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In vitro comparative evaluation of dentinal microcracks during root canal instrumentation using rotary and reciprocating file systems with FESEM analysis

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Abstract:
Root canal instrumentation may induce dentinal microcracks, yet comparative evidence across rotary and reciprocating file systems remains limited. Therefore, it is of interest to evaluate the 80 extracted premolars instrumented with ProTaper Gold, TruNatomy, WaveOne Gold, or Reciproc Blue, with FESEM assessment at 3 mm, 6 mm and 9 mm levels. All systems produced microcracks, but ProTaper Gold showed the highest incidence, followed by TruNatomy, while WaveOne Gold and Reciproc Blue showed fewer defects. Reciproc Blue showed the lowest microcrack occurrence across all root levels. Thus, data shows that reciprocating systems, especially Reciproc Blue, may better preserve dentinal integrity during root canal preparation.

Keywords: Dentinal microcracks, root canal instrumentation, rotary files, reciprocating files

Background:

Endodontic files and root canal irrigants are used to instrument the root canals adequately, clean the root canal space and then obturate the whole root canal system in three dimensions as part of root canal treatment. This process removes bacteria and residual sick organic and inorganic debris **[1]**. Endodontic files create craze lines and microcracks when they come into touch with the root canal's dentinal walls during biomechanical preparation **[1]**. The use of Ni-Ti (Nickel-Titanium) files for root canal instrumentation may cause cracks to develop on the root canal dentin. This, in turn, can cause occlusal stress, which can lead to vertical root fractures **[2].** The quantity of root canal dentin removed correlates directly with the production of microcracks, which in turn leads to VRF **[3]**. Endodontically treated teeth showed long-term functional survival rate but are more prone to fracture compared to vital teeth **[4]**. Bier *et al.* **[2]** and Milani *et al.* **[5]** reported that root fracture do not happen instantly, but rather a gradual propagation of tiny, less pronounced craze lines in tooth structure. According to Kim *et al.* **[6]**, who found a correlation between the design of Ni-Ti files and the frequency of VRFs, the design of the files leads to the buildup of tensile stresses on the root canal dentin when the canal is being instrumented. There have been many changes to endodontic Ni-Ti file systems over the years, mostly to the metallurgy and production process, but also to the design, cross-sectional form, angle and depth of flutes **[1, 6]**. Reduced clinician weariness, more efficient and accurate root canal instrumentation and shorter clinical treatment times were the goals of the introduction of rotary Ni-Ti file systems. However, depending on the files tip design, cross-sectional geometry, taper, pitch and flute shape, the rotational force of these files may induce microcracks to develop in the root canal dentin. The size of these microcracks is also determined by these factors **[7].** Both rotational and reciprocal motions are compatible with Ni-Ti file systems. Within the root canal, rotary action entails a complete 360º revolution. Rotary Ni-Ti files outperform stainless steel files in many ways: they need less transportation of canals, allow for speedier root canal preparation and instrumentation, center canals more accurately, prepare round-shaped canals with less dentin removed and more **[8].** During the back-and-forth action of the file in reciprocal movement, it spins in both the clockwise and anticlockwise directions at uneven degrees. The cutting direction, known as Counter-Clock Wise (CCW), has an angle of 150º, while the non-cutting direction, clockwise, has an angle of 30º. The file is more resistant to cyclic fatigue because it is subjected to less stress in a reciprocating action. Minimizing stress on the root canal dentin and reducing microcrack development, reciprocal file movement mimics hand file movement. The file goes toward the root apex on its own, eliminating the requirement for the physician to drive it apically **[9].** Dentsply's ProTaper Gold (PTG) rotary file system is made with unique advanced heat treatment technology and features Ni-Ti. It is manufactured by Tulsa Dental Specialties in Tulsa, OK, USA. The ProTaper Universal rotating file system from Dentsply Maillefer in Ballaigues, Switzerland, has identical geometrical properties. PTG files display a gradual taper and a convex triangular cross-section. The following eight sizes of these files are available: SX (tip size 19, taper 0.04), S1 (tip size 18, taper 0.02), S2 (tip size 20, taper 0.04), F1 (tip size 20, taper 0.07), F2 (tip size 25, taper 0.08), F3 (tip size 30, taper 0.09), F4 (tip size 40, taper 0.06) and F5 (tip size 50, taper 0.05) **[10].** Dentsply Sirona's TruNatomy Rotary file system (TN; Maillefer, Ballaigues, Switzerland) uses 0.8 mm Ni-Ti wire instead of the more typical 1.2 mm. A heat treatment gives the file more flexibility and resistance to cyclic fatigue, so it can be bent to fit any shape. During instrumentation, the file glides easily through the root canal while preserving the root canal's natural structure and avoiding the needless loss of dentin. The three sizes of anatomy shaping files are Small (20/0.04 taper), Prime (26/0.04 taper) and Medium (36/0.03 taper). All three sizes have an off-centered cross-section **[11].** The reciprocating motion of Ni-Ti files was first suggested by Yared in 2008. This method is an improvement to Roane J's Balanced force technique of root canal instrumentation, which was originally described in 1985 **[12].** Two more modern reciprocating file systems, Reciproc Blue (RPB) from VDW in Munich, Germany and WaveOne Gold (WOG) from Dentsply Maillefer in Ballaigues, Switzerland, are made using a unique thermal treatment method using M (Memory)-Wire based Ni-Ti alloy. The reciprocating kinematics used by the previous WaveOne file (Dentsply Maillefer, Ballaigues, Switzerland) are also used by the 13th WaveOne Gold (WOG) file. The WOG files have a controlled memory effect because the Ni-Ti alloy is thermally treated in its martensitic phase while being progressively heated and then cooled. 20 is the little size, 25 is the main size, 35 is the medium size and 45 is the big size of WOG. The file and the root canal walls make alternating one-point contacts because to their rounded tips and parallelogram-shaped cross-sectional form **[13]**. Version 4.0 of the Reciproc file system was released by VDW in Munich, Germany and is known as Reciproc Blue. With an S-shaped cross-sectional design, this single-file system typically employs one of three files (R25, R40, or R50) to accomplish full root canal instrumentation **[14].** The thermionic emitter, a heated tungsten filament cathode, was the electron source in the first scanning electron microscopes (SEMs). In 1975, tungsten cathodes were replaced by lanthanum hexaboride cathodes. However, thermoelectric emitters have a poor brightness and cause filament evaporation, also known as thermal drift, which limits optical performance at higher resolutions and they generate a high current with a beam size of 4 to 8 nanometers. FESEM stands for field emission scanning electron microscope and describes a specific kind of scanning electron microscope that has an electron gun as its emitter. With a beam size concentrated to 2 nm, FESEM delivers a greater electron density than SEM, leading to superior resolution. The electromagnetic lenses and apertures used in FESEM concentrate the electron beam into a pinpoint sharp spot that is about a thousand times smaller than that of SEM. This allows for more precise and detailed imaging of microscopic fractures and other microscopic features, as well as a larger depth of focus and field than is possible with SEM **[15, 16].** Therefore, it is of interest to use field emission scanning electron microscopy (FESEM) to examine the production of dentinal microcracks at three root canal levels using two rotary file systems (TruNatomy and ProTaper Gold) and two reciprocating file systems (WaveOne Gold and Reciproc Blue).

Materials and Methods:

Eighty human permanent mandibular single rooted premolar teeth that had recently been removed were gathered from the following locations: Bodri, Bilaspur, Chhattisgarh; Triveni Institute of Dental Sciences; Hospital and Research Centre. All patients gave their informed permission before we used their removed teeth in the study. The following approvals were obtained: TIDSHRC/IEC/2023/D007. These committees oversee the institution's ethics and research. Radiovisiography (RVG) (Kodak, Carestream Health India Pvt Ltd, Maharashtra, India) was used to obtain digital periapical radiographs of teeth in the buccolingual and mesio-distal directions in order to establish the existence of a single root canal. Included teeth were those that were clinically and radiographically confirmed to be free of the following conditions: carious lesions, fractures, fissures on the root surface, calcifications and endodontic treatment. The research only included teeth that were removed for orthodontic treatment or had considerable root canal curvature (evaluated according to Schneider's criteria) **[17]** ranging from 10^o to 20^o degrees. All teeth that were removed were collected, stored, sterilized and handled in accordance with the standards set forth by the Occupational Safety and Health Administration (OSHA) **[18]**. The teeth were thereafter preserved in a 0.5% thymol solution (Chembur, Maharashtra, India) and left at room temperature until they were required. In order to access the root canals, all specimens underwent endodontic access cavity preparation utilizing a contra-angle airoter hand piece (NSK, Japan) coupled to an Endo access bur no. 2 (Dentsply, Sirona, Switzerland). The DG-16 endodontic explorer, made by Hu-Friedy in Chicago, USA, was used to find root canals. The apical patency and working length of each specimen were determined by inserting a no. 10 K (Kerr)-file (Mani, Japan) into the root canal and seeing the file's tip at the apical anatomic foramen. Then, 0.5mm was subtracted from the file's length. Next, we used a marker pen (Kokuyo Camlin Pvt. Ltd.) to write the specimen numbers on the crown area of the teeth, starting from 1 and going all the way up to 80. To make the specimens easier to handle, more stable and identifiable during root canal instrumentation, they were uniformly coated with polyvinyl siloxane addition silicone impression material (Neopure, Orikam Healthcare Pvt. Ltd, India) and then embedded in self-curing acrylic resin (DPI-RR Cold Cure, Dental Product of India, Mumbai) blocks up to the cementoenamel junction. Afterwards, each of the four groups was given twenty specimens at random from the total number of specimens (n=80). In Group 1 (n=20), root canal instrumentation was performed on all specimens using the crown-down technique and the ProTaper Gold (PTG) rotary file system (Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA). The file sequence was as follows: SX (tip size 19, taper 0.04), S1 (tip size 18, taper 0.02), S2 (tip size 20, taper 0.04), F1 (tip size 20, taper 0.07), F2 (tip size 25, taper 0.08) and F3 (tip size 30, taper 0.09). The procedure was repeated until the pre-determined working length was reached, with RPM (revolutions per minute) and 1.5-5.1 N-cm torque in a pecking motion, as per the manufacturer's instructions. In Group 2, there were 20 specimens. All of them were root canal instrumented using the crown-down technique and the TruNatomy (TN) rotary file system from Dentsply Sirona in Maillefer, Ballaigues, Switzerland. The files used were Small (tip size 20, taper 0.04), Prime (size 26, taper 0.04) and Medium (tip size 36, taper 0.03). The procedure was repeated until the pre-determined working length was reached at 500rpm and 1.5N-cm torque in a pecking motion, as instructed by the manufacturer. In Group 3, there were 20 specimens. All of them were root canal instrumented using the crown-down technique. The instrumentation was done with a WaveOne Gold (WOG) reciprocating file system from Dentsply in Maillefer, Switzerland. The files used were Small (no.20), Primary (no.25) and Medium (no.35), with a 7% taper. The procedure was repeated until the pre-determined working length was reached at 350 rpm and 1.8 Ncm torque, as instructed. Tenth group: All specimens underwent root canal instrumentation using the crown-down technique. The instrumentation was performed using the Reciproc Blue (RB) reciprocating file system from VDW in Munich, Germany. The files used were no. 25 (tip size 0.25mm, 8% taper) and no. 40 (tip size 0.40mm, 6% taper). The procedure was repeated until the pre-determined working length was reached at 300rpm and 2.5Ncm torque while brushing, as instructed by the manufacturer. In accordance with the guidelines provided by the manufacturer, the rotary and reciprocating file systems were moved using a torque-controlled endomotor handpiece (CanalPro CL2, Coltene Endo, Coltene Whaledent Pvt. Ltd, Alstatten, Switzerland). To ensure consistency in the amount of time spent instrumenting each specimen, a digital timer was used for both rotary and reciprocating files. But the time it took to change the files and irrigate the root canals was not considered. During root canal instrumentation, 2 milliliters of 17% EDTA solution (Ethylene Diamene Tetraacetic Acid) from Prevest DenPro in India, 2 milliliters of 3% sodium hypochlorite solution from the same source and 3 milliliters of normal saline from NIVY Remedies in India were utilized as root canal irrigants. These solutions were placed in a disposable syringe that was attached to a 27-gauge side-vented endodontic irrigation needle from Prime Dental Products Pvt. Ltd in Bhiwandi, India. The root canals were subsequently dried using sterile absorbent paper points from DiaDent in Korea. For instrumentation purposes, each rotary and reciprocating file was used in no more than five root canals before being replaced. Each root canal was instrumented by the same endodontic specialist with sufficient expertise in root canal instrumentation procedures to exclude the possibility of operator variability. Following this, the specimens were delicately extracted from the blocks of acrylic resin and the silicone imprint substance was thoroughly removed. To avoid frictional heat production, the specimens were sectioned perpendicular to their long axis using a straight micromotor handpiece (NSK, Japan) coupled to a double-sided diamond disc (DFS, Germany) operating at low speed in a continuous water coolant. From the pre-determined working length, three cross-sections of each root were obtained: one at 3mm (the apical-third), one at 6mm (the middle-third) and one at 9mm (the coronal-third). All of the samples taken from each species were labeled uniquely for the sake of easy identification. All materials were kept wet throughout the testing procedures in glass beakers filled with distilled water (Agrawal Pharmaceuticals, New Delhi, India) to avoid any artifacts caused by dehydration. Each specimen's coronal, middle and apical-third samples were then analyzed at a magnification of 1000X using a Field Emission Scanning Electron Microscope (FESEM) (Quanta FEG 250, FEI Company (Thermo Fisher Scientific), Oregon, United States). Root dentin free of craze lines or microcracks on either the exterior or interior surface of the root was considered to have no defect in the evaluation of dentinal flaws, as previously detailed by Shemesh *et al.* **[19]**. Root canal dentin was considered defective if it showed signs of craze lines, partial cracks, microcracks, or fractures on either the outside or inside of the canal. Using the scoring standards established by Burklein *et al.*, all dentinal microcracks were quantified using Image J software (Wayne Rasband, NIH, Bethesda, USA) **[20]**. A score of '0' indicates the absence of craze lines or cracks on either the exterior or interior surface of the root. The root canal lumen is not reached by the craze lines that extend from the exterior root surface, which results in a score of 1. The fracture line extends from the root canal wall but does not reach the exterior root surface, resulting in an incomplete crack (scoring '2'). If the crack runs the length of the root canal and the outside of the root, we call it a complete fracture and give it a score of 3. In order to assess dentinal microcracks, one impartial assessor blindly reviewed all FESEM photomicrographs from each sample. In order to guarantee that the scores were accurate, we used intra-rater reliability testing, which involved having the same examiner re-evaluate a portion of the samples (20% of the total) after a week to determine the examiner's scoring consistency. An ICC value of 0.95 was considered to be very reliable. After collecting the scores for each sample, they were tallied and entered into a statistical program. SPSS (Statistical Package for the Social Sciences) Version 20 was used to conduct statistical analyses on the tabulated data that was saved in Microsoft Excel. A non-parametric Chi-square test was used to compare the four groups. It was deemed statistically significant when the P (Probability) value is less than 0.05.

Results:

All four groups' specimens have tiny fissures in the tooth enamel. Specimens in Group 2 (using TruNatomy rotary files) and Group 1 (using ProTaper Gold rotary files) exhibited the second-and third-highest numbers of dentinal microcracks, respectively. Dentinal microcracks were found to be less common in Group 4 (Reciproc Blue reciprocating files) and Group 3 (WaveOne Gold reciprocating files). On the other hand, Group 4 specimens had the fewest dentinal microcracks **(Table 1).** In terms of the rotary file methods used, Group 1 specimens had a greater number of dentinal microcracks than Group 2 specimens. When comparing the two groups inter-group pair-wise, a statistically significant difference was seen ($P<0.05$). The number of dentinal microcracks was lower in the apical-third and middle-third of root canals compared to the coronal-third in both groups. Dentinal microcracks were more common in Group 3 specimens than in Group 4 specimens when using the reciprocating file system, although there was no statistically significant difference between the two groups when comparing them pair-wise ($P>0.05$). Dentinal microcracks formed

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consistently throughout the root canal length in all three groups (coronal, middle and apical-thirds) **(Table 2 and Figure 1).**

Table 1: Number and Percentage (%) of root canals with Dentinal microcracks among all specimens in four groups

3-Levels of Root canal	Scoring criteria of Dentinal Microcracks	Group 1 (PTG Rotary)	Group 2 (TN Rotary)	Group 3 (WOG Reciprocating)	Group 4 (RB Reciprocating)
Coronal-third	**SCORE 0**	0 (0%)	4 (20%)	12 (60%)	12 (60%)
	SCORE 1	1 (5%)	5 (25%)	4 (20%)	5 (25%)
	SCORE 2	9 (45%)	5 (25%)	4 (20%)	3 (15%)
	SCORE 3	10 (50%)	6 (30%)	0 (0%)	0 (0%)
Middle-third	**SCORE 0**	1 (5%)	5 (25%)	10 (50%)	12 (60%)
	SCORE 1	1 (5%)	6 (30%)	4 (20%)	6 (30%)
	SCORE 2	9 (45%)	4 (20%)	4 (20%)	2 (10%)
	SCORE 3	9 (45%)	5 (25%)	2 (10%)	0 (0%)
Apical-third	**SCORE 0**	2 (10%)	5 (25%)	10 (50%)	11 (55%)
	SCORE 1	1 (5%)	6 (30%)	4 (20%)	6 (30%)
	SCORE 2	8 (40%)	4 (20%)	4 (20%)	2 (10%)
	SCORE 3	9 (45%)	5 (25%)	2 (10%)	1 (5%)

Table 2: Pair-wise Inter-group comparison of Dentinal microcracks among the four groups tested using Chi-Square test.

Pair-wise Inter-group Comparison	Coronal-third of root canals	Middle-third of root canals	Apical-third of root canals
Group 1 vs Group 2	0.031 (S)	0.02 (S)	0.049 (S)
Group 1 vs Group 3	0.016 (S)	0.001 (S)	0.004 (S)
Group 1 vs Group 4	0.014 (S)	0.001 (S)	0.001 (S)
Group 2 vs Group 3	0.016 (S)	0.04 (S)	0.04 (S)
Group 2 vs Group 4	0.014 (S)	0.03 (S)	0.048 (S)
Group 3 vs Group 4	0.96 (NS)	0.35 (NS)	0.69 (NS)

S: Significant; NS: Non-Significant

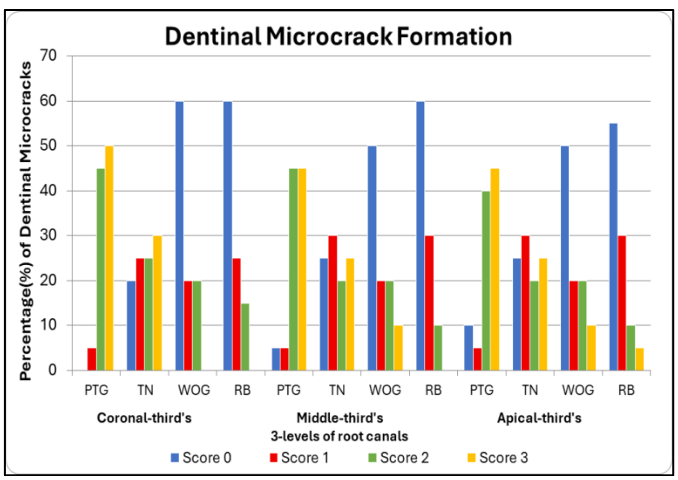

Figure 1: Vertical Bar Graph representing Percentage (%) of Dentinal microcracks at Coronal, Middle and Apical-thirds of root canals among the four groups

Discussion:

In order to treat root canal treatment, the inflammatory and necrotic tissue is removed, the root canal microbiota is eliminated and the root canal system is three-dimensionally sealed to avoid infection recurrence. Preparation of the endodontic access cavity, chemo-mechanical preparation and obturation are the three main steps in root canal therapy. In chemo-mechanical preparation, endodontic files are used to instrument the root canals. Root canal irrigants are used to clean or disinfect the canals. Then, the root canal system is three-dimensionally obturated **[21].** Root canal instrumentation is now more efficient and accurate thanks to rotary endodontics, which also shortens treatment times **[1].** Various endodontic Ni-Ti rotary file systems are currently on the market. Thirty percent of the mandibular molars' mesial roots were found to have cracks when Yoldas *et al.* **[1]** used ProTaper rotary files to instrument them. But when using Protaper rotary files to instrument the roots of mandibular premolars, Bier *et al.* **[2]** discovered fractures in 16% of those roots. Several factors, including the use of teeth with varying root canal structure, contribute to these conflicting results. Whether root canal instruments employed rotary or reciprocating motion files did not affect the occurrence of dentinal microcracks, according to our research. Root canal instrumentation involves making contact between the dentin walls and the endodontic file, which causes the root canal diameter to expand. Microcracks in the dentin and an increased risk of vertical root fractures (VRF) might result from increased stress during canal instrumentation. The kinematics, design, taper, cross-sectional form and mechanical properties of files—including their metallurgy—determine the stress levels **[22].** The current research examined dentinal microcracks using FESEM. Using FESEM, one may see surface topography features as tiny as a nanometer. Compared to scanning electron microscopy (SEM) pictures, its topographical information is three to six times greater and it offers images with a depth of focus that is almost infinite and clean, with less electrostatic distortion, down to 11/2 nanometers **[23].** According to Yoldas *et al.* **[1]**, the amount of dentinal microcracks was shown to be correlated with the following characteristics of canal instrumentation files: tip design, cross-sectional geometry, constant or progressive taper, constant or varied pitch and flute shape. Therefore, the kinematics motion of files, their design, size and taper were the factors in our current investigation. In this research, we found that rotary file systems caused more dentinal microcracks to occur than reciprocating file systems. Traditional rotary file systems provide frequent motion stress and persistent torque impact on the root canal walls; however, files that reciprocate aid to bypass this. In order to avoid creating dentinal microcracks, it is necessary to use a technique called reciprocating motion. This motion centers the file within the root canal and allows it to release itself when the blades are engaged in the root canal dentin during instrumentation. This interrupts the application of flexural and torsional stress **[22, 24].** Patented thermomechanical heat treatment is used in the production process of both Reciproc Blue and WaveOne Gold files. This treatment imparts a characteristic blue color to the former and a gold color to the latter, resulting from the deposition of titanium dioxide at 60-80 nm and 100-120 nm, respectively **[13].** Shape memory alloys with increased amounts of stable martensitic phases and controlled transition temperatures have better mechanical characteristics and clinical performance **[25]**. We found that compared to previous rotary file systems, Reciproc Blue and WaveOne Gold produced much less dentinal microcracks. This is likely because these files' metallurgical behavior makes the Ni-Ti alloy more pliable, ductile and precurved. A study conducted by Kim *et al.* **[6]** found that when curved canals are instrumented, dentinal defects such microcracks are more likely to occur due to the increased stress concentration in the apical root canal dentin caused by stiffer endodontic file designs. Since M-wire alloy is used to make reciprocating file systems, it is more flexible than traditional Ni-Ti alloy files, which means that our current study's endodontic files would have been less likely to cause dentinal microcracks (Pereira *et al.* **[26]**; Peters *et al.* **[27]**). Dentinal microcracks are more often caused by rotary files' rotating pressures on root canal walls, which create an excessive concentration of stress and, according to Yoldas *et al.* **[1]**, more dentinal cracks than reciprocation action. The results of our study align with those of Liu *et al.* **[28]**, who found that root canals instrumented with rotary files resulted in 50% dentin cracks compared to 5% when prepared with reciprocating files and that there was a significant difference in the formation of dentinal defects between the two technologies. According to research conducted by Jalali *et al.* **[29]**, Kfir *et al.* **[30]** and Caballero *et al.* **[31]**, rotary files were shown to produce a higher number of dentinal microcracks compared to reciprocating files. When compared to other file systems, the ProTaper Gold rotary system produced a greater number of dentinal microcracks throughout all three root canal levels in our research. One possible explanation is that the root canal dentin experiences increased stress concentration and the development of dentinal microcracks as a result of the constant torque and continual rotating force exerted by the PTG files. Rotating a PTG file away from the root canal's center increases stress on the dentinal walls, which in turn causes microcracks and, in extreme cases, vertical root fractures due to cyclic masticatory stresses, as the file lacks radial land **[29].** The results of our study corroborate those of Abou El Nasr *et al.* **[32]**, which found that root canal instrumentation systems using a larger number of files sequentially resulted in more dentinal microcracks than systems using fewer files, regardless of whether the motion was rotary or reciprocating. Based on our research, the following file systems were used in the root canal instrumentation process: PTG rotary file system, TN rotary file system and WOG reciprocating file system. In contrast, the Reciproc file system only utilized two files. TruNatomy files shown fewer microcrack development compared to ProTaper Gold files, among the rotational file systems used in our investigation. Because of its convex triangular cross-sectional shape, ProTaper Gold files create a three-point contact with the root canal walls when they rotate during instrumentation. This causes the file to transfer additional stress, which in turn causes more dentinal microcracks to develop. However, with TruNatomy files, the cross-sectional design is off-center parallelogram. This means that there is only one or two points of contact between the file and the root canal wall whenever the file rotates in the canal during instrumentation. As a result, there is minimal stress and the incidence of dentinal microcrack formation is lower **[33].** In contrast to the results reported by Burklein *et al.* **[20]**, who found that full-sequence rotary file systems for canal instrumentation result in a lower proportion of incomplete dentinal fractures, our investigation found the opposite to be true. In line with previous research by Liu *et al.* **[28]**, which found that dentinal microcracks are more common at coronal-levels than at apical-thirds of root canals, our study found that both rotary file systems caused dentinal microcracks more frequently at coronal-thirds of root canals than at middle and apical-thirds during canal instrumentation. We found the same thing as Versluis *et al.* **[34]**, who found that the stresses produced at the root canal instrumentation site, which is 1mm short of the Apical Foramen (AF), were only one-third as high as the stresses produced at the root canal instrumentation site, which is at the coronal level. This disparity could be because different files have different tapers as they approach the coronal third, which is known to increase the stress on the canal walls and lead to dentinal microcracks **[19, 35].** Vertical root fractures are more likely to occur with more root canal dentin removal during canal instrumentation, as described by Wilcox *et al.* **[36]** and greater taper results in less root canal dentin thickness circumferentially. The question of whether or not all dentinal microcracks result in vertical root fractures remains unresolved **[36]**. Further investigation into the effect of these microcracks on the implicated tooth's long-term prognosis is also necessary. When studying mechanical characteristics (the creation of dentinal microcracks), the findings may be impacted by how the removed teeth are stored before, during and after root sectioning and canal instrumentation **[20].** In order to avoid artifacts caused by dehydration, all specimens used in this investigation were kept wet in glass beakers filled with distilled water. We did our best to replicate periodontal ligament and alveolar bone using acrylic resin blocks and silicone-based impression material, however these materials fall short when it comes to periodontal ligament's viscoelastic qualities **[37].** In this work, we assessed the occurrence of dentinal microcracks at three distinct root canal levels using a tried and true sectioning method **[1, 20 and 28].** We were unable to standardize the downward force applied with each file system during root canal instrumentation and our study's limitations include the fact that both rotary and reciprocating files have variable tip sizes and tapers, as well as differences in the number of files used sequentially. As a means of standardization in further research, Endographe, a force analyzer device may be used **[38]**. Because this anatomical homogeneity does not really reflect actual conditions, our research only included teeth with moderate root canal curvature, defined as 10º-20º and no excessive anatomical curvature or complexity.

Conclusion:

All four root canal instrumentation systems produced dentinal microcracks, with ProTaper Gold and TruNatomy showing higher prevalence than the other systems. Rotary systems produced more microcracks in the coronal third, while Reciproc Blue showed the fewest microcracks across the evaluated root canal levels. Further clinical studies are needed to determine the clinical significance of these findings and the effect of Reciproc Blue on treatment outcomes.

References:

[1] Yoldas O *et al. J Endod.* 2012 **38**:232. [PMID: 22244643]
[2] Bier CAS *et al. J Endod.* 2009 **35**:236. [PMID: 19166781]
[3] Fuss Z *et al. J Endod.* 2001 **27**:46. [PMID: 11487164]
[4] Tang W *et al. J Endod.* 2010 **36**:609. [PMID: 20307732]
[5] Milani AS *et al. Iran Endod J.* 2012 **7**:177. [PMID: 23130076]
[6] Kim HC *et al. J Endod.* 2010 **36**:1195. [PMID: 20630298]
[7] Bergmans L *et al. Am J Dent.* 2001 **14**:324. [PMID: 11803999]
[8] Gambill JM *et al. J Endod.* 1996 **22**:369. [PMID: 8935064]
[9] Bürklein S & Schäfer E. *J Endod.* 2012 **38**:850. [PMID: 22595125]
[10] Elnaghy AM & Elsaka SE. *Indian J Dent Res.* 2016 **27**:37. [PMID: 27054859]
[11] Riyahi AM *et al. Int J Dent.* 2020 **2020**:3190938. [PMID: 32184827]
[12] Yared G. *Int Endod J.* 2008 **41**:339. [PMID: 18081803]
[13] Karataş E *et al. J Endod.* 2015 **41**:261. [PMID: 25476974]
[14] Plotino G *et al. Int Endod J.* 2012 **45**:614. [PMID: 22268461]
[15] Crewe AV. *North Holland.* 1973 **11**:225. [DOI: 10.1016/S0079-6638(08)70137-9]
[16] Perdigão J *et al. J Endod.* 2007 **33**:259. [PMID: 17320709]
[17] Schneider SW. *Oral Surg Oral Med Oral Pathol.* 1971 **32**:271. [PMID: 5284110]
[18] Tate WH & White RR. *J Dent Educ.* 1991 **55**:583. [PMID: 1910059]
[19] Shemesh H *et al. Int Endod J.* 2009 **42**:208. [PMID: 19228210]
[20] Bürklein S *et al. J Endod.* 2013 **39**:501. [PMID: 23522545]
[21] Schilder H. *J Endod.* 2006 **32**:281. [PMID: 16554195]
[22] Kulangara AT *et al. Cons Dent Endod J.* 2020 **5**:1. [DOI: 10.5005/jp-journals-10048-0057]
[23] https://www.ijpbs.com/ijpbsadmin/upload/ijpbs_60f7bc8470dc4.pdf
[24] Wei X *et al. Dent Mater J.* 2017 **36**:243. [PMID: 28302945]
[25] Topçuoğlu HS *et al. Int Endod J.* 2017 **50**:713. [PMID: 27344032]
[26] Pereira ES *et al. Int Endod J.* 2012 **45**:469. [PMID: 22188417]
[27] Peters OA *et al. Int Endod J.* 2014 **47**:505. [PMID: 23998507]
[28] Liu R *et al. J Endod.* 2013 **39**:1054. [PMID: 23880276]
[29] Jalali S *et al. Iran Endod J.* 2015 **10**:252. [PMID: 26523141]
[30] Kfir A *et al. Clin Oral Investig.* 2017 **21**:405. [PMID: 27025212]
[31] Caballero H *et al. Int Endod J.* 2015 **48**:229. [PMID: 24766442]
[32] Abou El Nasr HM *et al. J Endod.* 2014 **40**:849. [PMID: 24862715]
[33] Jaju KK *et al. Int J Dent Oral Sci.* 2021 **8**:3209. [DOI: 10.19070/2377-8075-21000654]
[34] Versluis A *et al. Int Endod J.* 2006 **39**:931. [PMID: 17107537]
[35] Kim HC *et al. J Endod.* 2010 **36**:147. [PMID: 20003955]
[36] Wilcox LR *et al. J Endod.* 1997 **23**:533. [PMID: 9587326]
[37] Arias A *et al. J Endod.* 2014 **40**:982. [PMID: 24935548]
[38] Blum JY *et al. J Endod.* 2001 **27**:503. [PMID: 11501586]