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RESEARCH ARTICLE

EFFECT OF CONTINUOUS ROTATION AND RECIPROCATING MOTION ON DENTINAL MICROCRACK FORMATION IN ROOT CANAL USING SINGLE FILE SYSTEMS: A SEM STUDY

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ABSTRACT

Background: Root canal preparations using (NiTi) rotary instruments induces momentary stress concentrations in the root dentin that lead to formation of microcracks. **Objective:** The objective was to evaluate the incidence of dentinal microcrack formation after root canal preparation using two Continuous rotation : One Shape , Trunatomy & two Reciprocating motion: Wave one Gold, Reciproc blue single file systems under SEM. **Materials and Methods:** Sixty freshly extracted single root permanent mandibular premolars were selected, decoronated and divided into four groups(n=15) according to the motion used i.e. continuous rotation: Group 1 A(One Shape), Group 1 B (Trunatomy)& reciprocating motion: Group 2 A (Wave one Gold), Group 2 B (Reciproc blue). After instrumentation, specimens were sectioned horizontally at 3 mm, 6 mm and 9 mm from the apex, dried in a critical point dryer and then was mounted on metallic stubs and gold sputtering was done. The examination of the specimens were done under Scanning electron microscope (SEM) at 100X magnification. **Result:** Minimum amount of microcracks were observed in Group 1 B (Trunatomy) at all the three cross-sectional levels of root. The experimental data was compared using using Pearson chi square test. Dentinal microcrack formation between Group 1A v/s Group 1B and Group 1 B v/s Group 2 A showed no statistically significant difference at 6mm and 9mm levels, however at 3mm distance from the apex, there was a significant difference among both the groups. There was no significant difference among the other groups. **Conclusion:** There is no definitive conclusion concerning the clinical implications of these dentinal defects in long term. More studies on this topic and the development of more effective methods and analysis are required.

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INTRODUCTION

Primary aim of endodontic treatment is to reduce the bacterial load, preserve the tooth structure and improve resistance to fracture that lead to long term survival rate. Thus, chemomechanical preparation is the important step which affects the outcome of endodontic treatment. Earlier stainless steel files were used for the root canal preparation but they have certain shortcomings such as inherent stiffness, apical extrusion of debris, more working time and greater patient fatigue. To meet this challenge, nickel titanium (NiTi) rotary file system came into being in the 19th century, undergone revolutionary changes in terms of construction and physical characteristics since its inception and has made chemomechanical preparation effortless and predictable. NiTi rotary file system has certain advantages like increased flexibility and a shorter working time over stainless steel files (Li Mei-Lin et al. 2017).

These instruments are able to improve both the morphological characteristics and safety of canal shaping. Moreover, they allow efficient cleaning and shaping of root canals due to their property of shape memory, improved cutting efficiency and exclusive super elasticity. However, these rotary files can lead to dentinal microcrack formation because of higher number of rotations, variable speed and torque that exerts different levels of stresses on root canal wall during instrumentation. According to Pedulla et al. (2016), variation in tip diameter, tapers, cross section, kinematics, core diameter and different heat treatments affect the behaviour of the file. Root canal preparations using these NiTi rotary instruments induces momentary stress concentrations in the root dentin that lead to formation of microcracks which may weaken the tooth structure. Propagation of microcracks or craze lines over a period of time can lead to vertical root fracture (VRF). Normally while preparing the root canal, multiple NiTi files of different taper and diameter are used to

gradually enlarge the root canal which can lead to cross contamination and causes instrument fatigue. In recent years, technological advances in Ni Ti rotary file systems have allowed the opportunity to shape the root canals with single files activated in rotary and reciprocating movements. Rotary movement includes a full 360° rotation in the canal. It provides a more constant engagement of file tip in the root canal that forces it to follow the canal hence better control for maintaining the central axis. In addition it has an advantage of its enhanced ability to collect and convey debris in the coronal direction from the canal ramifications and apical region. In reciprocating motion, special counterclockwise (cutting action) and clockwise movements (release of the instrument) alike the balanced force technique which decreases the torsional and flexural stresses, increase resistance to cyclic fatigue and decreased the screw in effect (De-deus *et al.* 2014). The advantage of reciprocating technique is only one file is required to shape the root canals which decreases the shaping time by upto 40% (Kumar *et al.* 2015). A single file system has developed for shaping vast majority of canals, regardless of their length, diameter or curvature focusing on the concept of 'Less is more' (Kulungara AT *et al.* 2020). It has added an advantage of reducing instrument fatigue. This concept reduces the preparation time, lowers cross contamination between patients and decreases potential for file separation.

One shape, a single file system has inbuilt stereotyped continuous rotation motion, optimal cutting action at 3 zones of root canal and greater flexibility.

Wave One Gold has an alternating offset parallelogram shaped cross section that limits its engagement between file and dentin hence reduces screw in effect. In addition its thermal process and post machining procedure offers better cyclic fatigue resistance and flexibility.

Reciproc Blue has high efficiency and cutting performance, which is provided with the combination of its S shaped cross section, cutting angles and thermally improved material.

Trunatomy serves to preserve dentin due to its regressive taper, heat treatment and slim shape. The files are less destructive for the root canal wall consequently produces less microcracks.

Therefore, the aim of present invitro study was to evaluate the incidence of dentinal microcrack formation after root canal preparation using two Continuous rotation : One Shape , Trunatomy & two Reciprocating motion: Wave one Gold, Reciproc blue single file systems under SEM.

MATERIALS AND METHODS

60 freshly extracted single root permanent mandibular premolars were collected from out-patient Department of Oral and Maxillofacial Surgery, Punjab Government Dental College and Hospital, Amritsar. The coronal portions of all the selected teeth were removed by using diamond rotary disc mounted on mandrel in a straight handpiece under water cooling with a syringe at slow speed leaving approximately 15 mm of the root length. The root surface was coated with a silicon impression material and embedded in acrylic block. Then all the samples were divided into following groups:

Group1A: One shape file (Micromega, Besacon, Cedex, France) in continuous rotating motion (n=15)

Group1B:Trunatomy file (Dentsply, Sirona, Malleifer, Switzerland) in continuous rotating motion (n=15)

Group 2A: Wave One Gold file (WOG, Dentsply, Maillefer, Switzerland) in reciprocating motion (n=15).

Group 2B: Reciproc Blue file (VDW, GmbH, Munich, Germany) in reciprocating motion (n=15)

The pulp tissue was extirpated and canal patency was assessed with a 10 K-file. The file was introduced into the canal until it was visible at the apical foramen and the true working length was established by

subtracting 1.0 mm from this measurement and the glide path was done with no. 15 K file.

Group 1 A: The selected root canals were prepared in a crown down technique with the aid of (Orikam E-connect) endomotor by using One-Shape file system (n=15) consisting of a tip size of 25 and a constant taper of 6% in continuous rotating motion, working at 350 rpm and Torque-2.5 N/cm². Three in and out motions were gently performed in the apical direction until the working length was reached.

Group 1 B: The root canals were prepared with Trunatomy (TRN) file (n=15) having a tip size of 26 and with the decreasing taper of 4%. It was used in continuous rotation at 500 rpm with a torque of 1.5 Ncm. The instrument was used in an in and out pecking motion of about 3mm in amplitude with apical pressure and then it was removed from the canal and cleaned until the working length was reached.

Group 2 A: The root canals were prepared with Wave One gold (WOG) primary single file having a tip size of 25 and taper of 7% . The preparation was performed with in-and -out pecking movements of the instrument with 3mm of amplitude until WL was reached. It was operated on WAVE ONE ALL MODE, according to the manufacturer's instructions.

Group 2 B: The root canals were prepared with Reciproc blue (n=15) R25 having tip size of 25 and taper of 8% which then decreases. The file system was operated on RECIPROC ALL MODE, according to the manufacturer' s instructions with up and down pecking motion with the amplitude of 3mm until cervical and middle third of canal was reached.

After each file instrumentation, 3ml of 3.0% of sodium hypochlorite (NaOCl) followed by a 1 min 17% EDTA rinse was done. Final irrigation was done with distilled water. After the mechanical preparation all the above samples were sectioned horizontally at 3 mm, 6 mm and 9 mm from the apex with the aid of slow speed handpiece under constant water coolant with a diamond disc. Microphotographs of each specimen was captured at 100x magnification using Scanning electron microscope (SEM).

The microphotographs obtained were categorized according to the following criteria (GP, Aishwarya et.al 2022). No Crack (No)- Root dentin surface is devoid of any microcracks or craze line originating from canal lumen. Crack (Yes)-Root dentin surface having craze line, microcracks or fractures originating from the root canal lumen. The results regarding the presence of dentinal defects were expressed as the number and percentage of samples with microcracks in each group at 3, 6 and 9mm levels of root and statistical analysis was done using Pearson's Chi square test.

RESULTS

Table 1 shows that in Group 1(A), 1(B), 2 (A) & 2(B), the specimen were observed by three examiners for the presence and absence of dentin microcracks in root sections at 3mm, 6mm and 9mm levels. The presence of dentinal defects were expressed as the number and percentage of samples with microcracks in each group. The observations of the present study revealed that percentage(%) of specimen with microcrack formation at 3mm, 6mm and 9mm levels in Group 1 A(One shape) was 60%,33.3%& 13.3% ; Group 1 B (Trunatomy) was 13.3%,6.7% & 6.7% ; Group 2A (Wave One Gold) was 46.7%, 26.7% & 26.7% and Group 2B (Reciproc Blue) was 40%,33.3% & 26.7% respectively. The statistical analysis of the data was performed by using Pearson chi square test and the level of significance was kept as p value< 0.05. Intergroup comparison of dentinal microcrack formation between Group 1A v/s Group 1B & Group 1 B v/s Group 2 A showed no statistically significant difference at 6mm and 9mm levels (p value> 0.05), however at 3mm distance from the apex, there was a significant difference among the groups (p value <0.05). There was no significant difference between Group 1A v/s Group 2 A, Group 1A v/s Group 2 B, Group 1 B v/s Group 2A, Group 1 B v/s Group 2 B & Group 2 A v/s Group 2 B at all three cross-sectional levels.

Table 1. The incidence of dentinal defects by the experimental groups at each level(3mm, 6mm and 9mm) of root

MICROCRACKS	Group 1 A (ONE SHAPE) No. (%)	Group 1 B (TRUNATOMY) No. (%)	Group 2A (WAVE ONE GOLD) No.(%)	Group 2B (RECIPROC BLUE) No.(%)	X ² value	P value
TOTAL	15(100)	15(100)	15(100)	15(100)	df=3	
3mm						
YES	9(60)	2(13.3)	7(46.7)	6(40)	7.222	0.065;NS
NO	6(40)	13(86.7)	8(53.3)	9(60)		
6mm						
YES	5(33.3)	1(6.7)	4(26.7)	5(33.3)	3.822	0.281;NS
NO	10(66.7)	14(93.3)	11(73.3)	10(66.7)		
9mm						
YES	2(13.3)	1(6.7)	4(26.7)	4(26.7)	3.006	0.391;NS
NO	13(86.7)	14(93.3)	11(73.3)	11(73.3)		
3mm v/s 6mm	X ² =2.143 p=0.143; NS	X ² =0.370 p=0.543 ;NS	X ² =1.292 p=0.256; NS	X ² =0.144 p=0.705; NS		
3mm v/s 9mm	X ² =7.033 p=0.008*	X ² =0.370 p=0.543; NS	X ² =1.292 p=0.256; NS	X ² =0.600 p=0.439;NS		
6mm v/s 9mm	X ² =1.677 p=0.195; NS	X ² =0.000 p=1.000 ;NS	X ² =0.000 p=1.000; NS	X ² =0.159 p=0.690;NS		

Chi- Square Test : X² : Chi-Square; df : Degree of freedom; NS: p>0.05; Not significant, *p<0.05; Significant

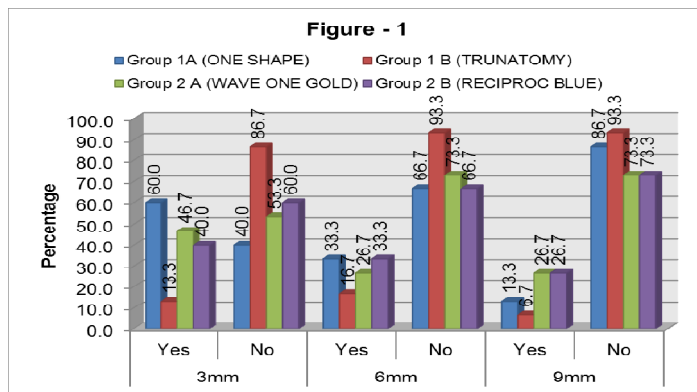
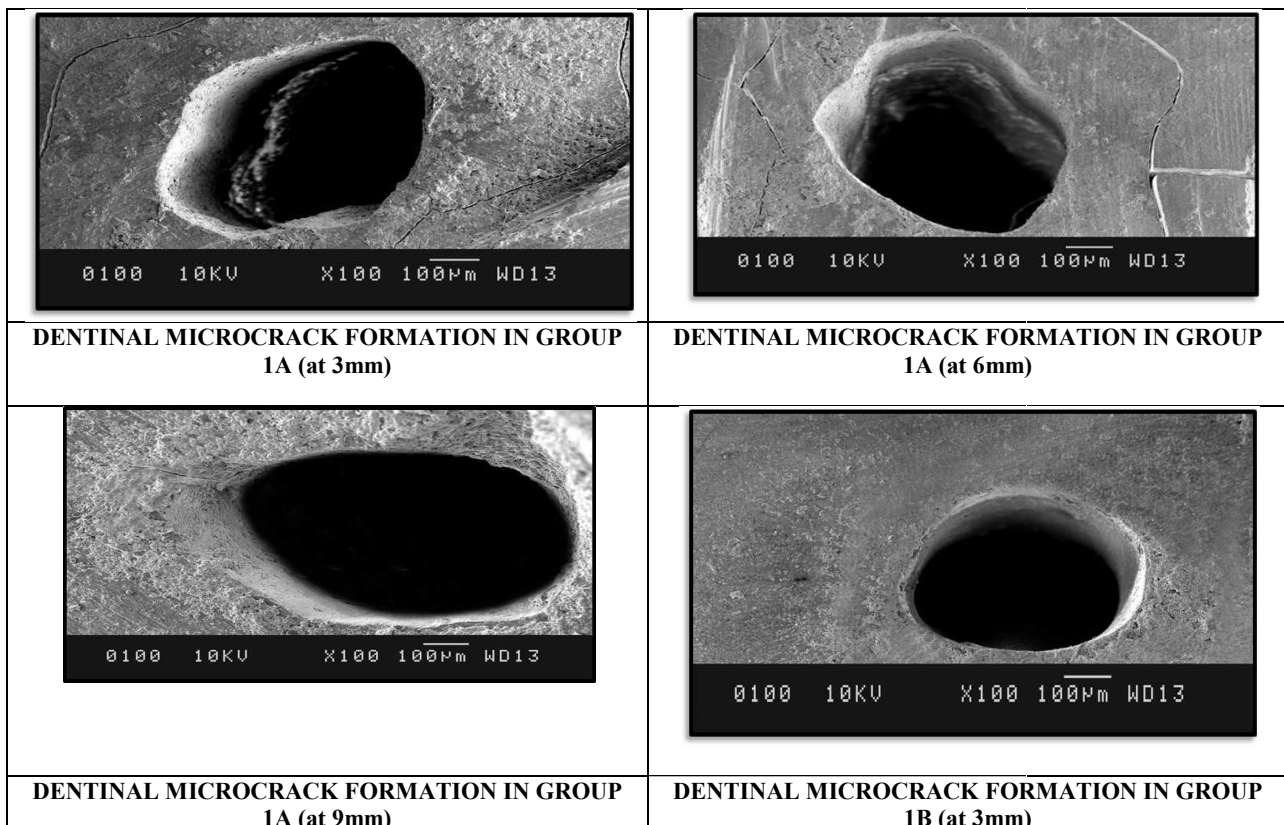
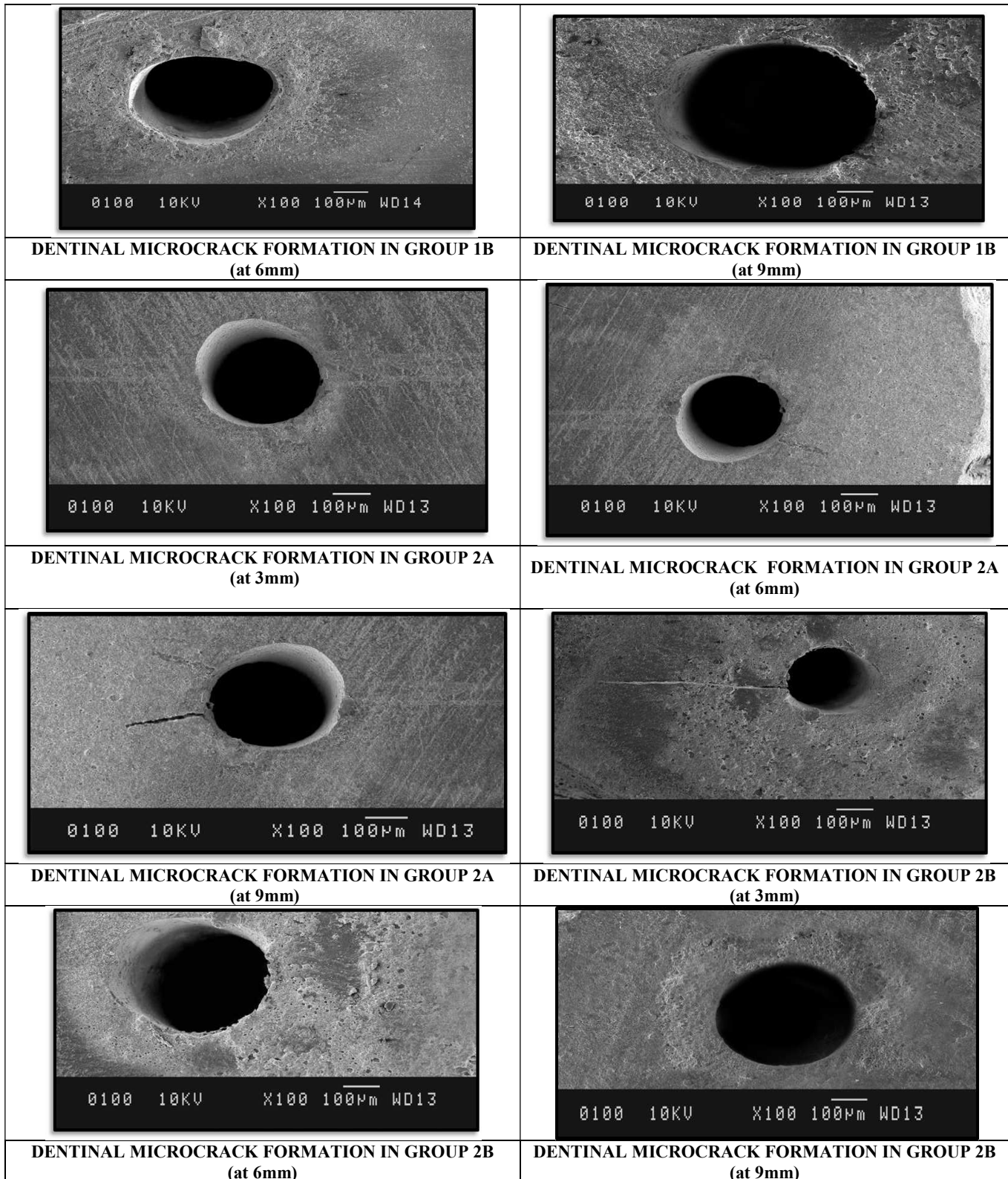


Figure Showing Comparison of Dentinal Microcrack Formation Of Group (1a), (1b), (2a) & (2b) At Three Different Cross Sectional Levels





Pearson chi square test for the incidence of dentinal defects in Group 1 A (One Shape) showed significant difference between 3mm v/s 9mm (p value <0.05), however no significant difference was found between 3mm v/s 6mm & 6mm v/s 9mm levels (p value >0.05). In Group 1B (Trunatomy), 2A(Wave One Gold) & 2B (Reciproc blue), no significant difference was observed between 3mm v/s 6mm, 3mm v/s 9mm & 6mm v/s 9mm levels (p value >0.05).

DISCUSSION

Chemomechanical preparation of root canal induces stresses on dentin and causes microcracks and craze lines into the root dentin. Hence, importance is laid to ensure minimal iatrogenic harm to the root dentin during endodontic treatment procedure, thus improving the

prognosis of tooth. The present study investigated the effect of One shape (OS), Trunatomy (TRN), Wave One Gold (WOG) and Reciproc Blue(RB) single file systems on dentinal microcrack formation of mandibular premolars using the SEM. Our results showed more microcracks with OS than TRN, WOG and RB file systems. This result was compatible with Pathak et.al(2020) that demonstrated that OS file system was associated with more dentinal microcrack than the WOG file. However, TRN system produced least number of cracks compared to other systems. Mandibular first premolars were used in our study due to their small dimension and thin dentinal walls that are more prone to stress caused by shaping. Moreover, in our study a silicon impression material was used for coating the cemental surfaces of root as it simulates the periodontal ligament space and acts as a

major stress absorber. The layer allowed the root to move within a little space and also avoids external reinforcement and then all roots were embedded in acrylic block that simulates bone. Increased incidence of apical delta ramifications in the apical 1mm of the root may mimic cracks and affect the interpretation of the results, thus we avoided it by removal of 1mm of the apical root. And also, it provided a flat surface for better visualization of cracks under SEM and helped in determining the WL correctly. Scanning electron microscope was utilized for the evaluation of dentinal microcrack formation. The advantage of using SEM is that, it observes the defects at submicron level at required magnification and final evaluation can be done by preserving the microphotographs (Polineni *et al.* 2016). SEM is known for their high magnification, good resolution and larger depth of field which is not possible with other optical microscopes. It uses electromagnets rather than lenses allowing the operator to have more control over the degrees of magnification, thereby providing strikingly clear images (Punitha and Shashikala 2011). Higher concentrations of NaOCl irrigation significantly reduce the elastic modulus and torsional resistance of root dentin than the lower concentrations and physiologic saline. For this reason, the use of 3% NaOCl solution was considered for irrigation purposes.

The crack formation is affected by the design and taper of the file due to altered stress degrees provoked by files on the canal surfaces. In this study, OS showed maximum number of cracks at 3mm, 6mm and 9mm levels which was 60%, 33.3% & 13.3%. This may be related to the triangular cutting edges in the apical third, 2 cutting edges in the coronal third and a cross section that progressively changes from 3 to 2 cutting edges. This design affects the shaping forces on the root dentin, these forces may cause root fracture. The results of the present study are in concurrence with Pedulla *et al.* (2016) who compared dentinal crack formation during root canal instrumentation using Wave one gold and One shape file systems. They observed that One shape file created more number of microcracks when compared with WOG. Pearson chi square test for the incidence of dentinal defects in Group 1 A (One Shape) showed significant difference between 3mm v/s 9mm (p value <0.05), however no significant difference was found between 3mm v/s 6mm & 6mm v/s 9mm levels (p value >0.05). Reciprocating instruments WOG and RB showed same number of dentinal microcracks at 9mm level (26.7%). This might be due to similar metallurgical behaviour, special CW/CCW movements & their martensitic phase during clinical use. The current results are in accordance with Kulangara AT *et al.* (2020) who found that RB and WOG showed similar cracks at the coronal third level.

Group 2A showed no statistically significant difference postoperatively among 3mm, 6mm and 9mm levels. The results of this study are consistent with the results of the studies conducted by John ER *et al.* (2021) and Abdul-hamed S *et al.* (2020) who observed no significant difference at three levels within the group. In Group 2B, statistical analysis revealed no significant difference at three levels of root. Similarly, Ozlek E *et al.* (2020) reported non significant difference within the group.

Of all the tested file systems, minimum number of cross-sections with microcracks were observed in Group 1 B (Trunatomy) at 3, 6 and 9mm levels of root as 13.3%, 6.7% & 6.7%. This may be accredited to the union of the file geometry, regressive tapers and the slim, highly flexible wire which enables efficient root canal treatment while removing only dentin where clinically needed hence preserves the structural dentin. Trunatomy (TRN) instruments are having off centered parallelogram cross section design, therefore when each time file rotates in the canal, there is atleast 1 or 2 point contacts between the instrument and root canal wall. Other file systems showed more number of contact points (at least 2) with the canal wall during biomechanical preparation. The combination of the standardized file design and the heat treatment allow to have a flexibility that decreases the occurrence of stresses on dentinal walls. Moreover, the lower dentinal microcracks incidence could be related to the taper of the file which is different and smaller than the other groups. No significant difference was observed between 3mm v/s 6mm, 3mm v/s 9mm & 6mm v/s 9mm levels (p value >0.05). The results are in association

with Jaju KK *et al.* (2021) who found no significant difference within group (TRN) at all the three levels.

In the current study, four selected single files have different designs and movement in the root canal which may have an impact on generation of microcracks. Periodontal ligament was simulated using silicon impression material which doesn't provide exact intraoral environment and make teeth brittle. Moreover, storage conditions of teeth might have influenced the consequences of our study. Thus, generalization of results to the clinical setting must be done with caution. Future clinical studies are required to obtain more reliable results.

CONCLUSION

Under the condition of this ex vivo study, it can be concluded that all tested single file systems (One shape, Trunatomy, Wave one gold and Reciproc blue are capable of initiation of dentinal defects during root canal instrumentation. Multiple factors of single file systems are responsible for inducing dentinal damage but flexibility of NiTi instruments because of heat treatment and geometric features seems to influence the incidence of microcracks more than kinematics. This is an in-vitro study, hence there is possibility of the clinical scenarios and outcome to be completely different. Multiple studies on the topic and the development of more effective methods and analysis are necessary.

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LIST OF ABBREVIATION USED

EDTA	:	Ethylenediaminetetraacetic acid
CW	:	Clockwise
CCW	:	Counter-Clockwise
NiTi	:	Nickel Titanium
OS	:	One Shape
TRN	:	Trunatomy
WOG	:	Wave One Gold
RB	:	Reciproc Blue
mm	:	Millimeter
no.	:	Number
%	:	Percentage
VRF	:	Vertical root fracture
Rpm	:	Revolutions per minute
NaOCl	:	Sodium hypochlorite
SD	:	Standard Deviation
SEM	:	Scanning Electron Microscope
v/s	:	Versus
i.e.	:	That is

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