the root canals were rinsed with a totally 40 ml 5.25% NaOCl, and a #15 K-file was used to confirm patency during instrumentation. Then, each canal was dried with sterile paper points. Both canals in the same root were prepared using the same instrument and a new instrument was used for another mesial root.

Dentinal Microcrack Evaluation

The images of the specimens before and after the canal preparation were superimposed using Data Viewer software (Bruker micro-CT). The cross-section images of the roots from the apex to the top of the root were examined to detect any dentinal microcracks (n = 7320).

Statistical analysis

The images were analyzed by two precalibrated examiners to identify the presence of dentinal microcracks. In the case of divergence, the images were examined together until reaching an agreement. The formation of the new microcrack was recorded for groups and the data were then statistically analyzed by using chi square test. Data was therefore expressed as frequency. All calculations were performed with SPSS 23 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp, USA) statistical software. Confidence interval was set to 95% and p<0.05 was considered statistically significant.

Results

A total of 21960 cross-sections were examined. Figure 1 shows the number of slices in each group with new formation of microcracks (Figure 2). The SAF and Reciproc systems caused a higher rate of new microcrack formation than that found in the PTN ($p < 0.001$). There were significant differences in the new microcrack formation between Reciproc and SAF groups ($p < 0.001$).

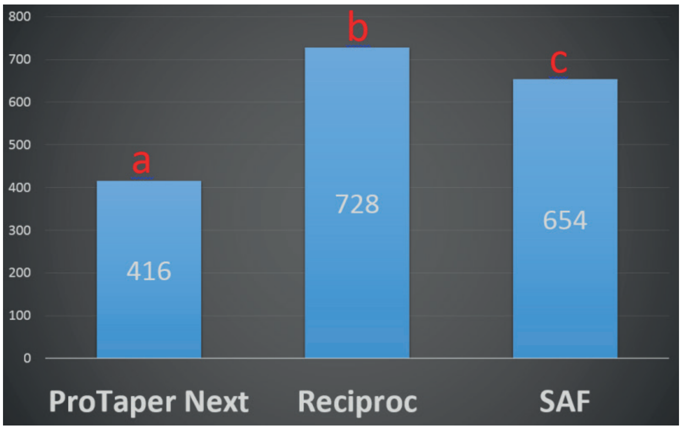

Figure 1. *The number of slices in each group with new formation of microcracks.*

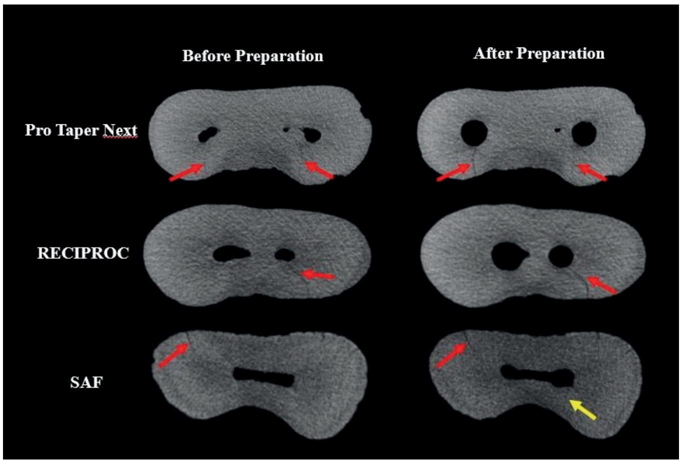

Figure 2. *Representative cross-sectional images of 3 from each experimental group. Red arrows point at microcraks already present before preparation, yellow arrow point at new microcrack.*

Discussion

In the root sectioning studies, the percentage of dentinal defects created by PTN ranges from 11.6% to 33.3% (12,13); the Reciproc ranges from 3% to 40% (1,4,11,14,15). These researches demonstrated a clear association between root canal preparation and created / propagation of dentinal microcracks. Conversely, the studies that used micro-CT conducted by De-Deus et al. (8,9) reported that mechanical enlargement processes cannot be related to the formation of new microcracks. However, in another micro-CT study by Ceyhanli et al. (10), the evaluated instrumentation systems increased the number of microcracks when compared to preoperative images. Similarly, in the current study, the root canal preparation with SAF, Reciproc, and PTN systems caused new formation of microcracks.

In the root sectioning studies, dentinal microcrack formation was not recorded after the root canal preparation with SAF 1.5 mm (3,11). However, Hin et al. (16) reported that the percentage amount of dentinal damage was 10% by SAF 2.0 mm. In the root sectioning studies, preoperative and postoperative findings cannot be compared and there is no research using micro-CT about microcracks formation by SAF in literature. In the present study, microcrack formation was recorded after canal shaping procedures with SAF 2.0 mm. The rate of newly formed microcrack caused by the SAF system was found statistically higher than that of PTN ($p < 0.001$). These conflicting findings may be due to the different instrumentation sizes (1.5 mm and 2.0 mm) and the differences between the evaluation methods.

According to root sectioning studies, the microcrack formation may be caused by rotational forces that were applied to the root canal walls, and this may be related to instrumentation kinematics, such as tip design, cross-section geometry, taper pitch design, and fluted form (4,15). In a study, Burklein et al. (4) reported that reciprocating files produced significantly more incomplete dentinal microcracks than full-sequence rotary systems. However, Liu et al. (11) and Ashwinkumar et al. (14) informed that the Reciproc instrument caused fewer microcracks than full-sequence rotary instruments. In the present study, Reciproc system caused the highest rate of newly formed microcracks.

In the literature, most of the studies reported that root canal treatment procedures, such as root canal shaping, obturation, and retreatment, cause microcracks in root dentin (4,12). In recent years, many destructive studies examining dentinal microcracks using stereomicroscope have been conducted (3,15). In these studies, samples are obtained by conventional root sectioning method, which causes the loss of a significant amount of dentin. Only a few slices per tooth can be analysed, and root sectioning can cause microcracks in the root dentin (9). In addition, the most important disadvantage of this method is, that because of the impossibility of investigating preoperative root dentin, it is not decided that the present microcracks occur due to the root canal preparation, are already present before, or occur during the root sectioning. Recently, micro-CT has been used in assessing dentinal microcracks. Micro-CT supplies a three-dimensional, highly accurate establishment of the precise location of preoperative microcracks and previously existing dentinal defects throughout the root dentin (8,9). contrast with traditional root sectioning methods, it is possible to evaluate hundreds of slices for each tooth in root using micro-CT imaging. In addition, micro-CT imaging is a non-destructive method that averts the necessity for cutting specimens. This approach arranges further experiments on the same samples, such as investigating the effect of obturation retreatment post placement and removal procedures on developing dentinal defects. Thus, in the present study a non-destructive method (micro-CT) imaging system was used to evaluate newly formed microcracks.

Conclusion

Within the limitation of this experimental study, it can be stated that the Reciproc and SAF are more likely to cause higher rate of newly formed microcraks than the ProTaper Next system.

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Ethics committee approval: The ethics committee of Ordu University Faculty of Dentistry has approved the study protocol (17.04.2014-2014/02).

Informed consent: Informed consent was obtained from all participants.

Peer review: Externally peer-reviewed.

Author contributions: FÇ, EBÇ, BS and AK participated in designing the study. FÇ, EBÇ, BS and AK participated in generating the data for the study. FÇ, EBÇ and FFK participated in gathering the data for the study. FÇ, EBÇ and BS participated in the analysis of the data. FÇ and EBÇ wrote the majority of the original draft of the paper. FÇ and EBÇ participated in writing the paper. All authors approved the final version of this paper.

Conflict of interest: The authors have no conflicts of interest to declare.

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Türkçe öz: *ProTaper Next, Reciproc ve Self-Adjusting File sistemleri kullanılarak yapılan instrumantasyondan sonra yeni oluşan mikroçatlakların karşılaştırılması. Amaç: Bu çalışmanın amacı, ProTaper Next, Reciproc ve Self-Adjusting File (SAF) sistemleriyle yapılan kök kanal instrumantasyonundan sonra yeni oluşan mikroçatlakların mikro-bilgisayarlı tomografi kullanılarak karşılaştırmalı olarak değerlendirilmesidir. Gereç ve Yöntem: 30 adet mandibular molar dişin mesial kökü ProTaper Next, Reciproc ve SAF sistemleriyle hazırlanmak üzere rastgele 3 deneysel guruba ayrıldı (n=10). İşlem öncesi ve işlem sonrası, 13.68 µm izotropik çözünürlükte taramalar yapıldı. Elde edilen kesit görüntüleri üzerinde, yeni dentinal mikroçatlak oluşumunun varlığı incelendi. Bulgular: SAF ve Reciproc sistemler, ProTaper Next sistemine göre daha yüksek oranda yeni mikroçatlak oluşumuna sebep oldu (p < 0.001). Reciproc ve SAF gurupları arasında da yeni mikroçatlak oluşumu açısından anlamlı bir tespit edildi (p < 0.001). Sonuç: Reciproc ve SAF sistemler, ProTaper Next sistemiyle karşılaştırıldığında daha yüksek oranda yeni mikroçatlak oluşumuna sebep olmuştur. Anahtar kelimeler: Dentinal mikroçatlak; mikro-bilgisayarlı tomografi görüntüleme; Protaper Next; Reciproc; Self-Adjusting File.*

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