ORIGINAL ARTICLE

Comparative Evaluation of Dentinal Microcrack Formation by Single Reciprocating File Systems: An *In Vitro* Study

Ashitha T Kulangara[1], A Devadathan[2], Baby James[3], Jose Jacob[4], Manuja Nair[5]

Abstract

Introduction: The purpose of this *in vitro* study was to compare and evaluate the formation of dentinal microcracks after root canal preparation while using four single reciprocating file systems [WaveOne (WO), Reciproc (RC), WaveOne Gold (WOG), Reciproc Blue (RCB)].

Materials and methods: Seventy-five extracted mandibular premolars were randomly selected. A total of 15 teeth were left unprepared and served as control, and the remaining 60 teeth were divided into four groups. WaveOne files, Reciproc files, WaveOne Gold files, and Reciproc Blue files were used to prepare the canals. Roots were then sectioned at 3, 6, and 9 mm from the apex and the cut surface was observed under the scanning electron microscope (SEM) for the presence of dentinal microcracks.

Results: The control group were not associated with microcracks, while all the single file systems tested resulted in dentinal microcrack formation. Among the groups, tooth prepared with WaveOne Gold and Reciproc Blue files showed fewer cracks than other experimental groups; however, no significant difference was found between them ($p > 0.05$).

Conclusion: Root canal preparation with reciprocating files resulted in dentinal microcracks. WaveOne Gold and Reciproc Blue files caused less microcracks than WaveOne and Reciproc files. Heat-treated instrument produced less microcracks than M-wire instruments.

Keywords: Dentinal microcracks, Reciproc Blue, Reciprocating, Single file system, WaveOne Gold.

Conservative Dentistry and Endodontic Journal (2020): 10.5005/jp-journals-10048-0057

Introduction

Vertical root fracture (VRF) is one of the frustrating complications of root canal treatment. The root fracture might occur as a result of a microcrack or craze line that propagates with repeated stress application by occlusal forces. These dentinal microcracks are clinically difficult to diagnose and treat, progressing to VRF and ultimately tooth loss.[1,2]

Root canal shaping procedures and rotary instrumentation have the potential to induce microcrack formation, which can extend to complete fractures under functional load. Several factors of nickel-titanium (Ni-Ti) files such as different heat treatments, designs, cross-sectional shape, and kinematics may influence the generation of cracks.[3,4] Furthermore, some other cofactors that promote VRF are the use of high concentrations of sodium hypochlorite,[5] the tooth anatomy,[6] the placement of prosthetic posts,[7,8] and different obturation techniques.[9]

Shemesh et al.[10] reported that canal preparation had created significant dentin defects such as fractures, craze lines, and incomplete cracks. Bier et al.[11] also reported that canal preparation using rotary Ni-Ti files induced significantly more dentinal defects than hand files and attributed this to the significantly higher number of rotations of the rotary systems.[12]

Advances in Ni-Ti instruments and their kinematics allowed the possibility to shape root canals with single-file systems activated in rotary or reciprocating motion, focusing on the concept "Less Is More," thereby requiring less time than full-sequence rotary systems.

The reciprocating movement is claimed to relieve stress on the instrument by special counterclockwise (cutting action) and clockwise (release of the instrument) movements, and it is assumed that this movement reduces the risk of cyclic fatigue caused by tension and compression.[13,14] Reciprocating movements could also reduce the screw-in effects, thus preventing the unintended overextension of instrument beyond the apical foramen.

[1–5]Department of Conservative Dentistry and Endodontics, Pushpagiri College of Dental Science, Thiruvalla, Kerala, India

Corresponding Author: Ashitha T Kulangara, Department of Conservative Dentistry and Endodontics, Pushpagiri College of Dental Science, Thiruvalla, Kerala, India, Phone: +91 9497553602, e-mail: ashithathomas57@gmail.com

How to cite this article: Kulangara AT, Devadathan A, James B, *et al.* Comparative Evaluation of Dentinal Microcrack Formation by Single Reciprocating File Systems: An *In Vitro* Study. Cons Dent Endod J 2020;5(1):1–4.

Source of support: Nil

Conflict of interest: None

Reciproc (REC) (VDW, Munich, Germany), WaveOne (WO) (Dentsply Maillefer), and the recently marketed WaveOne Gold (WOG) (Dentsply Maillefer) and Reciproc Blue (RCB) (VDW, Munich, Germany) are the main examples of commercially available single-file reciprocating systems.

Several studies using these reciprocating Ni-Ti systems showed better canal centring ability, uniform canal preparation, and better debris and smear layer removal when compared with continuous rotary Ni-Ti instruments.[15–17] However, there are only few studies in the literature regarding the occurrence of microcracks using these single-file systems. Thus, the purpose of this study was to investigate the formation of microcracks after canal preparation with these different single-file systems.

Materials and Methods

A total of 75 mandibular premolars were randomly selected from 15- to 30-year-old patients extracted for orthodontic reasons, based on the inclusion criteria of mature apices, straight root canals (<5°)

and Weine's type I canal anatomy pattern, and exclusion criteria of cracked tooth or fractured tooth. Proximal radiographs of each tooth were taken to confirm the canal anatomy pattern.

All teeth were inspected under dental operating microscope 20× magnification to predetermine the existence of any lines or cracks, and those with any defects were discarded and replaced by similar one. The crown of each tooth was sectioned at the cementoenamel junction, using the diamond disk under water coolant. An additional silicon impression material of putty consistency was used for coating the cemental surface of roots to simulate periodontal ligament space. The samples were randomly assigned to the following groups ($n = 15$):

- Group I: No preparation (Control)
- Group II: WaveOne (WO, Primary)
- Group III: Reciproc (REC, R25)
- Group IV: WaveOne Gold (WOG, Primary)
- Group V: Reciproc Blue (RCB, R25)

Fifteen root canals were left unprepared and served as the control group. The remaining 60 teeth were subjected to the procedures described below.

The canals were located using a DG-16 endodontic explorer. The patency and working length (WL) of each canal were determined by passing the size-10 K-file to the anatomic foramen. This length was recorded, and the final WL was established 0.5 mm short. After confirming apical patency, shaping procedures were performed as follows:

Root Canal Preparation

All instruments were operated with a 6:1 reduction handpiece powered by a torque-controlled motor using preset programs "WaveOne" or "Reciproc" according to manufacturer's instructions (X-Smart Plus Endo Motor, Dentsply, Sirona). The files were used with a progressive up and down movement no more than three to four times with minimal apical pressure. The files were then removed and wiped clean. Irrigation was performed using 3% sodium hypochlorite solution. The same procedure was repeated until the file reached the WL. After completion of the procedure, canals were rinsed with 2 mL distilled water and all the roots were kept in distilled water throughout the experimental procedures.

Sectioning and Microscopic Examination

All roots were sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex with a hard tissue microtome under water coolant. All the sections were then gold sputtered and viewed under a scanning electron microscope (SEM) (IsoMet 5000 linear precision saw) for the presence of microcracks. A total of 45 sections were examined in each group.

"No defect" was defined as root dentin devoid of any craze lines or microcracks originating from the canal lumen. "Defect" was defined if any craze lines, microcracks, or fractures were present originating from the root canal lumen.[18] The statistical analysis was done using the one-way ANOVA test. The p value < 0.05 was considered as statistically significant.

Results

Proportion of teeth with microcracks at three different levels of root canal is given in Table 1 and illustrated in Figure 1.

From the results, it can be inferred that group I (no preparation) presented with no microcracks at all the three levels, while all the single file systems tested resulted in dentinal microcrack formation. Group IV (WOG) and group V (RCB) showed less roots with microcracks than group II (WO) and group III (REC); however, no significant difference was found between them in crack formation

Table 1: Proportion of teeth with microcracks at three different levels of root canal

	No. of samples with microcracks			
Groups	*Coronal section (n = 15)*	*Middle section (n = 15)*	*Apical section (n = 15)*	*Total (n = 45)*
Group I (No preparation)	0	0	0	0
Group II (WaveOne files)	9	10	15	34
Group III (Reciproc files)	8	9	12	29
Group IV (WaveOne gold files)	4	5	9	18
Group V (Reciproc blue files)	4	4	6	14

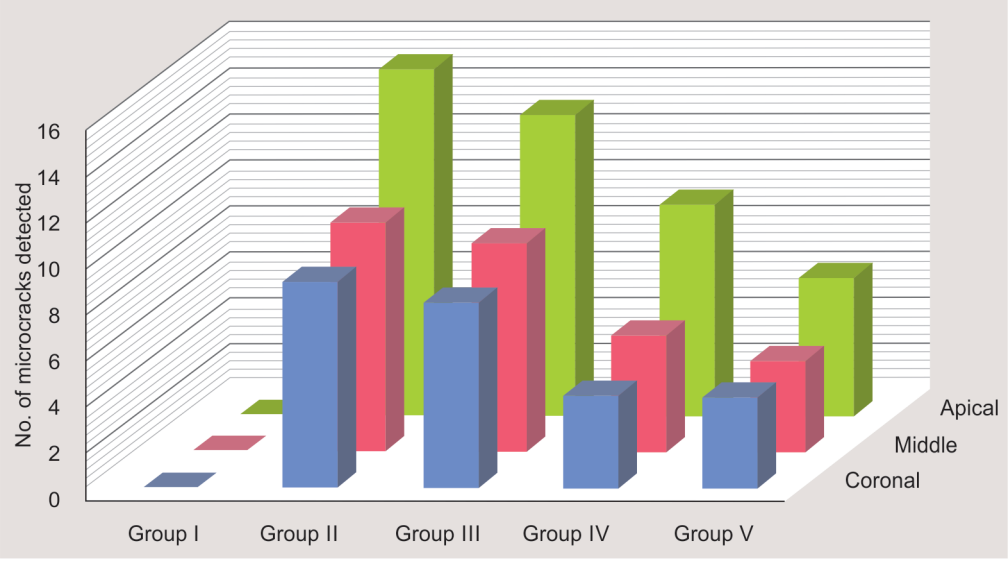
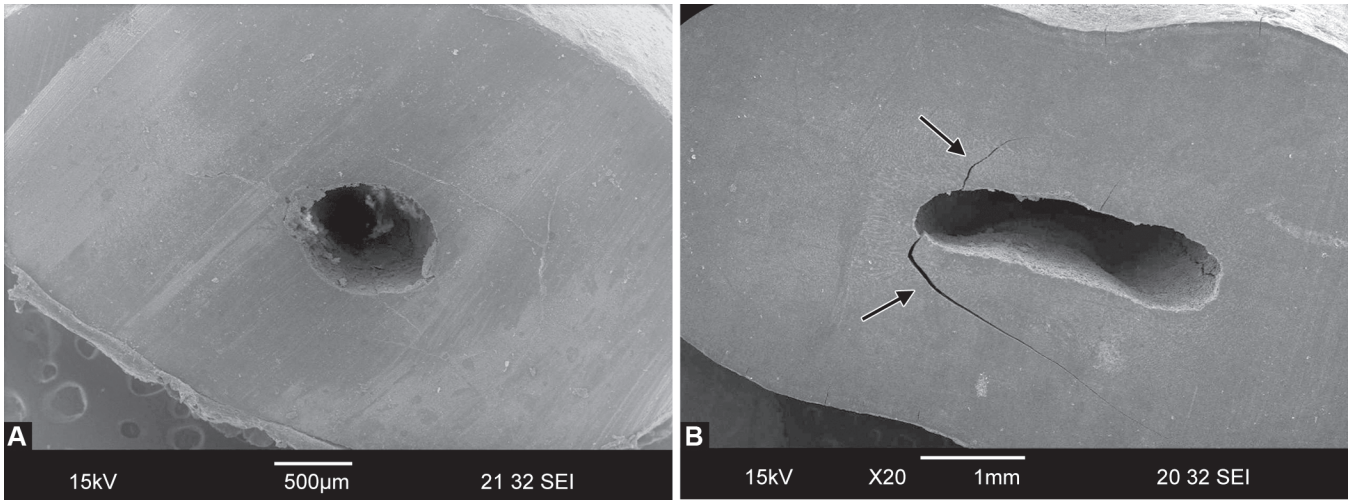


Fig. 1: No. of microcracks detected at three different levels of root canal



Figs 2A and B: SEM images at 6 mm cross-section without any dentinal defects (A) with dentinal defects (B)

($p > 0.05$). The apical section (3 mm) showed the major number of microcracks for all of the tested files (Fig. 2).

Discussion

Vertical root fracture is the most undesirable clinical experience and root canal-treated teeth present with greater probability. During preparation, a canal is shaped by the contact between instrument and dentin walls. These contacts create many momentary stress concentrations in dentin; such stress concentrations may leave dentinal microcracks in which VRF can initiate.

Higher stresses in the root during instrumentation can be expected to increase dentinal microcracks and thus increase VRF risks. Contact stress levels are determined by the mechanical behavior of files such as their cross-sectional shape, design, taper, metallurgy, as well as the kinematics.

All four single-file systems tested in this study created microcracks. This finding is in agreement with the previous reports.[19–22] The files tested had similar kinematics and taper along their length and the variables tested were the cross-sectional shape, design, and metallurgy.

All the instruments tested have been designed specifically for use in reciprocation. Compared to continuous rotation, a large rotating angle in cutting direction (CCW) and a smaller angle in the opposite direction (CW) allow the file to be immediately disengaged and safely progress along the canal path, while reducing the effect of a screwing effect and the resultant stress on dentin.[13,14] Similarly, all the instruments used have the same nominal size, tip size 25, with 0.08 taper. Taper is constant in the apical 3 mm of the instruments but reduces in the middle and coronal portion of the working part of the instrument.

WaveOne and WaveOne Gold files have modified convex triangular cross-section at the tip and a convex triangular cross-section in the middle and coronal portion of the instrument, while Reciproc and Reciproc Blue files have S-shaped cross-section with two cutting blades.

Reciproc and WaveOne files are made of a special nickel-titanium alloy called M-wire. Various metallurgical laboratory techniques (e.g., DSC, XRD, and SEM) revealed that M-wire contains the austenite phase with small amounts of martensite and R-phase at body temperature. Hence, M-wire maintains a superelastic state and two-stage stress-induced transformation through R phase, which in turn lead to increased flexibility and improved resistance to cyclic fatigue of the instruments.[23,24]

Whereas Reciproc Blue and WaveOne Gold files undergo proprietary thermomechanical heat treatment, prior to manufacturing and post machining giving the file a distinctive blue and gold color, due to the deposition of titanium dioxide, 60–80 nm and 100–120 nm, respectively.[13] This treatment controls the transition temperatures, creating a shape memory alloy, with more amount of stable martensitic phase and less Vickers hardness, which is claimed by the manufacturer to result in superior mechanical properties and performance of the Ni-Ti instruments.[25,26]

Overall Reciproc Blue and WaveOne Gold files caused significantly less microcracks than Reciproc and WaveOne; this might be attributed to their metallurgical behavior. Reciproc Blue and WaveOne Gold files are in the martensite phase during clinical use; the material is soft, ductile, and can easily be precurved, while Reciproc and WaveOne are in the austenite phase during clinical use; the material is quite hard, strong, and not prebendable, leading to a greater number of microcracks.

In this study, 3% NaOCl was used as irrigating solution; this might also have a negative effect on the property of the dentin, affecting its flexural strength and modulus of elasticity, which could in turn increase the risk of fracture due to repeated loading.

One of the limitation of the study is that sectioning of teeth was done to study the microcrack formation, as it is a destructive method, a part of the sample is lost during the cutting procedure, resulting in the evaluation of only a few samples per root and also the cracks developing on the longitudinal axis of the root could not be assessed as well as the preoperative condition of the dentin tissue. Other imaging modalities used for the detection of microcracks include endoscopy, infrared thermography, optical coherence tomography, and microcomputed tomography.

Clinically, the reported failure due to VRF is low. Vertical root fracture can result due to one or combination of the following factors: physical traumatic injury, occlusal prematurities, repetitive

parafunctional habits of heavy stressful chewing, or resorption-induced pathological root fractures.[27]

It is not clear whether all microcracks would lead to VRF, and this needs to be studied further. With the recent technological advances made in the field of imaging and their application will undoubtedly lead to a more thorough understanding of microcrack formation and development.

Conclusion

Within the limitations of the study, it could be concluded that root canal preparation with reciprocating instruments resulted in dentinal defects. Reciproc Blue and WaveOne Gold files caused less microcracks than Reciproc and WaveOne files. Heat-treated instrument produced less microcracks than M-wire instruments.

References

1. Versiani MA, Souza E, De-Deus G. Critical appraisal of studies on dentinal radicular microcracks in endodontics: methodological issues, contemporary concepts, and future perspectives. Endodon Topics 2015;33(1):87–156. DOI: 10.1111/etp.12091.
2. Tsesis I, Rosen E, Tamse A, et al. Diagnosis of vertical root fractures in endodontically treated teeth based on clinical and radiographic indices: a systematic review. J Endod 2010;36(9):1455–1458. DOI: 10.1016/j.joen.2010.05.003.
3. Kim Y, Chang S-W, Lee J-K, et al. A micro-computed tomography study of canal configuration of multiple-canalled mesiobuccal root of maxillary first molar. Clin Oral Investig 2013;17(6):1541–1546. DOI: 10.1007/s00784-012-0852-8.
4. Yoldas O, Yilmaz S, Atakan G, et al. Dentinal microcrack formation during root canal preparations by different NiTi rotary instruments and the self-adjusting file. J Endod 2012;38(2):232–235. DOI: 10.1016/j.joen.2011.10.011.
5. Sim TPC, Knowles JC, Ng Y-L, et al. Effect of sodium hypochlorite on mechanical properties of dentine and tooth surface strain. Int Endod J 2001(2):13. DOI: 10.1046/j.1365-2591.2001.00357.x.
6. Wu M-K, van der Sluis LWM, Wesselink PR. Comparison of mandibular premolars and canines with respect to their resistance to vertical root fracture. J Dent 2004;32(4):265–268. DOI: 10.1016/j.jdent.2003.12.002.
7. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. Endod Top 2006;13(1):57–83. DOI: 10.1111/j.1601-1546.2006.00201.x.
8. Kishen A, Kumar GV, Chen N-N. Stress-strain response in human dentine: rethinking fracture predilection in postcore restored teeth. Dent Traumatol 2004;20(2):90–100. DOI: 10.1111/j.1600-4469.2004.00250.x.
9. Onnink PA, Davis RD, Wayman BE. An in vitro comparison of incomplete root fractures associated with three obturation techniques. J Endod 1994;20(1):32–37. DOI: 10.1016/s0099-2399(06)80024-5.
10. Shemesh H, Bier CAS, Wu M-K, et al. The effects of canal preparation and filling on the incidence of dentinal defects. Int Endod J 2009;42(3):208–213. DOI: 10.1111/j.1365-2591.2008.01502.x.
11. Bier CAS, Shemesh H, Tanomaru-Filho M, et al. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod 2009;35(2):236–238. DOI: 10.1016/j.joen.2008.10.021.
12. Kwak SW, Lee CJ, Kim SK, et al. Comparison of screw-in forces during movement of endodontic files with different geometries, alloys, and kinetics. Mater 2019;12(9):1506. DOI: 10.3390/ma12091506.
13. Plotino G, Grande NM, Testarelli L, et al. Cyclic fatigue of reciproc and WaveOne reciprocating instruments: cyclic fatigue of reciprocating instruments. Int Endod J 2012;45(7):614–618. DOI: 10.1111/j.1365-2591.2012.02015.x.
14. Varela-Patiño P, Ibañez-Párraga A, Rivas-Mundiña B, et al. Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod 2010;36(1):157–159. DOI: 10.1016/j.joen.2009.09.023.
15. Burklein S, Hinschitza K, Dammaschke T, et al. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: reciproc and WaveOne versus Mtwo and ProTaper. Int Endod J 2012;45(5):449–461. DOI: 10.1111/j.1365-2591.2011.01996.x.
16. Berutti E, Paolino DS, Chiandussi G, et al. Root canal anatomy preservation of WaveOne reciprocating files with or without glide path. J Endod 2012;38(1):101–104. DOI: 10.1016/j.joen.2011.09.030.
17. Özyürek T, Yılmaz K, Uslu G. Shaping ability of Reciproc, WaveOne GOLD, and HyFlex EDM single-file systems in simulated S-shaped canals. J Endod 2017;43(5):805–809. DOI: 10.1016/j.joen.2016.12.010.
18. Ashwinkumar V, Krithikadatta J, Surendran S, et al. Effect of reciprocating file motion on microcrack formation in root canals: an SEM study. Int Endod J 2014;47(7):622–627. DOI: 10.1111/iej.12197.
19. Burklein STP, Schafer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. J Endod 2013;39(4):501–504. DOI: 10.1016/j.joen.2012.11.045.
20. Pawar AM, Thakur B, Kfir A, et al. Dentinal defects induced by 6 different endodontic files when used for oval root canals: an in vitro comparative study. Restorat Dentis Endodont 2019;44(3):e31. DOI: 10.5395/rde.2019.44.e31.
21. Cakici F, Cakici EB, Sadik B, et al. Comparison of newly formed microcracks after instrumentation using Protaper next, Reciproc and self-adjusting file systems. Eur Oral Res 2019;53(1):21. DOI: 10.26650/eor.201972917418.
22. Tang YH, Xu R, Zhu Q, et al. Comparison of dentinal microcracks formation in severely curved root canal with different Ni-Ti instruments. Shang J Stomatol 2019;28(6):581.
23. Alapati SB, Brantley WA, Iijima M, et al. Metallurgical characterization of a new nickel-titanium wire for rotary endodontic instruments. J Endod 2009;35(11):1589–1593. DOI: 10.1016/j.joen.2009.08.004.
24. Plotino G, Grande NM, Testarelli L, et al. Cyclic fatigue of reciproc and Reciproc blue nickel-titanium reciprocating files at different environmental temperatures. J Endod 2018;44(10):1549–1552. DOI: 10.1016/j.joen.2018.06.006.
25. Topçuoğlu HS, Düzgün S, Aktı A, et al. Laboratory comparison of cyclic fatigue resistance of WaveOne gold, Reciproc and WaveOne files in canals with a double curvature. Int Endod J 2017;50(7):713–717. DOI: 10.1111/iej.12674.
26. Zupanc J, Vahdat-Pajouh N, Schäfer E. New thermomechanically treated NiTi alloys–a review. Int Endod J 2018;51(10):1088–1103. DOI: 10.1111/iej.12924.
27. Berman LH, Hartwell GR. Diagnosis Hargreaves KM, Cohen S, ed. Pathways of the pulp. St Louis, MO, USA: Mosby Elsevier; 2011. pp. 2–39.