Comparative Evaluation of Dentinal Cracks Formation After Root Canal Preparation Using Three Different Rotary File Systems - A Stereomicroscopic *In Vitro* Study

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Abstract

Aim and Objective: The present in-vitro study was conducted with an aim to analyse and compare the incidence of dentinal cracks formation after root canal preparation with TruNatomy, One Curve and Hyflex EDM rotary files using a stereomicroscope.

Material and Methods: 60 human caries free single-rooted mandibular premolar with straight, fully formed apices verified radio graphically were selected for the study. Samples were grouped as file used for root canal preparation. Group 1: TruNatomy, Group 2: OneCurve, Group 3: Hyflex EDM,Group 4:Control -no preparation Done. The samples stained with methylene blue dye (0.5%). All roots horizontally sectioned at 3,6 and 9 mm from the apex. The sections were observed under stereomicroscope to determine the absence or presence of crack.

Result: The result of this study showed that all the groups except control group exhibited dentinal cracks least number of cracks was shown by group 1 (TruNatomy) followed by Group 3 (Hyflex EDM) and maximum was seen in Group 2 (OneCurve). The study also

showed that maximum dentinal cracks observed at 3 mm level from apex followed by at 6 mm and least at 9 mm in each of the group.

Conclusion: All the rotary files that were tested produced dentinal cracks. TruNatomy files group was associated with less number of cracks compared to OneCurve and Hyflex EDM files group. All the file showed more dentinal cracks at apical region compared to middle and coronal region of root.

Keyword: Dentinal cracks, Stereomicroscope, Rotary files

INTRODUCTION

The primary goal of endodontic therapy is to eliminate the infected dental tissue and disinfect the entire root canal using various instruments and materials. Root canal preparation with rotary endodontic files removes more root dentin and may result in weakening of dentin integrity, leading to a reduction in the fracture resistance of treated tooth. Root canal preparation procedures can damage the root canal dentin causing dentinal cracks.[1]

NiTi rotary instruments have the advantages of increased flexibility and shortened working time, while instrument separation and dentinal crack formation are its major disadvantages.[2] Technological advancements in rotary nickel–titanium (NiTi) instruments has led to new design, concepts, and easier, faster, and better root canal shaping. Root canal shaping procedures and rotary instrumentation with NiTi instruments can induce crack formation.[3]

Crack is defined as a defect with complete crack lines extending from inner root canal space up to the outer surface of the root.[4,5] Dentinal cracks or root fracture occur when the tensile stress in the root canal wall exceeds the tensile stress of dentin.[14] Rotary NiTi files with large tapers can produce increased friction and stresses on the canal wall and cause dentinal cracks in root dentin.[6]

The newly developed TruNatomy instruments are manufactured from heat-treated NiTi alloy with parallelogram cross-section design.[7] This file system uses a 0.8 mm NiTi wire instead of 1.2 mm NiTi wire, which offers maximum preservation of pericervical dentin and tooth integrity due to instrument geometry, regressive tapers, and the slim design.

One Curve is a heat-treated single-file system that was released in 2018. The heat-treated NiTi alloy is called C. Wire. C. Wire technology is reported to provide a controlled memory and a pre-bending feature to the file for easier access to the root canal.[8] The variable cross-sections with a triangular-shaped at the tip of the instrument and S-shaped near the shaft are claimed to allow effective cutting and centered trajectory.[9]

HyFlex EDM files are controlled memory instruments, manufactured using a unique process called electrical discharge machining (EDM).[10] Electrical Discharge Machining uses spark erosion to harden the surface of NiTi files in the manufacturing process, which gives the files excellent flexibility and fracture resistance.[11] Spark initiated in this process is melting and vaporizing the material of the workpiece in its top layer.[12,13] Like Hyflex CM files, HEDM files have controlled memory effect and regenerative properties.[12]

In this study we compare the incidence of dentinal cracks formation after root canal preparation with TruNatomy, One Curve and Hyflex EDM rotary files.

MATERIAL AND METHODS

The study protocol was approved by the Ethics committee, presenting with statement number RUHS-CDS/EC/2021/PG-The/013.Freshly extracted,single- rooted mandibular human premolar (n=60) with completely formed root and closed apices, with no cracks or structural anomalies were used for this study. The teeth were disinfected in a 0.1% thymol solution for 24 h. Throughout the experiment, the teeth will be stored in purified filtered water. Periapical radiographs of the teeth in the buccolingual and mesiodistal directions were obtained with the intention of visualising inflammatory resorptions and calcifications as well as the presence of a single root canal.

The coronal portions of the teeth were removed using a double-sided diamond disc with low rotation and under water refrigeration leaving roots of approximately 13 mm in length. The samples were inspected under a stereomicroscope with 10X

magnification to detect any pre-existing cracks or fracture lines. teeth with such findings were excluded from the study.

All the teeth were examined and compatible with a K-file#10 made from stainless steel (Dentsply Maillefer, Ballaigues, Switzerland). The length of the canal was determined by inserting the file until the tip became visible on the apical foramen. The canal length was defined as the distance between the tip of the file and the reference plane. The working length (WL) was calculated by subtracting 1 mm from the obtained length.

Roots were immersed into molten wax and then, all the samples were embedded in acrylic resin blocks. The wax on the root surface was cleaned with the help of a curette prior to the polymerization of the acrylic resin. A silicone impression material (Vinyl Polysiloxane impression material, 3M ESPE, Seefeld, Germany) covered the root surface. All the roots were then embedded into acrylic resin again. Initially, the root canals were irrigated with 2 mL of a 3% sodium hypochlorite solution (NaOCl). The glide path of all the samples was made with a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). The tooths were worked in a wet environment. One operator performed all root canal instrumentation.

The specimens were randomly divided into four group (n=15) based on instrumentation technique used.

GROUP 1 (n=15) **:** 15 premolars were instrumented with TruNatomy files system (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) using crown-down technique. Canal orifice was shaped using TruNatomy Orifice Modifier and a glide path was achieved using #17 TruNatomy Glider till the working length. Subsequently, #20 TruNatomy small files and #26 TruNatomy Prime shaping files at speed of 500 rpm and a torque of 1.5Ncm were used to complete the preparation till the working length.

GROUP 2 (n=15): The root canals were prepared with the One Curve file in a continuous rotary motion at a speed of 300 rpm and a torque of 2.5 N/cm. with an estimated working length. Size. The OneFlare (25/.09) file used to enlarge the orifice and after that OneGlide (14/.03)file is inserted to the working length according to the manufacture instructions. the OneCurve 25/.04 and 25/.06 files are used to shape the canal to full working length.

GROUP 3 (n=15)**:** The following sequence of Hyflex EDM file used to prepare the canal with Xsmart endomotor. Hyflex EDM orifice opener is used to enlarge the orifice and after that Hyflex EDM glide path is inserted to the working length according to the manufacturer`s instructions. Hyflex EDM 20/.05 and 25/.08 files are used to shape the canal to full working length. The Hyflex EDM files are used in a gentle in and out motion with a rotational speed of 500rpm and 2.5 Ncm torque.

GROUP 4 (n=15): left unprepared

A complete rotation with light pecking in and out motion will be done for instrumentation. With the use of each instrument, the canal was irrigated with 2 mL of 3% NaOCl and 5 ml of saline and 5 ml of 17% ethylene diamine tetra acetic acid between each instrument change, followed by final rinse with 2 ml of distilled water. The instruments were used only once according to the manufacturer instructions.

Sectioning and Microscopic Examination

The samples stained with methylene blue dye (0.5%) for 24 hours and washed in running water and after that washed with distilled water.

All roots were marked at 3,6 and 9 mm from the apex using a marker. All roots were horizontally sectioned at 3,6 and 9 mm from the apex with rotating diamond disc positioned perpendicularly to the to root canal axis, under copious water cooling. Each slices are examined under 40x magnification using stereomicroscope to detect the presence or absence of dentin micro-cracks. Pictures were taken with camera attached to stereomicroscope and examined the sections for dentinal cracks. PowerPoint presentation for each root sections would be prepared with three images on each slide for blind study by examiner.

Defects that extending from the inner canal lumen was considered as dentinal crack having been produced by the instrument. The data collected will be subjected to statically analysis.

OBSERVATION AND RESULT

Normality of data was checked using Shapiro wilk test. Thus, inferential statistics were performed using parametric tests of significance. Pearson Chi-square test was used to determine the differences between groups. The results regarding the presence

of dentinal defects were expressed as the number and percentage of samples with microcracks in each group. Level of statistical significance was set at $p < 0.05$.

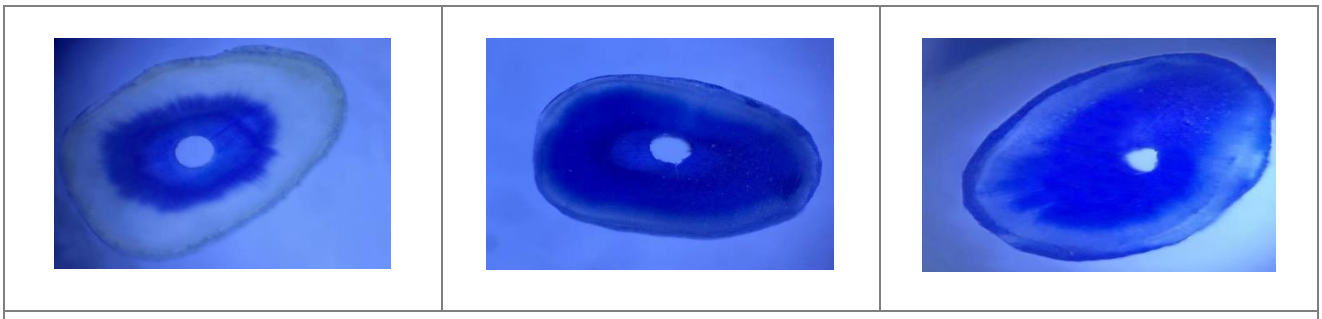
The results showed that at 3mm level, the number of teeth in which cracks were observed were 2 (13.3%) in group 1, 5 (33.3%) in group 2, 3 (20.0%) in group 3 and 0 (0.0%) in group 4.

At 6mm level, the number of teeth in which cracks were observed 1(6.7%) in group 1, 3 (20.0%) in group 2, 2 (13.3%) in group 3, and 0 (0.0%) in group 4.

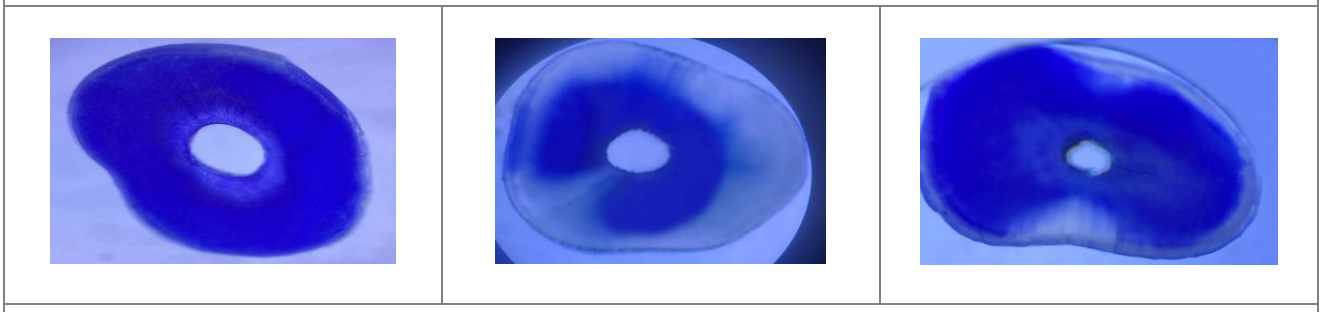
At 9mm, the number of teeth in which cracks were observed 1(6.7%), 2(13.3%) in group 2, 2 (13.3%) in group 3, and 0 (0.0%) in group 4.

At all three horizontal sections, TruNatomy has shown (8.88%) less number of cracks followed by Hyflex EDM (15.15%) and maximum in OneCurve (22.2%) though $p>0.05$ thus, statistically insignificant difference has been found.

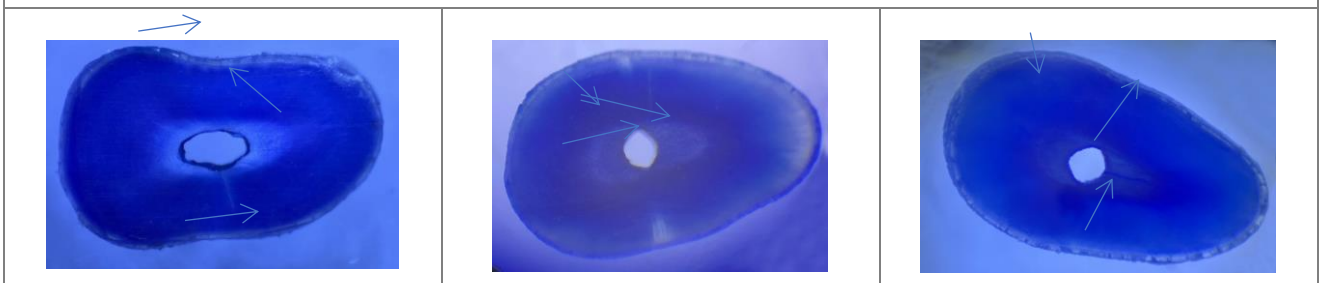
In all file systems, more cracks has been found at 3mm (TruNatomy 13.3%, Hyflex EDM 20% and OneCurve33.3%) followed by 6mm (TruNatomy 6.7%, HyflexEDM 13.3% and OneCurve 20%) and least at 9mm (TruNatomy 6.7%, Hyflex EDM 13.3% and OneCurve 13.3%) though $p>0.05$ thus, statistically insignificant difference has been found.



The Arrow Shows dentinal crack by TruNatomy file at 3,6 and 9 mm level



The Arrow Shows dentinal cracks by OneCurve file at 3, 6 and 9 mm level



The Arrow Shows dentinal cracks by OneCurve file at 3, 6 and 9 mm level

Table 1: Intergroup comparison of the number of teeth in which cracks were observed on the horizontal sections at 3mm

			Cracks at 3mm		Total
			Absent	Present	
Group	Group 1	N	13	2	15
		%	86.7%	13.3%	100.0%
	Group 2	N	10	5	15
		%	66.7%	33.3%	100.0%
	Group 3	N	12	3	15
		%	80.0%	20.0%	100.0%
	Group 4	N	15	0	15
		%	100.0%	0.0%	100.0%
Total		N	50	10	60
		%	83.3%	16.7%	100.0%
P value			0.100, ns		

[a]Chi square test, Level of significance at $p < 0.05$*

Graph 1: Intergroup comparison of the number of teeth in which cracks were observed on the horizontal sections at 3 mm

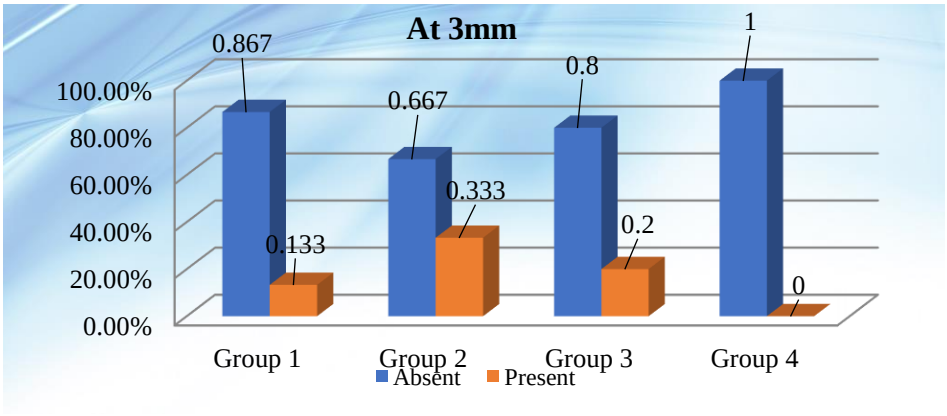


Table 2: Intergroup comparison of the number of teeth in which cracks were observed on the horizontal sections at 6 mm

			At 6 mm		Total
			Absent	Present	
Group	Group 1	N	14	1	15
		%	93.3%	6.7%	100.0%
	Group 2	N	12	3	15
		%	80.0%	20.0%	100.0%
	Group 3	N	13	2	15
		%	86.7%	13.3%	100.0%
	Group 4	N	15	0	15
		%	100.0%	0.0%	100.0%
Total		N	54	6	60
		%	90.0%	10.0%	100.0%
P value			0.295, ns		

[a]Chi square test, Level of significance at $p < 0.05$*

Graph 2: Intergroup comparison of the number of teeth in which cracks were observed on the horizontal sections at 6 mm

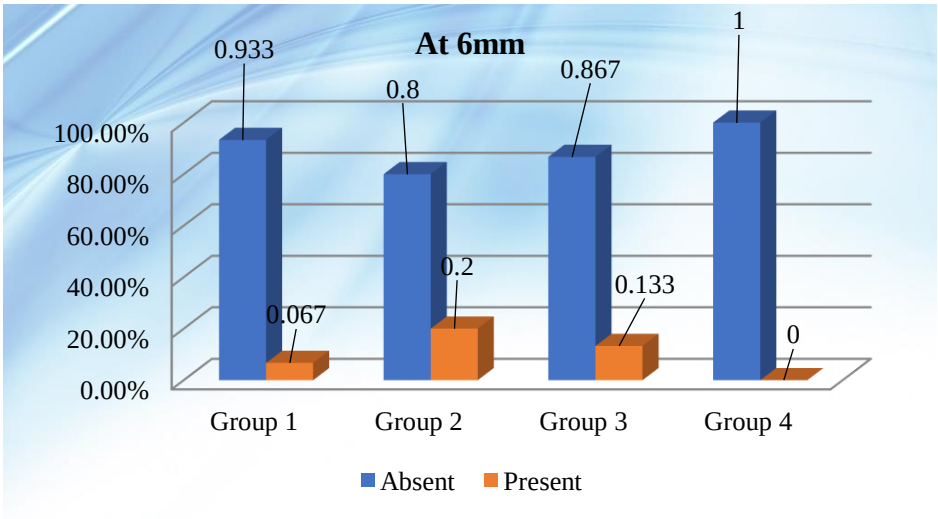
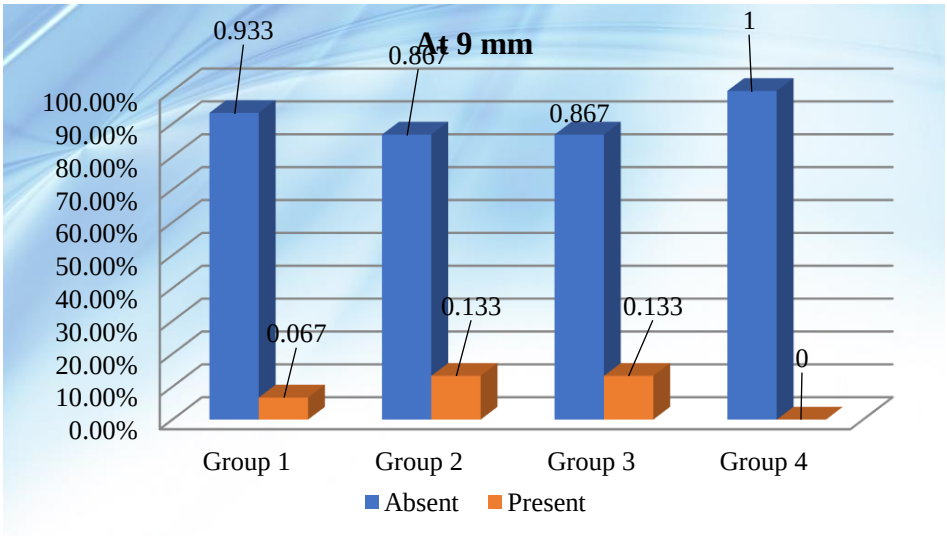


Table 3: Intergroup comparison of the number of teeth in which cracks were observed on the horizontal sections at 9 mm

			At 9 mm		Total
			Absent	Present	
Group	Group 1	N	14	1	15
		%	93.3%	6.7%	100.0%
	Group 2	N	13	2	15
		%	86.7%	13.3%	100.0%
	Group 3	N	13	2	15
		%	86.7%	13.3%	100.0%
	Group 4	N	15	0	15
		%	100.0%	0.0%	100.0%
Total		N	55	5	60
		%	91.7%	8.3%	100.0%
P value		0.494, ns			

Graph 3: Intergroup comparison of the number of teeth in which cracks were observed on the horizontal sections at 9 mm



DISCUSSION

Biomechanical preparation is an important step to achieve success in endodontic treatment. At times, dentine damage can occur during root canal cleaning and shaping. The contact between the instrument and canal walls during preparation creates momentary stress concentrations in the root dentin, which may lead to dentinal defects from which vertical root fracture can originate. Instrument features such as tip design, cross-sectional geometry, taper, pitch design, and flute form may be related to dentinal crack formation.[14]

Traditionally, root canal preparation was carried out using stainless steel endodontic files manipulated by hand. In recent years advances in rotary nickel titanium instruments have led to new design and techniques of root canal preparation. but the major drawback associated with rotary NITI instrumentation is the incidence of dentinal defects which further leads to vertical root fracture (VRF).[15]

When Ni-Ti rotary instrument are used, a rotational force is applied to the root canal walls. Thus, they can create micro cracks or craze lines in the root dentin. The extent of such a defect formation may be related to the tip design cross section geometry, constant or progressive taper type, constant or variable pitch and flute form.[16]

The stresses generated from inside the root canal are transmitted through the root to the surface where they might overcome the bonds holding the dentine together. Fracture occurs when the tensile stress in the canal wall exceeds the ultimate tensile strength of dentine.

Using Ni-Ti engine-driven instruments for root canal preparation has become the fundamental of endodontic treatments. These instruments have many advantages such as less operation time, increased cleanliness of root canal walls and fewer procedural accidents (apical canal transportation, perforations and ledges). These properties mostly stem from the increased flexibility of Ni-Ti alloy which helps in preservation of root canal curvatures.[17]

Freshly extracted teeth were used in the study to minimize its interference with crack formation outcome. Teeth were disinfected with 0.1% thymol solution and subsequently stored in distilled water to prevent dehydration of samples, as dehydration can have impact on crack formation. Acrylic blocks and silicone impression material were used to simulate bone and PDL, respectively. PDL simulation acts as a stress absorber during preparation, thereby better mimicking the clinical situation.

Mandibular first premolars were used in our study due to their smaller dimensions and their thin dentinal walls that are more prone to the stress caused by shaping. This approach was applied since the likelihood of micro crack formation with large tapered files is higher in mandibular premolars than in other teeth.

TruNatomy has an off-centered parallelogram cross-section design with regressive taper. It has been argued that TruNatomy instruments maintain the remaining dentine and tooth intactness due to the instrument design, regressive tapers, and the thinned design, along with the heat treatment of the Ni-Ti alloy. According to manufacturer all files operate at higher speed with less torque:500 rpm and 1.5 Ncm torque run in continuous motion. with just two cutting edges it encounters less applied pressure, ensuring precision with increased ease of use. Thermal treatment provides greater flexibility with improved fatigue resistance.

One Curve (Micro-Mega, Besancon, France) is a heat-treated single-file system that was released in 2018. The heat-treated Ni-Ti alloy is called C. Wire. C. Wire technology is reported to provide a controlled memory and a pre-bending feature to the file for easier access to the root canal. Although One Curve files have a single tip size (size 25) and constant taper (6%), different shape designs are available. The variable cross-sections with a triangular-shaped at the tip of the instrument and S-shaped near the shaft are claimed to allow effective cutting and centered trajectory.[10]

HyFlex EDM files are controlled memory instruments, manufactured using a unique process called electrical discharge machining (EDM). Electrical Discharge Machining uses spark erosion to harden the surface of Ni-Ti files in the manufacturing process, which gives the files excellent flexibility and fracture resistance. In addition, thanks to the controlled memory, the risk of root transportation and perforation is reduced by

the files more easily following the root canal anatomy. HEDM uses three different cross sections: quadratic in apical third, trapezoidal in middle third and almost triangular in the coronal third[18].

A crack is defined as the defect originating from the inner root canal space and propagating to the periphery. All other defects that did not originate from the canal wall, as craze lines were not considered as cracks.

In this study determination of the microcracks was investigated by stereomicroscope after teeth sectioning which can be a cause for dentinal defects. However, no cracks have been seen in the control group which means that the microcracks developed due to preparation and not tooth sectioning process.

In the present study, all root canal shaping files, produced microcracks in root dentin. These findings are in accordance with Yoldas et al[13]. And Bürklein et al[4], who found cracks in the root canals prepared by rotary NiTi instruments but not in the root canals instrumented with hand K file.

All tested files have proven to produce microcracks at all levels. The overall results have shown a statistically insignificant difference between the incidence of microcracks between the tested files. The highest incidence of the microcracks were present in the OneCurve group followed by the HEDM and the least with TruNatomy.

This study is in accordance with a study done by Cirakoglu N et al[19]., Jaju K et al[20]., Johnson J et al[21]., Ozlek E et al[18].

Cirakoglu N et al[19] evaluated and compare the microcracks formation in apical root dentin as a result of root canal preparation with protaper next, protaper gold and TruNatomy files in which TruNatomy caused statististically significant fewer cracks than other two other rotary Ni-Ti system.

Jaju K et al[20] evaluate and compare the dentinal cracks after root canal preparation with Protaper Gold, TruNatomy, and Profit S3 in which TruNatomy files produced lesser number of cracks than other two files.

Johnson J et al[21] Compare and evaluated formation of dentinal cracks using three NI-TI rotary files TruNatomy, XP Endoshaper, Protaper Gold, in which TruNatomy showed the statistically significant lowest percentage of cracks(7.8%) as compared to other two file systems, XP Endoshaper(26.7%), Protaper(15.6%).

Ozlek E et al[18] evaluate and compare the formation of dentinal cracks after root canal preparation with Reciproc Blue, OneCurve and, Hyflex EDM rotary files, in which Hyflex EDM showed statistically significant less dentinal cracks then other file systems used.

Lower dentinal crack incidence in the TruNatomy group may be attributed to the taper differences between TruNatomy and the other groups. It has been argued that TruNatomy instruments are less destructive for root canal system due to the regressive tapers and the heat treatment the Ni-Ti alloy. The slenderized pattern might have caused relatively fewer apical cracks in the TruNatomy system.

TruNatomy revealed the least number of microcracks. This can be referred to the instrument's geometry, i.e., off centered parallelogram cross section, regressive tapers, and slim design. These results comes in agreement with Yoldas et al[13] who concluded that the number of microcracks formed following instrumentation is dependent on the file design features.

Pedulla E et al[24] compared the development of microcracks following root canal preparation using One Shape, F6 SkyTaper, Hyflex EDM, WaveOne, Reciproc, and WaveOne Gold in which less microcracks visible in Hyflex EDM and WaveOne Gold compared to other experimental group.

Different speeds and torques have been used for three-file systems according to manufacturer's instructions. According to Peter et al.[7] and Capar et al[22], the increased rotational speed is related to increased cutting efficiency and lesser crack formation.

Hyflex EDM and One Curve files evaluated in this study produced rotary motion and caused dentinal crack formation at the rate of 15.55% and 22.2%, respectively. Although they have the same kinematics, the reason for crack formation at different rates with these file systems is primarily because the recommended speed of Hyflex EDM is higher than that of One Curve. Therefore, we think that the reason why Hyflex EDM caused less dentinal crack formation compared to One Curve is that it has high cutting efficiency due to high speed[18].

Taper angles of the files used in root canal preparation are effective on dentinal crack formation. Increasing taper angles cause higher stress in the canal wall, and therefore more dentinal cracks are formed. One Curve files (6%) constant taper from the apical to the coronal region) produce more dentinal cracks because of being more tapered compared to Hyflex EDM.

Studies have shown that the files manufactured from M-Wire NiTi alloy have higher flexibility and higher cyclic fatigue resistance compared to conventional NiTi files. In addition, controlled memory files have been reported to be more flexible than both M-Wire NiTi alloy and conventional NiTi wire. HyFlex EDM and One Curve are two controlled memory files, one of which is manufactured by electrical discharge machining (EDM) method and the other is manufactured from C. Wire alloy.

In this study, more dentinal cracks were observed in the apical region compared to the middle and coronal regions with all tested files, and no statistically significant difference was found. The 3 mm apical part of the root is considered to be the most critical region in terms of the risk of dentinal crack formation during root canal shaping[18].

In a study by ***Sindi et al[23],*** the occurrence of microcrack formations in the coronal level (9mm) was 33.3% and the same percentage in both the middle (6mm) and apical level (3mm). Similar to the results of the present study a study by ***Pedullà et al[24]*** showed that all the systems i.e one shape, skytaper, HyflexEDM, Wave one Gold, caused cracks, mainly in the apical section (3 mm). Similar results were reported by ***Karatas et al[25]*** and ***Ustun Y et al[26].*** Contrary to the results of the present study, studies by ***Adorno et al[27] and Liu et al[28]*** found out that the cracks in the coronal region were more abundant than the cracks in the apical region for all the three groups.

The occurrence of stress due to successive instrumentation, and low capability to the thin and fragile dentin in the apical area to the mechanical stress produced by direct contact with the instrument tip, may cause the formation of cracks. The tip design, cross-sectional geometry, pitch, taper, and flute of rotary instruments could affect the crack formation Additionally, the use of a single-file system for root canal shaping causes more stress in the apical region, the most fragile part of the root.

Within the limitations of this study, it could be concluded that multiple factors cause dentinal cracks. Instrument features such as tip design, cross-sectional geometry, taper, pitch design, and flute form may be related to dentinal crack formation. The flexibility of NiTi instruments because of heat treatment seems to influence the incidence of microcracks more than other factors.

The possible limitations of our *in vitro* study are the sectioning method, difficulty in identifying internal pre-existing cracks, and the inability to standardize the speed and torque of the rotary files used.

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