A Comparative Evaluation of Root Microcracks Formation after Root Canal Preparation with Various Rotary and Reciprocating File Systems-A Stereomicroscopic Study

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Abstract

Aim: The aim of this study is to evaluate and compare dentinal microcracks formation during root canal preparation by different commercially available nickel-titanium (NiTi) file systems.

Materials and Method: Ninety freshly extracted permanent single-rooted teeth were selected. All specimens were decoronated and divided into six groups of 15 each. Teeth were mounted in the acrylic block to simulate periodontal ligaments. Fifteen teeth served as a control in which no treatment was performed. Experimental groups were instrumented with TruNatomy rotary files, ProTaper rotary files, WaveOne Gold in rotary motion, WaveOne Gold in reciprocating files, Reciproc Blue file systems. Roots were then sectioned 3 and 6 mm from the apex, and the cut surface was observed under a stereomicroscope and checked for the presence or absence of dentinal microcracks.

Results: Chi square analysis displays a statistically significant higher cracks were noted in group 5 (6.7%) when compared to other groups ($\chi2$ value =79.83; P=0.001).

and least cracks were noted in Group 1 when compared to other groups at 3mm from Apex. A statistically significant higher cracks were noted in group 4 (6.7%) when compared to other groups ($\chi 2$ value =79.83; P=0.001). and least cracks were noted in Group 1 (93.3%) when compared to other groups at 6mm from Apex.

Conclusion: All the files created microcracks in the root dentin at the two levels with ProTaper Gold and Reciproc Blue showing highest no. of cracks whereas TruNatomy and single file systems presented with satisfactory results with least microcracks.

Keywords: Dentinal microcracks, root canal preparation, TruNatomy, ProTaper Gold, WaveOne Gold, Reciproc Blue

Introduction

In order to save a patient's natural tooth structure and function, root canal treatment removes infected or diseased pulp tissue and replaces it with healthy pulp tissue. The purpose of endodontic instrumentation is to enlarge the canal diameter, therefore removing germs, debris, and tissue; to provide a canal space for medicament administration; and to optimize the canal geometry for proper obturation.[1] The success of endodontic therapy is correlated favorably with the adherence to best practices for cleaning and shaping. Root canal tools used for shaping should make as much surface area contact with the canal walls as possible for optimal disinfection, but the remaining root structure should be robust.[2-4] For many years, stainless-steel devices have been the standard of care for canal preparations. Manual stainless-steel file preparation of narrow, curved canals is laborious and results in insufficient apical expansion, limiting the efficiency of irrigation and obturation. There has been a rise in the number of commercially available proprietary systems for nickel titanium (NiTi) rotary instruments during the past decade. The primary benefits of NiTi files are their increased adaptability and decreased processing time. By the mid-1990s, NiTi instruments were finally being made available to the public. The active blades of the first NiTi files (such as the ProFile, Quantec, and GT files) were tapered at a set 4% and 6% over their whole length. The second generation of NiTi, including the Endosequence, ProTaper, and BioRace, had active cutting edges and reduced the number of tools needed to properly prepare a canal. The third generation of mechanical shaping files is distinguished by advancements in NiTi metallurgy. Manufacturers of rotary NiTi tools (such as the Twisted File, Hyflex CM, GT, Vortex, and WaveOne) have focused on the use of heating and cooling technologies to minimize cycle wear and increase safety when working in increasingly curved canals since 2007.[1,5-9] Reciprocation, which can be a repeated up-and-down or back-and-forth action, is afourth- generation breakthrough in canal preparation techniques. The current generation of instruments and supporting technologies has essentially realized the long-held promise of the single-file approach. The self-adjusting file (SAF) has a stroke of 0.4 mm in the vertical direction and vibrates with a constant watering rate. The mass and/or the axis of rotation are offset in the fifth-generation files. Commercial file brands like Revo S, ProTaper Next, OneShape, and Silk all include variants of this technology.[10-15] Root dentin damage during instrumentation is inevitable at times and can lead to dentinal cracks and minute delicate fractures, which in turn can cause treatment to fail. Occlusal stresses can cause root fracture if a microcrack or craze line develops in the root and then spreads with continued tension. Therefore this study was conducted to compare and contrast the frequency with which root microcracks formed during root canal preparation using different rotary and reciprocating file systems currently available in the market.

Aim and Objectives

The aim of this study is to compare and evaluate the frequency with which root microcracks formed during root canal preparation using different rotary and reciprocating file systems currently available in the market. The objectives of the study were a) the purpose of using a stereomicroscope following root canal preparation using different rotary and reciprocating file systems in the market is to examine the dentinal microcracks in the root canal wall and the apical region, b) the purpose of this study is to compare the number of microcracks formed in the root canal wall and the apical root surface after root canal preparation using various rotary and reciprocating file systems.

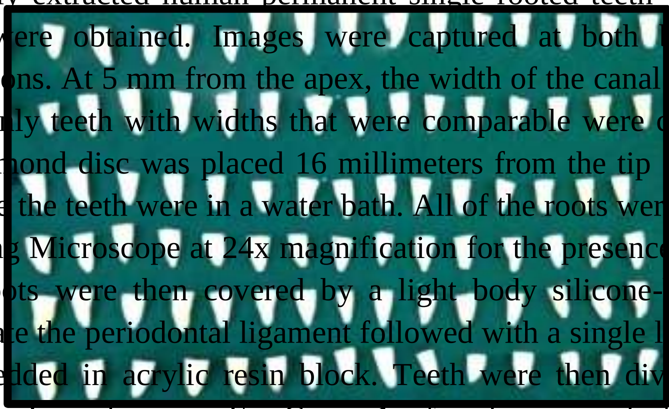
Materials and Method

The study was an in vitro investigation using single-rooted human teeth for this study. Samples were obtained from the Oral and Maxillofacial Surgery Outpatient Clinic. The Institutional Ethical Committee and the Scientific Committee both gave their approval for this project to proceed. A total of ninety freshly extracted single rooted teeth are chosen for this study to observe the dentinal microcracks in the root canal wall and to determine whether there was any significant difference in the number of microcracks formation in the root canal wall and the apical root surface after root canal preparation by different rotary and reciprocating file systems. Ninety permanent single rooted maxillary and mandibular incisors, canines, and premolars were selected. Sample size for each group was fifteen (n=15). Root microcracks observed in the samples were defined by dividing them into two different categories. They were samples with no cracks (absent) and samples with cracks (Present).

Table 1: Grouping Details

Group	System Used
1	Control group
2	BMP by TruNatomy rotary file system
3	BMP by WaveOne Gold files in reciprocatingmotion
4	BMP by ProTaper Gold rotary file system
5	BMP by RECIPROC Blue files
6	BMP by WaveOne Gold files in rotary motion

Study Design and Methodology



90 (ninety) freshly extracted human permanent single rooted teeth with single and straight canals were obtained. Images were captured at both buccolingual and mesiodistal positions. At 5 mm from the apex, the width of the canal was measured on both sides, and only teeth with widths that were comparable were chosen for further treatment. A diamond disc was placed 16 millimeters from the tip of each tooth and decoronated while the teeth were in a water bath. All of the roots were examined under a Dental Operating Microscope at 24x magnification for the presence of craze lines or fractures. The roots were then covered by a light body silicone-based impression material to simulate the periodontal ligament followed with a single layer of aluminum foil and be embedded in acrylic resin block. Teeth were then divided in 6 groups having 15 samples in each group. For Group 1, after the removal of the gross pulpal tissue, the working length of the canal was determined by inserting the #10 hand stainless steel K-file (Fifteen specimens) into the canal until the apical foramen was barely visible and then deducting 1 mm. For Group 2, the canals were shaped to a maximum size of F2 (25/0.08) with the use of a ProTaper Gold rotating file system. The Endomotor was then utilized to rotate a ProGlider Glide Path at 300 rpm with a torque of 2 N.cm. It was prepared in crown down approach. A hand file of size #10/0.02 K was employed until the estimated working length in filing was reached. The canals were irrigated with a 3% sodium hypochlorite solution. For Group 3 & 4, canals were prepared using a Primary (25/0.07) file using a WaveOne Gold reciprocating file system. A stainless steel hand file of size #10/0.02 K was used. Endomotor was then used to rotate a ProGlider Glide Path. Canals were then prepared using a Primary file in a crown-down, reciprocating motion using a previously specified WaveOne setting followed by irrigation. For Group 5, the canals were filed with a TruNatomy rotating file system. Stainless steel hands file of size #10/0.02 K in a watch- winding motion. Endomotor was utilized to rotate ProGlider Glide Path at 500 rpm followed by irrigation. For Group 6, canals were cleaned and disinfected using RECIPROC blue. Using a rotary motion and NiTiflex files, the canals were created. A Reciproc file of size #25 and.08 taper was employed continuously at a rate of 300 revolutions per minute. The apical foramen was then accessed using the "reciprocal" setting on a Reciproc blue file of size #25.08 taper. Using a diamond disc and a steady stream of water for cooling, we made horizontal cuts 3 and 6 mm from the root tip on allof the roots. All of the samples were sectioned, and then dyed with 1% Methylene blue dye to make finding cracks easier. The sections were then examined at 20 times magnification using a stereomicroscope. Digital photographs recorded the occurrence of fractures.

Fig 1: 90 (Ninety) Sample Teeth

Fig 2: Stereomicroscopic Image of Marked Mounted Tooth

Fig 3: Mounted Tooth inAcrylic Resin Block

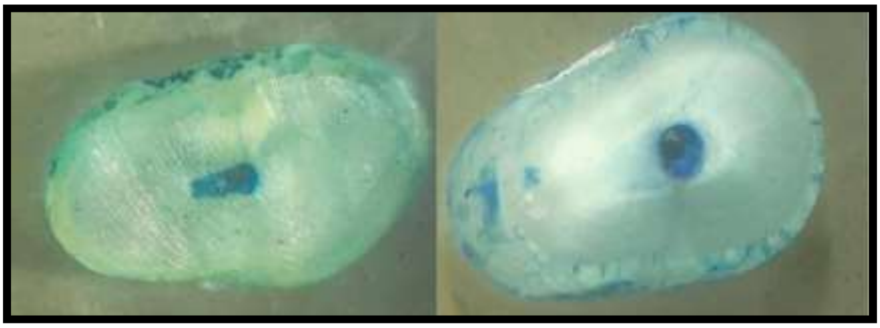


Fig 4: Group 1- Control Group Sections At 3mm, 6mm From The Apex

Fig 5: Group 2- TruNatomy Sections At 3mm, 6mm From The Apex

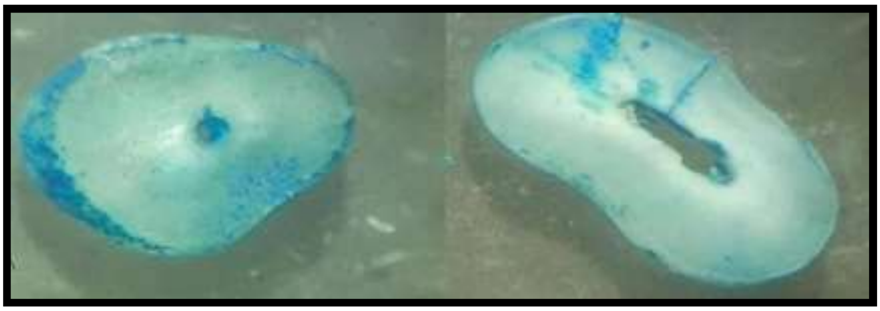


Fig 6: Group 3- WaveOne Gold (Reciprocating Motion) SectionsAt 3mm, 6mm FromThe Apex

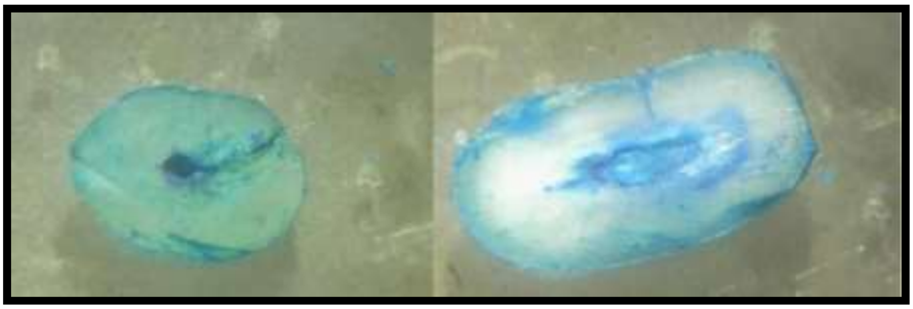


Fig 7: Group 4- ProTaper Gold Sections At 3mm, 6mm From The Apex

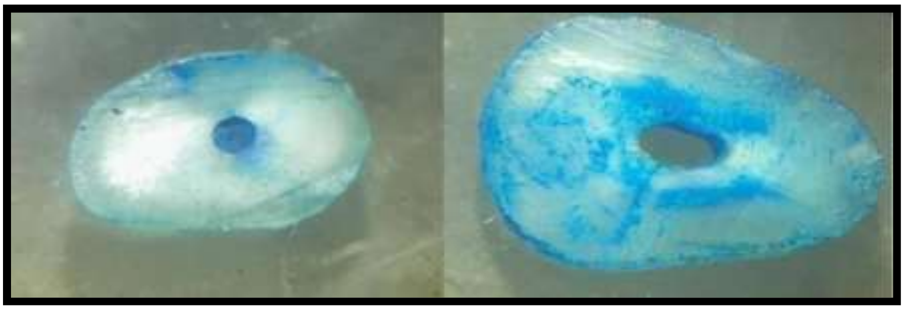


Fig 8: Group 5- Reciproc Blue Sections AT 3mm, 6mm From The Apex

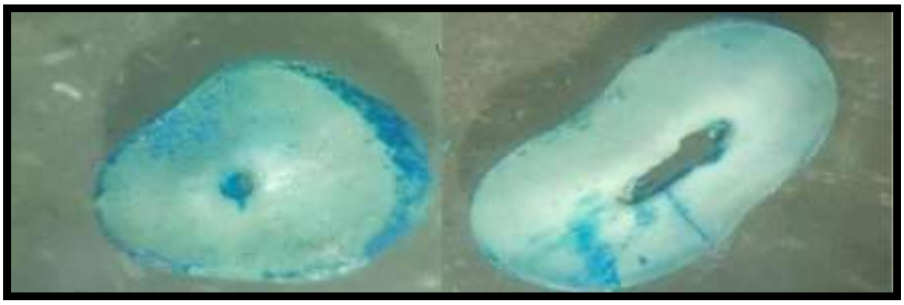


Fig 9: Group 6- WaveOne Gold (Rotary Motion) Sections AT 3mm,6mm From The Apex

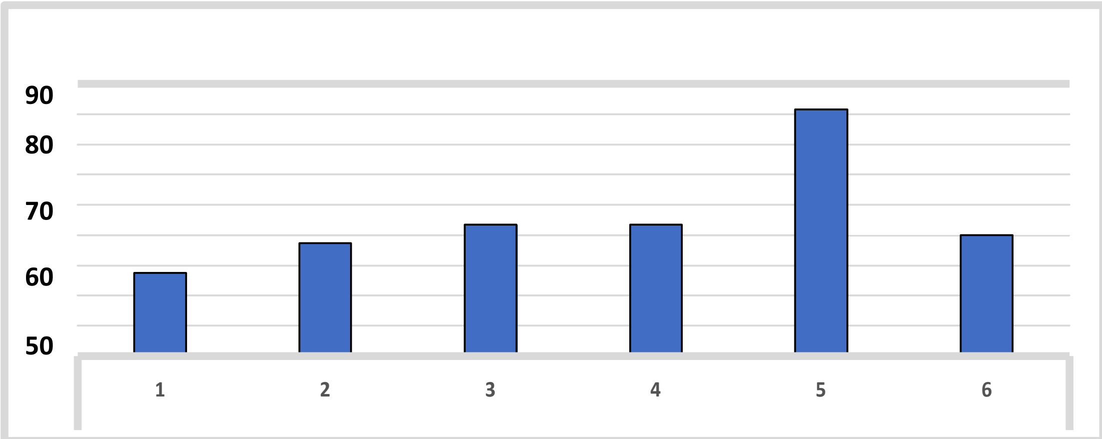
Results and Analysis

Krushkal Wallis test displays a statistically significant difference in number of cracks between different groups at 3 mm and 6 mm from apex. ($P<0.05$). Mann-Whitney U test displays no statistically significant difference between group 1 and group 2 at 3 mm and 6 mm from apex. (P>0.05). Mann-Whitney U test displays no statistically significant difference between group 1 and group 3 at 3 mm and 6 mm from apex. (P>0.05). Mann- Whitney U test displays no statistically significant difference between group 1 and group 4 at 3 mm (P>0.05) and a statistically significant higher mean rank among group 4 when compared to group 1 at 6 mm from apex (P<0.05). Mann-Whitney U test displays a statistically significant higher mean rank among group 5 when compared to group 1 at 3 mm and 6 mm from apex (P>0.05). Mann-Whitney U test displays no statistically significant difference between group 1 and group 6 at 3 mm and 6 mm from apex. (P>0.05) Mann-Whitney U test displays no statistically significant difference between group 2 and group 3 at 3 mm and 6 mm from apex. (P>0.05) Mann-Whitney U test displays no statistically significant difference between group 2 and group 4 at 3 mm (P>0.05) and a statistically significant higher mean rank among group 4 when compared to group 2 at 6 mm from apex. (P<0.05) Mann-Whitney U test displays a statistically significant higher mean rank among group 5 when compared to group 1 at 3 mm and 6 mm from apex. (P<0.05) Mann-Whitney U test displays no statistically significant difference between group 2 and group 3 at 3 mm and 6 mm from apex. (P>0.05) Mann- Whitney U test displays no statistically significant difference between group 3 and group 4 at 3 mm (P>0.05) and a statistically significant higher mean rank among group 4 when compared to group 3 at 6 mm from apex. Mann-Whitney U test displays no statistically significant difference between group 3 and group 6 at 3 mm and 6 mm from apex. (P>0.05) Mann-Whitney U test displays a statistically significant higher mean rank among group 5 when compared to group 4 at 3 mm from apex. (P<0.05) whereas group 4 displayed a statistically significant higher mean rank when compared to group 5. (P<0.05) Mann-Whitney U test displays no statistically significant difference between group 4 and group 6 at 3 mm (P>0.05) and a statistically significant higher mean rank among group 4 when compared to group 6 at 6 mm from apex. (P<0.05) Mann-Whitney U test displays a statistically significant higher mean rank among group 5 when compared to group 6 at 3 mm and 6 mm from apex. (P<0.05) Chi square analysis displays a statistically significant higher cracks were noted in group 5 (6.7%) when compared to other groups ($\chi 2$ value =79.83; P=0.001). and least cracks were noted in Group 1 when compared to other groups at 3mm from Apex. A statistically significant higher cracks were noted in group 4 (6.7%) when compared to other groups ($\chi 2$ value =79.83; P=0.001). and least cracks were noted in Group 1 (93.3%) when compared to other groups at 6mm from Apex.

Table: 1 Comparison of no. of cracks between different groups at 3,6mm mmfrom apex

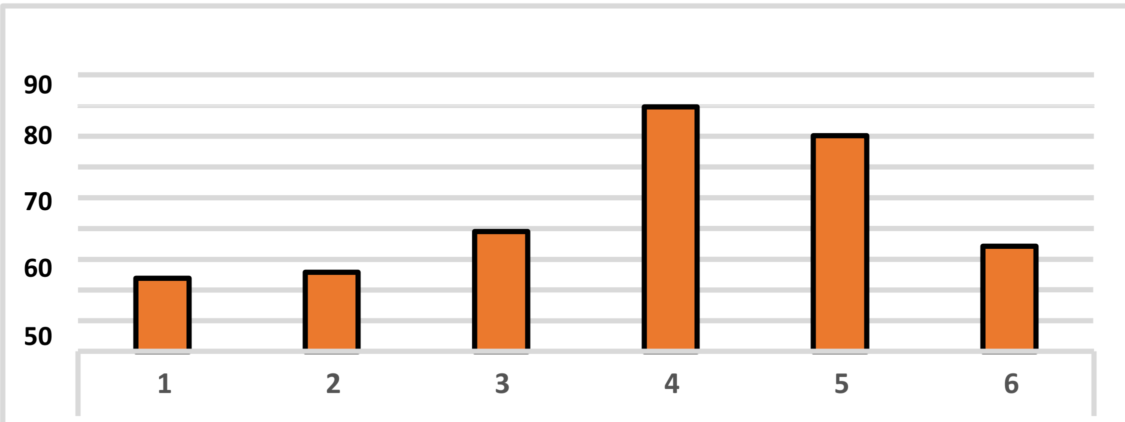
	Groups	N	Mean Rank	P value
	1	15	27.47	
	2	15	37.33	

3mm from apex	3	15	43.43	**<0.001***
	4	15	43.43	
	5	15	81.53	
	6	15	39.8	
6mm from apex	1	15	23.9	**<0.001***
	2	15	25.8	
	3	15	39.07	
	4	15	79.63	
	5	15	70.27	
	6	15	34.33	
*Statistical significance set at 0.05; N: Number of samples				



Graph 1: Graph showing cracks (n) between different groups at 3mm fromapex.

Graph 2: Graph showing cracks (n) between different groups at 6mm fromapex



Discussion

In comparison to traditional hand instrumentation, rotary nickel titanium tools have transformed root canal therapy by decreasing operator fatigue, shortening the time

needed to finish the preparation, and lowering the risk of procedural mistakes. Too much dentin is removed during radial root canal instrumentation, which can lead to increased stress and friction on the canal walls and the development of microscopic fissures or craze lines in the dentin.[16-19] Because root canal treatment success might be negatively impacted by root abnormalities brought on by instrumentation, resistance to root fracture is a crucial prognostic feature. New combinations and designs for rotational NiTi devices have made root canal shaping simpler, quicker, and more precise.[20-23] This study is necessary since there is a lack of information comparing the development of dentinal microcracks with the use of traditional files and the newer ones. All teeth were checked for pre-existing cracks or fractures in this investigation. Because some of these flaws may be internal and not apparent outwardly, it may be difficult to rule them out before the beginning of the trial. However, there were no microcracks in the control group, indicating that the microcracks seen were due to the preparation operations using NiTi rotary files.[24-29] In their study of endodontic preparation techniques they advocated using a silicone rubber-based impression material to simulate periodontal ligament because it is dependable and will aid in force distribution around the tooth when external pressures are applied. In order to standardize the root length, the sample teeth were decoronated at the level of 16 mm, roughly corresponding with the cemento-enamel junction (CEJ). The instrument's contact with the canal walls causes transient stress concentrations in the dentin, which might cause dentinal flaws that can trigger a vertical root fracture.[30-32] The shape of the instrument's tip, cross section, taper, pitch, and flutes may all have a role in the initiation of microcracks. The control group in the current study did not develop any microcracks. Root dentin was relatively unharmed by manual instrumentation using stainless steel hand files (0.02) because of the files' less abrasive motions in the canals than those of motorized files. The current study found that, compared to the other groups, the stainless steel file group caused the fewest microcracks on the sample teeth, making it the best. In order to separate the impacts of motion kinematics on dentinal microcrack development, this experiment compared instruments of the latest Ni Ti
generation that share a comparable taper and manufacturing process.[33-36] The majority of commercial preparation systems are not interchangeable since they all use various designs, kinematics, endodontic motors, and variable tapers. This means there is not much room for uniformity in the methods used for food preparation. That's why it's important to use the same quantity and quality of tools in subsequent research. Root fractures in the vertical plane are an unusual but possible consequence of root canal therapy. No one can agree on whether or not all microcracks result in vertical root fractures. Further research is also required to determine how the observed dentinal abnormalities would affect the tooth's long-term prognosis. In this work, bone and periodontal ligament were modeled using acrylic blocks and a silicone- based substance, although these materials' viscoelastic characteristics are not identical to those of real periodontal ligament. In order to assess whether or

not microcracks existed in various sections of the root canals, a sectioning technique was applied. Unfortunately, the present investigation may have been limited in its ability to assess the occurrence of microcracks in various root canal segments due to the destructive nature of the sectioning procedure. Few have postulated that the shape of the cannelure, as well as other factors including the geometry of the tip of the rotary instrument, the type of taper (constant vs. gradual), the number of steps in the taper,and whether the taper is constant or variable, all played a role in the development of dentinal microcracks. Methylene blue dye use during root canal preparation was beneficial in distinguishing instrumentation flaws from natural tissue damage. Wright et al. suggested methylene blue dye because its tiny dye molecules allowed for greater and deeper penetration into the fractures than the others. Therefore, methylene blue was employed to detect microcracks in the dentin in this investigation. Dentinal microcracks were not seen in the untreated control group when tissue was sectioned. Many have found similar results, therefore this supported their work.[37-38] A chemical solution is necessary for both biomechanical instrumentation and root canal cleaning. Another potential drawback of the current investigation is its inability to standardize speed and torque parameters among file systems. The downward force applied during instrumentation also proved difficult to standardize. It is possible that the teeth mounted on resin blocks don't accurately reflect the clinical appearance since they have straight root canals and no anatomical complexity. The use of resin blocks might cause the material to warm up and soften. Since very fewer studies were done with TruNatomy and Reciproc Blue file systems, so it is necessary to conduct additional researches using these two file systems as any recent advancement which comes up needs to be tested in a similar fashion.

Conclusion

Within the limitations of this in- vitro study, the instrumentation of root canals with ProTaper Gold and Reciproc Blue cause more crack formation in root canal dentin. The TruNatomy file systems have a tendency to cause fewer dentinal cracks whereas crack formation using WaveOne Gold file system (both in rotary and reciprocating motion) showed no significance difference.

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