



## Incidence of Dentinal Microcracks during Root Canal Preparation with Self Adjusting File, Reciproc Blue and ProTaper Next

Tomislav Katanec<sup>a</sup> , Ivana Miletić<sup>b</sup> , Gorana Baršić<sup>c</sup> , Lumnije Kqiku-Biblekaj<sup>d</sup> , Mirza Žižak<sup>e</sup> , Silvana Jukić Krmek<sup>f\*</sup>

<sup>a</sup> School of Dental Medicine, University of Zagreb, Gundulićeva 5, Zagreb, Croatia; <sup>b</sup> Department of Endodontics and Restorative Dentistry, University of Zagreb, Gundulićeva 5, Zagreb, Croatia; <sup>c</sup> Department of Quality, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Lucićeva 5, Zagreb, Croatia; <sup>d</sup> Division of Restorative Dentistry, Periodontology, and Prosthodontics, Medical University of Graz, Auenbruggerplatz 2, Graz, Austria; <sup>e</sup> Department of Physiology and Immunology, School of Medicine, University of Zagreb, Šalata 3, Croatia; <sup>f</sup> Department of Endodontics and Restorative Dentistry, University of Zagreb, Gundulićeva 5, Zagreb, Croatia

### ARTICLE INFO

Article Type: **Original Article**

Received: 18 Jul 2019

Revised: 21 Nov 2019

Accepted: 01 Dec 2019

Doi: 10.22037/iej.v15i1.26667

\*Corresponding author: Silvana Jukić Krmek, Department of Endodontics and Restorative Dentistry, University of Zagreb, Gundulićeva 5, Zagreb, Croatia.

E-mail: jukic@sfgz.hr

This work is licensed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International.

### ABSTRACT

**Introduction:** Forces formed during root canal instrumentation could cause the crack formation in dentinal walls. Their propagation may result in vertical root fracture and eventually tooth loss. The aim of the study was to explore microcrack formation after root canal preparation with Self-adjusting File (SAF), Reciproc Blue (RB), and ProTaper Next (PTN) instruments on young premolars by means of micro-computed tomography (micro CT). **Methods and Materials:** Forty-five upper premolars with two canals, were extracted due to orthodontic reasons from patients aged 16 to 20 years and stored for up to two months. The teeth were scanned with a micro-CT (Nikon XT H 225, Tring, UK) at structural resolution of 20.2 μm and randomly divided into three groups: SAF, RB, and PTN. Specimens were instrumented and irrigation was performed with 12 mL of 2.5% sodium hypochlorite (NaOCl) and 4 mL of 17% ethylenediaminetetraacetic acid (EDTA) per root canal. Subsequently, the specimens were scanned under the same conditions as before, in wet condition and 24 h after drying. The presence of microcracks in dentinal walls was evaluated using the image-processing software Volume Graphics VGStudio Max 3. **Results:** No dentinal defect was found in any evaluated specimen, neither in pre-nor post-operative scans in wet and dry condition. **Conclusion:** Under the circumstances of this *in vitro* study instruments with improved design and metallurgy do not cause dentinal microcracks in young premolar teeth.

**Keywords:** Dentin; Micro-Computed Tomography; Nickel-Titanium; Root Canal Preparation

## Introduction

Microcrack formation could be a serious side effect of mechanical root canal preparation that influences the integrity of the remaining hard tooth tissues and reduces its ability to withstand the functional and parafunctional forces. Dentinal microcracks, if propagate, could end up as a vertical root fracture, a condition with poor prognosis that is usually treated with the tooth extraction. A positive correlation between the root canal instrumentation and the appearance of microcracks has been reported in many studies [1-7]. Most of these studies have been performed by sectional methods that

could damage specimens, which calls into question the credibility of the results presented in these studies. The use of microcomputer tomography (micro-CT) in research on the effects of instrumentation on the dentin structure enables a three-dimensional evaluation of the sample without its destruction and additional mechanical action during the analysis of the results [8, 9]. In most of the micro-CT studies it was found that microcracks in the dentinal walls pre-existed in samples prior to the root canal preparation [8-13].

However, the question of the mechanical effects of root canal preparation and the appearance of microcracks still attracts the researchers' attention, especially after the discovery of the

influence of microcracks' on the prognosis of teeth that have undergone periapical surgery [14]. Furthermore, there are methodological issues with the microcrack studies (such as the conditions of sample storage, the presence of moisture during the micro-CT scanning, and the age of the specimens) that could influence the results [8, 15].

Over time, manufacturers have offered root canal instrument made of improved alloys and design features that should minimize the appearance of microcracks. The Self-adjusting File (SAF) system (ReDent Nova, Berlin, Germany) with its Pre-SAF system for the preparation of the glide path, is one of these new systems [16]. The SAF is a hollow, flexible instrument that abrades the dentinal walls with nickel-titanium lattice at vibrational kinematics. The Reciproc Blue (WDV, Munich, Germany) instrument is made of the blue nickel-titanium (NiTi) alloy, a new version of Reciproc that is used in reciprocating movement [17]. ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) is a new generation of rotary instruments with a rectangular cross-section and off-centre rotation that is responsible for the snake-like movements inside the root canal with full rotational kinematics [18].

Considering all above mentioned, this study is undertaken in order to clarify some methodological issues, sample selection and its storage, the influence of moist during examination on visibility of dentinal defects and the influence of newly developed instruments on dentinal wall integrity. The purpose of this *in vitro* study is to evaluate the effects of three new endodontic instrumentation systems with different kinematics together with their glide path instruments on the incidence of microcrack formation on young premolar teeth by means of micro computed tomography in wet condition and 24 h after drying.

## Materials and Methods

### *Specimen selection and preparation*

A total of 85 maxillary intact human upper premolars extracted due to orthodontic reasons at the Department of Oral Surgery from patients aged 16 to 20 were used for the study. The study was approved by the Ethical Committee of the Dental School (approval no. 05-11/2016).

The teeth were disinfected over 24 h at 4°C in 1% chloramine and were subsequently transferred to the saline solution up to two months before micro-CT scans. All the teeth were visually inspected under the stereomicroscope with magnification of 12× to exclude those with open apices, those that were root fractured

during the extractions and pre-existing dentinal defects. The specimens were decoronated using a diamond disc to standardize the working length about 12 mm. Apical patency was checked by inserting a #10 file (C-Pilot, VDW, Munich, Germany).

Preliminary low-resolution isotropic prescans were performed to evaluate the canal anatomy using an industrial micro-CT (Nikon XT H 225, Nikon Metrology, Tring, UK) with a target focal size of 0.7 μm, as well as a 400×300-mm, 14-bit flat panel detector with a 127-μm pixel size.

The periodontal ligament was simulated by a thin layer of polysiloxane impression material (Xantopren VL plus; Heraeus Kulzer, Hanau, Germany) on the root surface and the samples were embedded in blocks made of acrylic resin [19].

Based on an analysis of 3D models of these prescans, only two-rooted teeth with one canal (Vertucci type I) or single-rooted teeth of Vertucci type II had been selected for the study. A total of 45 teeth were selected and scanned at geometrical magnification of 6.3, which yielded a structural resolution of 20.2 μm. All teeth were scanned at X-ray energy of 110 kV and X-ray tube current of 140 μA with a 0.1 mm Cu filter, using 1440 projections at an exposure time of 333 ms. Beam hardening was reduced using a Hanning filter. Noise was reduced using a median filter, and surface detection was performed using an adaptive search algorithm (Volume Graphics VGStudio Max 3; GmbH, Heidelberg, Germany).

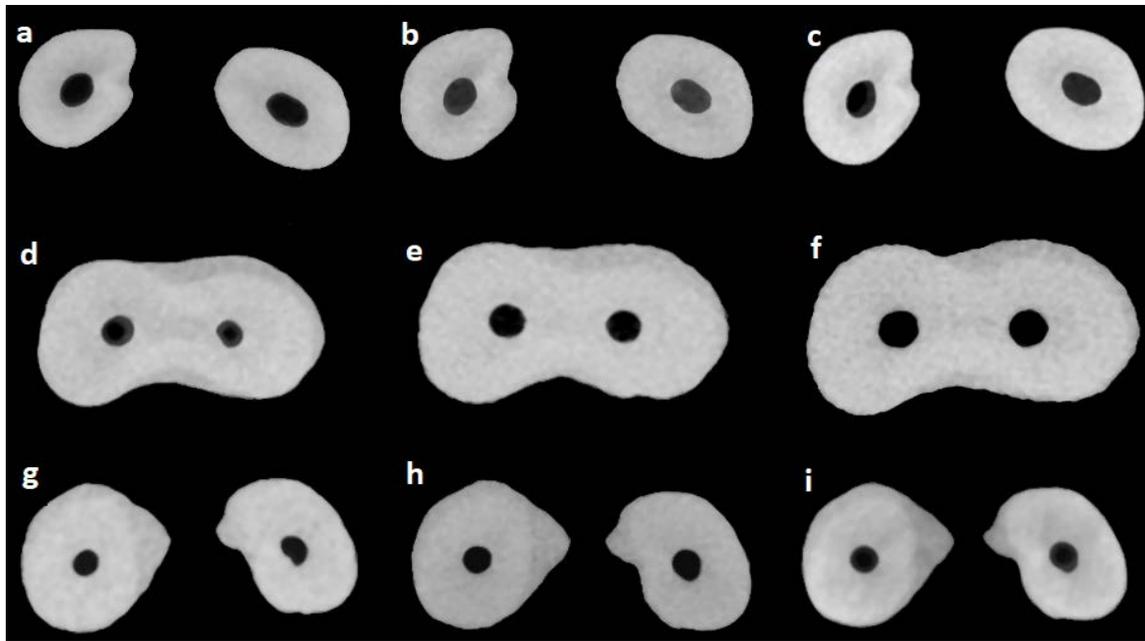
Samples were randomly assigned into three groups of 15 teeth each according the instrumentation technique: Self-Adjusting File (SAF), Reciproc Blue (RB), and ProTaper Next (PTN).

### *Root canal treatment*

All specimens were prepared under a dental operating microscope (Zeiss Extaro 300, Oberkochen, Germany) at 16× magnification.

For the SAF group (vibration kinematics), the glide path was created using the Pre-SAF set of instruments (ReDent Nova, Berlin, Germany). The coronal part of the root canal was prepared with the Pre-SAF OS (orifice shaper, sized #40/0.10) at 650 rpm and torque 1.5 Ncm. Consequently, the Pre-SAF 1 (sized #15/0.02) at 500 rpm and torque 1 Ncm and the Pre-SAF 2 (sized #20/0.04) at 500 rpm and torque 1.5 Ncm were used to the working length.

A specially designed RDT3 handpiece-head that converts the rotation motion in vibration, mounted on the EndoStation (ReDent and Acteon, Berlin, Germany) equipped with a peristaltic pump, was used for canal preparation with SAF instrument 1.5 mm in diameter at frequency of 5000 vibrations per minute and amplitude



**Figure 1.** Micro-computed tomography images of specimen instrumented with: Self adjusting file; A) Before; B) After the treatment ; C) After the 24 h of drying; Reciproc Blue ; D) Before; E) After the treatment and; F) After the 24 h of drying; ProTaper Next; G) Before; H) After the treatment; I) After the 24 h of drying

of 0.4 mm. The SAF instrument was inserted into the canal and operated with pecking motions to the working length for a total of four minutes. First, the canals were simultaneously irrigated through the hollow instrument with 2.5% NaOCl at a flow rate of 4 mL/min for two minutes. This was followed by one minute of irrigation with 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) by use of a syringe and needle.

In the last min, canals were irrigated with sodium hypochlorite (NaOCl). The total volume of NaOCl was 12 mL per canal. In the RB group (reciprocation kinematics), a Reciproc Gold motor (WDV, Munich, Germany) set at 10 cycles of reciprocation per second was used for the glide path creation with R-Pilot (WDV, Munich, Germany) and for consequent root canal preparation with Reciproc Blue 25 with the same pecking in-and-out motions repeated until the working length was reached. During instrumentation, each canal was irrigated with 10 mL of 2.5% NaOCl, and final irrigation was performed with 2 mL of 17% EDTA.

The glide path in the PTN group (full rotary kinematics) was created with ProGlider (300 rpm, 2.5 Ncm) (Dentsply Maillefer, Ballaigues, Switzerland) at a speed of 300 rpm with torque control set at 2.5 Ncm. Light apical pressure motions were applied until the full working length was reached. After that, ProTaper Next X1 and subsequently ProTaper Next X2 were each used in a brushing motion at a speed of 300 rpm with torque set at 4 Ncm to progress apically until reaching the working length. The instruments were driven by an X-Smart (Dentsply Maillefer) endodontic motor.

During instrumentation, each canal was irrigated with 10 mL of 2.5% NaOCl, and final irrigation was performed with 2 mL of 17% EDTA and 2 mL of 2.5% NaOCl to match the irrigation protocol used in previous groups.

After the root canal preparation, post-operative scans were performed in the same specimen positions and with the same micro-CT parameters as the first scan.

In order to check the influence of the moisture on visibility of microcracks, specimens were kept in dry conditions for 24 h and then scanned for the third time.

Two calibrated, blinded examiners evaluated the cross-sectional images using the image-processing software Volume Graphics VGStudio Max 3. The roots were divided into cervical, middle, and apical parts. Radiolucent lines present in the micro-CT sections would be categorized as microcracks. If the microcracks had been observed on post-operative scans, the corresponding pre-operative scan would have been analyzed to exclude pre-existing defects. In doubtful slices, the cross-sectional images were re-examined until an agreement was reached. For the purpose of validation of the screening process, the samples were analyzed again in two-week intervals.

## Results

After analysing 45 specimens with approximately 800 transverse cross-sections per tooth before and after root canal

instrumentation, no microcracks in the cervical, middle, or apical parts of the root were found on a single specimen. Moreover, 24 h drying period did not reveal any microcracks formation. Figure 1 is showing middle cross-sections of specimen from each group before, after root canal treatment and after 24 h of drying.

## Discussion

This micro-CT study did not reveal dentinal defects in any specimen prior and after the root canal preparation with three tested systems of different kinematics: vibration, reciprocation and continuous rotation, which is in line with most of micro-CT studies where the authors did not find new microcrack formations after root canal preparation [11-13]. Non-destructive micro-CT method could be assumed as gold standard for dentinal microcrack studies because it enables comparison of each sample before and after experimental procedures, thus making the samples to control themselves and eliminating the possibility of false positive results [9]. In contrast, the sectional methods, in which the sample is mechanically sliced and then, with or without a contrast medium, observed with the aid of magnification devices, have a possibility to induce dentinal defects by the sectional procedure itself. Most of those studies, showed an increased occurrence of microcracks after root canal preparation, especially those rotary ones [1, 2, 6, 20-23]. Apart from the nature of analytic method, the differences in results between this and other studies could be attributed to many factors affecting the outcome of the experiment such as sample selection, storage condition and tested instruments.

Despite the quite conclusive negative results of micro-CT studies about correlation between the root canal preparation and occurrence of microcracks [10-13], this topic is still current, especially after having concluded that there could be an insufficient sensitivity of the micro-CT assay and interference of moisture during the analysis, which could lead to doubtful results [8, 15, 24]. In the beginning of dentinal microcrack formation, there is no separation of the fragments, and it is questionable whether the resolution of some micro-CT devices is sufficient to detect such phenomena. In this study, the samples were scanned at a resolution of 20.6  $\mu\text{m}$  and drying of specimens was performed in order to allow visualisation of possible microcracks, unnoticed due to presence of the moisture [15].

Numerous studies do not consider the age of the patient as a criterion for inclusion, yet it is known that the physical and

mechanical properties of teeth changes with age [25-28]. In this study, teeth were extracted for orthodontic reasons from patients aged 16 to 20 years, which partly explains the absence of microcracks on scanned specimens prior to the instrumentation. In addition, the elasticity of the young bones and the attentive work of the surgeon during the extraction reduced the possibility of mechanical dentin damage, and the short, maximal two-month time period between extraction and experiment further contributed to this finding. Although most of micro-CT studies revealed the occurrence of microcracks before the endodontic procedure itself, in an *in-situ* study, De-Deus *et al.* [12] found that there was a lack of microcracks on teeth that were not endodontically treated and concluded that microcrack findings prior to the treatment of the canal were the result of extraction forces or tooth preservation conditions. In the research on extracted teeth that were not endodontically treated in the younger population, 3.7% of the teeth were found to have pre-existing microcracks, and in the elderly, 8.3% had microcracks defects [29].

Post-mortem changes in dentinal structures could greatly influence the results of *in vitro* studies and an important issue of dentinal defects studies that should be discussed is the sample storage conditions such as time period between extraction and the experimental procedure, and immersion solution. Microhardness of dentin is in an acceptable range if stored up to two months in de-ionized water [30], and this time the frame was selected as a maximal period of storage for this study. Although many dentinal defects studies used purified filtrated or distilled water for the preservation of extracted teeth [1, 6, 21, 23, 31], the immersion media used in this study was saline solution, resembling the natural environment in the body.

In this study, during root canal instrumentation with the above-mentioned systems, no new microcracks were found. All procedures recommended by the manufacturer were followed, including preflaring for SAF and glide path formation with the corresponding instruments for all three systems. In each sample, 12 mL of 2.5% sodium hypochlorite and 4 mL of 17% EDTA were used per canal. Although all these procedures affect the structure of the remaining dentin, they did not cause any microcrack formation.

The absence of dentinal defects in this research can also be partly explained by the improvement of alloys and the design of the instruments. SAF is an elastic instrument with mesh lattice that produces uniform forces on the root canal walls, and the root canal walls are prepared with the abrasive surface of nickel-titanium petals and vibration kinematics [32]. The

absence of microcracks with SAF in this research are consistent with the findings of sectional [33, 34] and micro-CT [11] studies, but in contrast with study of Hin *et al.* [35] who in his sectional study found microcracks in 10% of specimens treated with SAF. These contradictory results, particularly in sectional methods, could be explained by inconsistency of the used method. One of factors that could greatly influence the results, the age of the teeth donor [25, 27], is not reported, as well as the storage condition and the time passed between the extraction and experiment.

Reciproc Blue instruments made of a nickel-titanium alloy that undergoes an innovative thermal process are more flexible with increased cyclic fatigue resistance [36]. Although there are many studies on the occurrence of microcracks in samples treated with Reciproc [3, 4, 11, 22], no such data are currently available on the newer Reciproc Blue instrument. ProTaper Next is made of new M-Wire, an elastic nickel-titanium alloy. Its eccentric design of cutting edges allows snake-like movements in the canal and enables smaller, simultaneous points of contact of the instrument edges with the canal walls, resulting in less stress on the canal walls. Although sectional study has shown a higher incidence of microcracks in the ProTaper Next system (26% of roots) than in Hand files group (6.7%) [37], the micro-CT study did not reveal a causal relationship between canal preparation with ProTaper Next and new dentinal microcrack formation [31].

## Conclusion

Based on the results obtained in this *in vitro* study, root canal instrumentation with Self-adjusting File, Reciproc Blue, and ProTaper Next cannot be associated with the appearance of microcracks in the root canal walls of young patients' teeth. Further research with samples of a different age or tooth types is needed to draw a more precise conclusion on the influence of mechanical instrumentation on the integrity of root canal walls'.

## Acknowledgment

This study is funded by Croatian Science Foundation, "Investigation and development of new micro and nanostructure bioactive materials in dental medicine" BIODENTMED IP-2018-01-1719

Conflict of Interest: 'None declared'.

## References

- Burklein S, Tsotsis P, Schafer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. *J Endod.* 2013;39(4):501-4.
- Aydin U, Aksoy F, Karataslioglu E, Yildirim C. Effect of ethylenediaminetetraacetic acid gel on the incidence of dentinal cracks caused by three novel nickel-titanium systems. *Aust Endod J.* 2015;41(3):104-10.
- Li ML, Liao WL, Cai HX. A micro-computed tomographic evaluation of dentinal microcrack alterations during root canal preparation using single-file Ni-Ti systems. *Exp Ther Med.* 2018;15(1):494-9.
- Ustun Y, Aslan T, Sagsen B, Kesim B. The effects of different nickel-titanium instruments on dentinal microcrack formations during root canal preparation. *Eur J Dent.* 2015;9(1):41-6.
- Shemesh H, Bier CA, Wu MK, Tanomaru-Filho M, Wesselink PR. The effects of canal preparation and filling on the incidence of dentinal defects. *Int Endod J.* 2009;42(3):208-13.
- Kansal R, Rajput A, Talwar S, Roongta R, Verma M. Assessment of dentinal damage during canal preparation using reciprocating and rotary files. *J Endod.* 2014;40(9):1443-6.
- Bahrami P, Scott R, Galicia JC, Arias A, Peters OA. Detecting Dentinal Microcracks Using Different Preparation Techniques: An In Situ Study with Cadaver Mandibles. *J Endod.* 2017;43(12):2070-3.
- De-Deus G, Belladonna FG, Silva EJ, Souza EM, Versiani MA. Critical appraisal of some methodological aspects of using micro-CT technology in the study of dentinal microcracks in endodontics. *Int Endod J.* 2016;49(2):216-9.
- de Oliveira BP, Camara AC, Duarte DA, Heck RJ, Antonino ACD, Aguiar CM. Micro-computed Tomographic Analysis of Apical Microcracks before and after Root Canal Preparation by Hand, Rotary, and Reciprocating Instruments at Different Working Lengths. *J Endod.* 2017;43(7):1143-7.
- De-Deus G, Belladonna FG, Souza EM, Silva EJ, Neves Ade A, Alves H, Lopes RT, Versiani MA. Micro-computed Tomographic Assessment on the Effect of ProTaper Next and Twisted File Adaptive Systems on Dentinal Cracks. *J Endod.* 2015;41(7):1116-9.
- Bayram HM, Bayram E, Ocak M, Uygun AD, Celik HH. Effect of ProTaper Gold, Self-Adjusting File, and XP-endo Shaper Instruments on Dentinal Microcrack Formation: A Micro-computed Tomographic Study. *J Endod.* 2017;43(7):1166-9.
- De-Deus G, Silva EJ, Marins J, Souza E, Neves Ade A, Goncalves Belladonna F, Alves H, Lopes RT, Versiani MA. Lack of causal relationship between dentinal microcracks and root canal preparation with reciprocation systems. *J Endod.* 2014;40(9):1447-50.
- De-Deus G, Cesar de Azevedo Carvalhal J, Belladonna FG, Silva E, Lopes RT, Moreira Filho RE, Souza EM, Provenzano JC, Versiani MA. Dentinal Microcrack Development after Canal Preparation: A Longitudinal in Situ Micro-computed Tomography Study Using a Cadaver Model. *J Endod.* 2017;43(9):1553-8.
- Tawil PZ, Saraiya VM, Galicia JC, Duggan DJ. Periapical microsurgery: the effect of root dentinal defects on short- and long-term outcome. *J Endod.* 2015;41(1):22-7.

15. Rodig T, Muller C, Hoch M, Haupt F, Schulz X, Wiegand A, Rizk M. Moisture content of root canal dentine affects detection of microcracks using micro-computed tomography. *Int Endod J*. 2018;51(3):357-63.
16. Kfir A, Moza-Levi R, Herteanu M, Weissman A, Wigler R. Apical extrusion of debris during the preparation of oval root canals: a comparative study between a full-sequence SAF system and a rotary file system supplemented by XP-endo finisher file. *Clin Oral Investig*. 2018;22(2):707-13.
17. De-Deus G, Silva EJ, Vieira VT, Belladonna FG, Elias CN, Plotino G, Grande NM. Blue Thermomechanical Treatment Optimizes Fatigue Resistance and Flexibility of the Reciproc Files. *J Endod*. 2017;43(3):462-6.
18. Gohil UK, Parekh VV, Kinariwala N, Oza KM, Somani MCJJocdJ. Can active signals of cellphone interfere with electronic working length determination of a root canal in a dental clinic? An in vivo study. *J Conserv Dent*. 2017;20(3):170.
19. Soares CJ, Pizi EC, Fonseca RB, Martins LR. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. *Braz Oral Res*. 2005;19(1):11-6.
20. Cassimiro M, Romeiro K, Gominho L, de Almeida A, Silva L, Albuquerque D. Effects of Reciproc, ProTaper Next and WaveOne Gold on Root Canal Walls: A Stereomicroscope Analysis. *Iran Endod J*. 2018;13(2):228-33.
21. Harandi A, Mirzaeeraad S, Mehrabani M, Mahmoudi E, Bijani A. Incidence of Dentinal Crack after Root Canal Preparation by ProTaper Universal, Neolix and SafeSider Systems. *Iran Endod J*. 2017;12(4):432-8.
22. Priya NT, Chandrasekhar V, Anita S, Tummala M, Raj TB, Badami V, Kumar P, Soujanya E. "Dentinal microcracks after root canal preparation" a comparative evaluation with hand, rotary and reciprocating instrumentation. *J Clin Diagn Res*. 2014;8(12):ZC70-2.
23. De Carlo Bello M, Pillar R, Mastella Lang P, Michelon C, Abreu da Rosa R, Souza Bier CA. Incidence of Dentinal Defects and Vertical Root Fractures after Endodontic Retreatment and Mechanical Cycling. *Iran Endod J*. 2017;12(4):502-7.
24. Huang CC, Chang YC, Chuang MC, Lin HJ, Tsai YL, Chang SH, Chen JC, Jeng JH. Analysis of the width of vertical root fracture in endodontically treated teeth by 2 micro-computed tomography systems. *J Endod*. 2014;40(5):698-702.
25. Montoya C, Arango-Santander S, Pelaez-Vargas A, Arola D, Ossa EA. Effect of aging on the microstructure, hardness and chemical composition of dentin. *Arch Oral Biol*. 2015;60(12):1811-20.
26. Tagami J, Hosoda H, Burrow MF, Nakajima M. Effect of aging and caries on dentin permeability. *Proc Finn Dent Soc*. 1992;88 Suppl 1:149-54.
27. Kruzic JJ, Nalla RK, Kinney JH, Ritchie RO. Crack blunting, crack bridging and resistance-curve fracture mechanics in dentin: effect of hydration. *Biomaterials*. 2003;24(28):5209-21.
28. Arola D, Reprogel RK. Effects of aging on the mechanical behavior of human dentin. *Biomaterials*. 2005;26(18):4051-61.
29. PradeepKumar AR, Shemesh H, Chang JW, Bhowmik A, Sibi S, Gopikrishna V, Lakshmi-Narayanan L, Kishen A. Preexisting Dentinal Microcracks in Nonendodontically Treated Teeth: An Ex Vivo Micro-computed Tomographic Analysis. *J Endod*. 2017;43(6):896-900.
30. Aydin B, Pamir T, Baltaci A, Orman MN, Turk T. Effect of storage solutions on microhardness of crown enamel and dentin. *Eur J Dent*. 2015;9(2):262-6.
31. Cassimiro M, Romeiro K, Gominho L, de Almeida A, Costa L, Albuquerque D. Occurrence of dentinal defects after root canal preparation with R-phase, M-Wire and Gold Wire instruments: a micro-CT analysis. *BMC Oral Health*. 2017;17(1):93.
32. Hof R, Perevalov V, Eltanani M, Zary R, Metzger Z. The self-adjusting file (SAF). Part 2: mechanical analysis. *J Endod*. 2010;36(4):691-6.
33. 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 Endod*. 2012;38(2):232-5.
34. 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 Endod*. 2013;39(8):1054-6.
35. Hin ES, Wu MK, Wesselink PR, Shemesh H. Effects of self-adjusting file, Mtwo, and ProTaper on the root canal wall. *J Endod*. 2013;39(2):262-4.
36. Almeida GC, Guimaraes LC, Resende PD, Buono VTL, Peixoto IFC, Viana ACD. Torsional behaviour of Reciproc and Reciproc blue instruments associated to their martensitic transformation temperatures. *Int Endod J*. 2019.
37. Shori DD, Sheno PR, Baig AR, Kubde R, Makade C, Pandey S. Stereomicroscopic evaluation of dentinal defects induced by new rotary system: "ProTaper NEXT". *J Conserv Dent*. 2015;18(3):210-3.

*Please cite this paper as:* Katanec T, Miletić I, Baršić G, Kqiku-Biblekaj L, Žižak M, Jukić Krmek S. Incidence of Dentinal Micro Cracks during Root Canal Preparation with Self Adjusting File, Reciproc Blue, and ProTaper Next. *Iran Endod J*. 2020;15(1): 6-11. *Doi:* 10.22037/iej.v15i1.26667.