Original Research

Radicular dentinal microcracks during biomechanical root canal preparation using four minimally invasive endodontic files

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Abstract

Aim. The aim of the study was to compare the dentinal microcrack formation on human mandibular molars using 4 different minimally invasive file systems at 3, 6 and 9 mm from apex using a stereomicroscope.

Method. 125 mesial roots of mandibular molars were randomly divided into 5 groups and instrumented (n=25). Group 1: Control Group (CG), Group 2: Self Adjusting File (SAF), Group 3: XP-Endoshaper (XP), Group 4: TRUShape (TS), Group 5: V Taper 2H (VT). After instrumentation was completed, the roots were sectioned at 3 mm, 6 mm, and 9 mm from apex using a slow-speed circular saw. Digital images were captured using a 24x stereomicroscope by using a digital camera. Two operators independently checked each specimen for the presence of dentinal defects. Statistical comparison between the file systems was done using Chi-square ($p<0.05$).

Result. There was no statistically significant difference in the frequency of microcracks between the groups of file systems ($X2=4.509$, $p>0.05$). VT file system exhibited higher microcracks (25%) but was not statistically significantly higher than XP (12%), TRUShape (12%), and SAF (4%) endodontic file systems.

Conclusion. Within the limitations of this study, it can be concluded that all the file systems used in our research are minimally invasive files and produced few dentinal microcracks. VT files produced maximum while SAF produced the least number of micro-cracks.

Keywords: mandibular molar, microcracks, mesial root, nickel-titanium

Introduction

Vertical root fracture (VRF), is an appalling outcome of endodontic treatment, which often leads to tooth extraction [1]. Biomechanical preparation of root canal complex is an integral step in root canal procedure, however, research has shown it can lead to formation of craze line, fractures or incomplete cracks [2]. Previous research has concluded an association between nickel-titanium instrumentation (NiTi) and dentinal micro-cracks [3]. Conventional NiTi rotary or reciprocating instruments were thought to increase the incidence of defects in the root canal wall by accumulating stress on the dentin [1].

Advancement in NiTi instruments has led to minimizing structural loss during root canal procedures and are commonly known as minimally invasive files. MIE (Minimally Invasive Endodontics) is a concept of maximum preservation of the healthy tooth structure throughout endodontic therapy. The introduction of Self-Adjusting Files (SAF), gave a new dimension to the concept of MIE which effectively cleans and prepares the canal walls three-dimensionally [4]. SAF is

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made up of fine NiTi meshwork which is hollow from the inside. The application of constant delicate pressure and their highly compressible nature reduce the possibility of microcrack defect formation in the canal walls [5].

XP-Endo Shaper (XP), is a snake-shaped NiTi rotary system, which has an initial taper of 0.01 which changes to about 0.04 when the temperature is equivalent to that of the body temperature, i.e. 35° C. A final preparation size of 30/.04 can be achieved with the help of a single file system. As per the manufacturer, XP reduces the incidence of defects in the dentin as the file system applies less amount of stress on the walls, can adapt to the irregularities of the tooth wall and has increased resistance to cyclic fatigue [6].

The introduction of a novel heat-treated NiTi system rotary instrument named TRUShape 3D Conforming File (TRUShape) claims that the file has a taper of 0.8 mm which preserves more dentinal structure. This file system possesses an innovative design with a sweeping S-curve in the long axis, the instrument can shape canals to a larger envelope of Motion. TRUShape system has asymmetric triangular cross-section and a non-cutting tip and can flex within the canal and has the potential to improve the preparation of oval-shaped canals [7]. V-Taper 2H Rotary NiTi File System (VT) preserves coronal dentin by creating a deep apical shape. They have the lowest cost for shaping root canals [8].

To the best of our knowledge and literature search, no study has been reported on the incidence of dentinal microcracks that result from the use of all these minimally invasive files. Therefore, the aim of this present study was to compare the effects of using SAF, XP, TRUShape, and VT files on the incidence of dentinal defect formation using a stereomicroscope. The null hypothesis was that no difference exists in microcrack formation between all the groups.

Methods

The research work was performed in the Department of Conservative Dentistry and Endodontics following approval from the Institutional Ethical Committee (IEC/2018/21).

Sample selection

Gpower software with effect size of 0.3, alpha error probability 0.05, power at 0.77 and degree of freedom set at 4 yielded a sample size of 125. The periodontally compromised mandibular molars extracted with light force were included in the study. The selected specimens were radiographically examined to determine the curvature of root canals and pre-existing cracks under a microscope. Hand scalers were used to clean teeth. Specimens were stored in 0.1% thymol solution at room temperature. Human permanent mandibular molars with distinct mesial and distal roots were included. Only teeth with two separate and patent mesial canals and mature apices with no previous endodontic procedures were included. Teeth exhibiting curvature lesser than 20 degrees determined by Schneider's method were included in our study.

Sample preparation

Standardization was done by removing the coronal portion of the crown 15 mm from the apex of root. The access opening was refined using a 1 mm round bur (Mani Inc, Japan).

The distal root was removed using a carborundum disk. Apical patency was achieved with a size 10 K-file (Mani Inc, Japan) and then confirmed by visualizing the file tip through the apex. Reading was noted and working length was established 0.5 mm short. Glide path preparation was performed by manual K - files up to #15 and #20 K file size.

Roots were coated with silicone impression material (Zhermack Zetaplus, Italy) embedded in an acrylic resin (DPI, India) to simulate the periodontal ligament. To avoid dehydration of the samples, they were kept in distilled water at room temperature.

125 samples were numbered and divided into 5 groups randomly (n=25) depending on the type of minimally invasive files used. Randomizing software is available at www.randomizer.org

Group 1: Control Group (CG)
Group 2: Self Adjusting File (SAF)
Group 3: XP-Endoshaper (XP)
Group 4: TRUShape (TS)
Group 5: V Taper 2H (VT)

During the instrumentation, 5 ml of 5% of sodium hypochlorite (Neelkanth, India) was used as an irrigant per canal. After instrumentation was completed, the roots were sectioned at 3 mm, 6 mm, and 9 mm from the apex using a slow-speed circular saw with copious water cooling. Digital images of each sectioned root at 9, 6, and 3 mm were captured using a 24x stereomicroscope by using a digital camera. Two operators checked each specimen for the presence of dentinal defects. Only 1 crack was necessary for any section of a sample to count it as having a crack.

Statistical analysis

The data was collected in a Microsoft Excel sheet and was cross-checked for any errors. The data were then subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS, IBM version 20.0). The level of significance was set at 5% and a p-value ≤ 0.05 was considered statistically significant.

Descriptive statistics were used to find the frequencies and percentage of radicular dentinal microcracks at different sections during biomechanical root canal preparation using four minimally invasive

endodontic files. A Chi-square test was employed to compare the radicular dentinal microcracks between the file system and between the levels of radicular dentin sectioning.

Results

All the file systems produced dentinal cracks (Figure 1). There was no statistically significant difference in the frequency of microcracks between the groups of file systems (X2 = 4.509, p>0.05). VT file system exhibited higher microcracks (25%) but was not statistically significantly higher than XP (12%), TRUShape (12%), and SAF (4%) endodontic file systems. Table I compares the frequency of radicular dentin microcracks between different minimally invasive endodontic file systems using a chi-square test. Number and percentage of radicular dentinal microcracks at different sections during biomechanical root canal preparation is shown in table II.

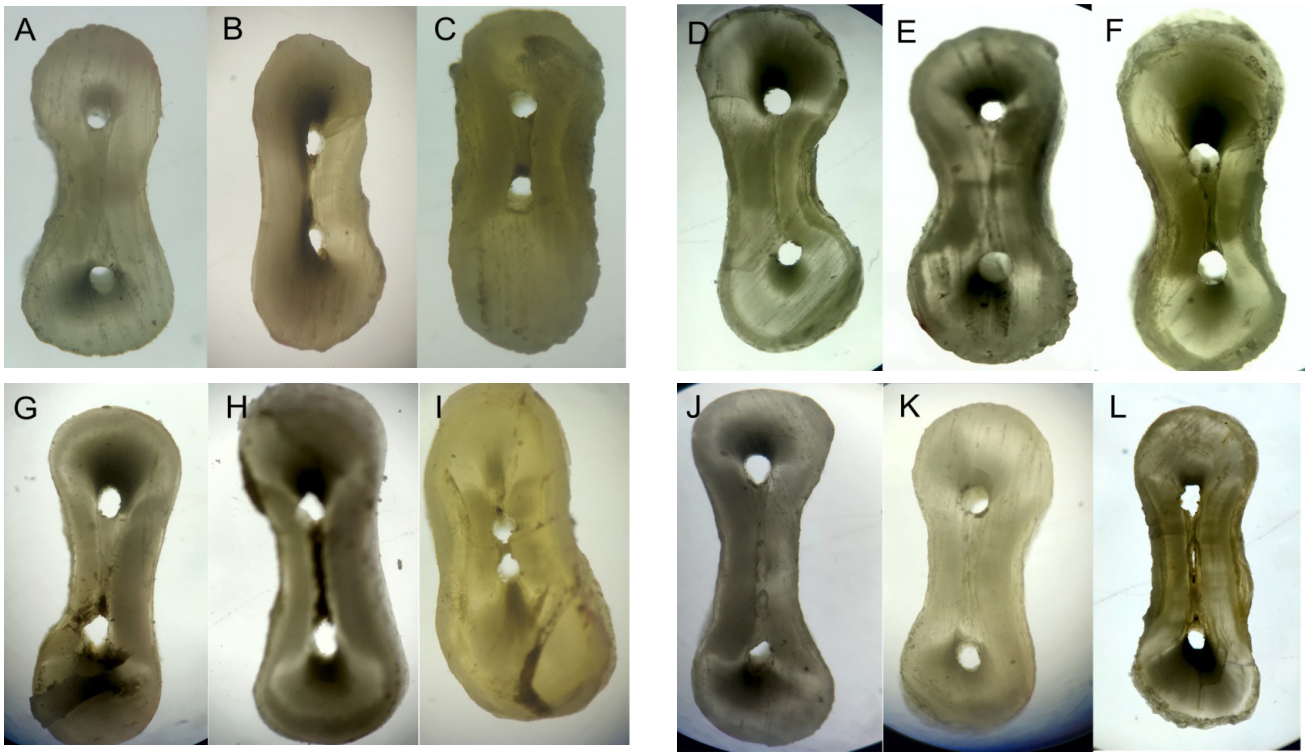

Figure 1. A), B) and **C)** showing cross-sectional images for SAF group at 9,6, and 3mm from apex. **D), E),** and **F)** showing cross-sectional images for XP group at 9, 6, and 3 mm from apex. **G), H),** and **I)** showing cross sectional images for TS group at 9, 6, and 3 mm from apex. **J), K),** and **L)** showing cross-sectional images for VT group at 9, 6, and 3 mm from apex.

Table I. Comparison of radicular dentinal microcracks among four minimally invasive endodontic files used for biomechanical root canal preparation.

File system	Cracks				Total		chi Square value	Sig.
	No cracks		Microcracks					
	n	(%)	n	(%)	N	(%)		
SAF	24	(96%)	1	(4%)	25	(100%)	4.509	0.262 (NS)
XP	22	(88%)	3	(12%)	25	(100%)		
TRU Shape	22	(88%)	3	(12%)	25	(100%)		
VT	19	(76%)	6	(24%)	25	(100%)		
Total	87	(87%)	13	(13%)	100	(100%)		

Test: Chi Square test; NS = Non Significant p>0.05

Table II. Number and percentage of radicular dentinal microcracks at different sections during biomechanical root canal preparation using four minimally invasive endodontic files.

Group	Crack	3 mm		6 mm		9 mm	
		n	(%)	n	(%)	N	(%)
Control	No crack	25	(100%)	25	(100%)	25	(100%)
	Micro crack	0	(0%)	0	(0%)	0	(0%)
SAF	No crack	25	(100%)	25	(100%)	24	(96%)
	Micro crack	0	(0%)	0	(0%)	1	(4%)
XP	No crack	25	(100%)	23	(92%)	24	(96%)
	Micro crack	0	(0%)	2	(8%)	1	(4%)
TRUShape	No crack	25	(100%)	24	(96%)	23	(92%)
	Micro Crack	0	(0%)	1	(4%)	2	(8%)
VT	No crack	25	(100%)	22	(88%)	21	(84%)
	Micro crack	0	(0%)	3	(12%)	4	(16%)

Discussion

Root canal instrumentation aims at the removal of bacterial, pulpal remnants, and other by-products while maintaining the integrity of root canal walls. This instrumentation is hypothesized to create dentinal defects [9]. The constant stress of occlusal force on dentinal craze lines and microcracks may later result in VRF [10]. Several factors are held responsible for creating dentinal defects such as instrumentation and root filling, sodium hypochlorite, tooth anatomy, and post-placement [9]. With the advancement in science and technology, numerous mechanically operated (rotated as well as reciprocating) nickel-titanium (Ni-Ti) file systems have been introduced in the field of endodontics aiming for an easier as well as effective root canal preparation. They are considered superior to stainless steel (S.S) hand files in terms of time taken for biomechanical preparation [9]. However, different cutting blade configurations, body taper, and design of tip could increase friction as well as the production of stresses within the root canal walls which may lead to the formation of microcracks that can result in VRF and then extraction [10,11].

SAF is a hollow thin NiTi lattice that is flexible and compressible. It does not have flutes or cutting edge. It produces vibrating movements which scrape dentin like sandpaper and enlarge the root canal with an up-and-down grinding motion. A continuous flow of irrigating agents facilitates the effect of cleaning and debridement and minimizes friction. It has a 3-dimensional adaptation to the root canal, applying constant delicate pressure on the root canal wall, which can reduce chances of over-preparation or weakening of the canal wall [12].

XP is a snake-shaped single file system with a continuous rotary movement [13]. It is manufactured from a special alloy known as MaxWire (Martensite-Austenite Electropolishing-Flex). Because of this new alloy, the shape of the file changes according to temperature, it changes from martensitic form to austenite phase, at a temperature equal or greater than 35ºC which changes the shape of the instrument into semicircular and thus adapt well against root canal wall while rotating and performing the eccentric motion. They contract or expand while advancing in the root canal for proper adaptation. According to the manufacturer, it has a unique geometry because of Booster tip, and has an initial diameter of ISO 15, which gradually increases to a diameter of ISO 30 and 1% taper, and can expand canal preparation corresponding to #30/.04 to adapt to the root canal [6]. Because of the smaller taper, these files are flexible and produce less dentinal stress, and can easily adapt to canal irregularities [14].

TRUShape is a novel heat-treated Ni-Ti rotary instrument. In this, a new heating process has been used after file machining, which will help to modify the crystalline phase and to subdue defects because of the machining process. The heating process has been applied after flutes are grounded into blanks from commercially available NiTi to set the file into characteristic bends. Temperature is about 300° C for 1 min to set the portion of the shaft and forming a non-linear shape. It is designed with a maximum fluted diameter of 0.8 mm and has a symmetrical triangular cross-section with a non-cutting tip [15]. It has a sweeping S-shaped curve with a decreasing taper and its apical 2 mm taper is 0.06. Its unique shape provides it with the ability to flex in the canal, so it can flex in the canal and can shape the root canal into a larger envelope of motion. This attempts to decrease coronal shape size and preserve bulk dentin and provide optimized canal debridement [16].

VT are controlled memory (CM) wire files with variable taper which creates deep apical shaping and conservative coronal preparation and preserves more healthy tooth structure at the heart of teeth i.e at the pericervical area. It is flexible, conservative, and efficient, designed parabolic cross-section, which makes it safe and resistant to fracture. Due to its lesser cross-sectional area

and decrease diameter of the shaft, VT showed reduced canal transportation and more canal centering ability [8].

In the present study, mesial roots of mandibular molars with mild and moderate curvatures (< 25 degrees) were taken for biomechanical preparation and evaluation of cracks because they have complex anatomies and curvature, which makes them difficult for a clinician during preparation [17]. These canals have constricted anatomy that may increase stress on the surface of dentin during preparation and, thus may increase the risk of crack formation [18].

In the current research, standardization was achieved by equalizing the length of the sample to 15 mm. In our research, during the entire procedure, except for the preparation time, all the teeth were kept in 0.1% thymol solution. Study have revealed that thymol solution can be used to store the teeth for 2 months without significantly altering the hardness of the tooth, thereby, not influencing the outcome of this research [20].

Silicon impression material and acrylic blocks were used to simulate periodontal ligament and bone since they act as major stress absorbers and can also influence the result of the studies. respectively, as reported in previous studies [4,11].

In this study, concurring previous reports, teeth were sectioned using an isometric saw under copious water cooling at different levels and then observed at 24x magnification under a stereomicroscope for evaluating microcracks [18,19].

The sectioning method has a disadvantage because of its destructive nature and possible microcracks generated by sectioning [20,21]. However, in our research, we evaluate that it did not happen because no microcrack was found in the control group, we may conclude that the defects seen were because of the canal preparation procedure. The sectioning method has also been used in previous studies utilizing micro-computed tomography before and after biomechanical preparation which confirmed it did not create micro-cracks [11].

A stereomicroscope was the most used tool for visualization of microcracks after horizontal sectioning of the tooth using a slow-speed circular saw. A microscope is an optical instrument that uses a lens or a combination of lenses and produces magnified images of small objects not seen by the naked eye. Studies for evaluating dentinal cracks using stereomicroscope were conducted using original magnification ranging from 9x up to 100x under high-level illumination [22]. The advantages of this method include a vast range of clinical research and a broad range of magnifications that can be used for visualization. Considering various advantages, disadvantages, and feasibility, we have employed the sectioning method followed by visualization under magnification with a stereomicroscope for our research.

The Control group showed no cracks, which indicates that the cracks were induced as a result of preparation by endodontic file systems and not due to the sectioning method. In our research, SAF produced low cracks compared to other groups. The reason may be its sandpaper-like movement that may result in less damage to dentin and less concentration of stress in the root canal. This is in accordance with the previous study by Yoldas et al. [4] who found no cracks in samples prepared with SAF. This may be due to ability of SAF system to adjust to canal and trying to regain the space by applying delicate pressure during preparation.

The taper of preparation may contribute to the formation of dentinal microcracks, as more dentin is removed, chances of crack formation are increased [27]. VT has a larger taper of 6%, which could explain a higher incidence of microcracks formation as compared to XP (4%), and SAF has no taper. The smaller taper of XP makes the file more flexible and generates less stress [23]. Smaller taper of files have shown to increase the vertical root fracture resistance of root canal treated teeth [24]. In our study, TRUShape has shown fewer cracks as in accordance with the previous study [2] due to its unique S-curve shape and novel heat treatment.

In this study at 3 mm sectioning, no file system showed any sign of microcracks. But at 6 mm sectioning, a higher percentage of microcrack was visible with VT (12%) file systems followed by XP-Endo (8%) and TRUShape (4%) system. At 9 mm, 16% of VT showed radicular dentinal cracks that were considerably more than TRUShape (8%) files. SAF and XP showed microcracks in about 4%. Cracks were not found in the apical 3 mm with all file systems. This may be because stresses generated at 1 mm short of apical foramen were only one-third of stress concentration at coronal third [25].

Saber and Schafer [26] found an incidence of 26% microcracks when instrumented with the Reciproc system. According to Sankhe [27] dentinal defects produced by Protaper Universal were 57.14%. In our study, overall crack produced by minimally invasive files is 13%, which is less compared to other file system used in previous studies. The limitation of this study is that it is an in-vitro study that may or may not simulate similar oral conditions.

The result of this study suggests that new minimally invasive file system may be less likely to cause microcracks than traditional NiTi file systems.

Conclusions

Within the limitations of this study, it can be concluded that all the file systems used in our research are minimally invasive files and produced few dentinal microcracks.

There was no significant difference in the frequency of microcracks between the group of file systems. VT files produced maximum while SAF produced the least number of micro-cracks.

References

1. Yoshino K, Ito K, Kuroda M, Sugihara N. Prevalence of vertical root fracture as the reason for tooth extraction in dental clinics. Clin Oral Investig. 2015;19:1405-1409.
2. 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;42:208-213.
3. Pandey SH, Patni PM, Jain P, Raghuwanshi S, Sanwatsarkar G, Chaturvedi A. Light emitting diode assessment of dentinal microcracks after root canal preparation with 4 different heat-treated file systems. Minerva Dent Oral Sci. 2021;70:257-262.
4. 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;38:232-235.
5. Plotino G, Giansiracusa Rubini A, Grande NM, Testarelli L, Gambarini G. Cutting efficiency of Reciproc and waveOne reciprocating instruments. J Endod. 2014;40:1228-1230.
6. Gu Y, Kum KY, Perinpanayagam H, Kim C, Kum DJ, Lim SM, et al. Various heat-treated nickel-titanium rotary instruments evaluated in S-shaped simulated resin canals. J Dent Sci. 2017;12:14-20.
7. Ebihara A, Yahata Y, Miyara K, Nakano K, Hayashi Y, Suda H. Heat treatment of nickel-titanium rotary endodontic instruments: effects on bending properties and shaping abilities. Int Endod J. 2011;44:843-849.
8. Oliveira JP, Miranda RM, Braz Fernandes FM. Welding and Joining of NiTi Shape Memory Alloys: A Review. Progress in Materials Science. 2017;88:412-466.
9. PradeepKumar AR, Shemesh H, Chang JW, Bhowmik A, Sibi S, Gopikrishna V, et al. Preexisting Dentinal Microcracks in Nonendodontically Treated Teeth: An Ex Vivo Micro-computed Tomographic Analysis. J Endod. 2017;43:896-900.
10. Goo HJ, Kwak SW, Ha JH, Pedullà E, Kim HC. Mechanical Properties of Various Heat-treated Nickel-titanium Rotary Instruments. J Endod. 2017;43:1872-1877.
11. 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;15:494-499.
12. 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;39:1054-1056.
13. Uslu G, Özyürek T, Yılmaz K, Gündoğar M, Plotino G. Apically Extruded Debris during Root Canal Instrumentation with Reciproc Blue, HyFlex EDM, and XP-endo Shaper Nickel-titanium Files. J Endod. 2018;44:856-859.
14. Silva EJNL, Vieira VTL, Belladonna FG, Zuolo AS, Antunes HDS, Cavalcante DM, et al. Cyclic and Torsional Fatigue Resistance of XP-endo Shaper and TRUShape Instruments. J Endod. 2018;44:168-172.
15. Peters OA, Arias A, Paqué F. A Micro-computed Tomographic Assessment of Root Canal Preparation with a Novel Instrument, TRUShape, in Mesial Roots of Mandibular Molars. J Endod. 2015;41:1545-1550.
16. Bayram HM, Bayram E, Ocak M, Uzuner MB, Geneci F, Celik HH. Micro-computed Tomographic Evaluation of Dentinal Microcrack Formation after Using New Heat-treated Nickel-titanium Systems. J Endod. 2017;43:1736-1739.
17. Uğur Aydın Z, Keskin NB, Özyürek T. Effect of Reciproc blue, XP-endo shaper, and WaveOne gold instruments on dentinal microcrack formation: A micro-computed tomographic evaluation. Microsc Res Tech. 2019;82:856-860.
18. 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;40:1443-1446.
19. Pedullà E, Genovesi F, Rapisarda S, La Rosa GR, Grande NM, Plotino G, et al. Effects of 6 Single-File Systems on Dentinal Crack Formation. J Endod. 2017;43:456-461.
20. De-Deus G, Belladonna FG, Souza EM, Silva EJ, Neves Ade A, Alves H, et al. Micro-computed Tomographic Assessment on the Effect of ProTaper Next and Twisted File Adaptive Systems on Dentinal Cracks. J Endod. 2015;41:1116-1119.
21. De-Deus G, Silva EJ, Marins J, Souza E, Neves Ade A, Gonçalves Belladonna F, et al. Lack of causal relationship between dentinal microcracks and root canal preparation with reciprocation systems. J Endod. 2014;40:1447-1450.
22. Versiani MA, Souza E, De-Deus G. Critical appraisal of studies on dentinal radicular microcracks in endodontics: methodological issues, contemporary concepts, and future perspectives. Endodontic Topics. 2015;33:87-156.
23. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod. 2009;35:236-238.
24. Lin GSS, Singbal KP, Noorani TY, Penukonda R. Vertical root fracture resistance and dentinal crack formation of root canal-treated teeth instrumented with different nickel–titanium rotary systems: an in-vitro study. Odontology. 2022;110:106-112.
25. Versluis A, Messer HH, Pintado MR. Changes in compaction stress distributions in roots resulting from canal preparation. Int Endod J. 2006;39:931-939.
26. Saber SE, Schäfer E. Incidence of dentinal defects after preparation of severely curved root canals using the Reciproc single-file system with and without prior creation of a glide path. Int Endod J. 2016;49:1057-1064.
27. Sankhe D. Evaluation of effect of Hyflex EDM on root dentin during root canal preparation-a stereomicroscopic study. Int J Med Dent Sci. 2017;6:1525.