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Dentinal Cracks in Root Surface Induced by different Nickel Titanium Rotary File Systems.

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Abstract:
Background: *Evaluating dentinal cracks in root canal surface after biomechanical preparation using rotary files systems as ProTaper Next,2 Shape and Race.*
Methodology*:Forty extracted human single canal mandibular premolars were weredecoronated perpendicular to the long axis of the tooth leaving roots (12±1mm) then positioned centrally in a mold using acrylic resin. Roots were randomly divided into 4 main groups(n=10) according to the Nickel Titanium (Ni-Ti) rotary file system used in preparation:**Group I:** Control group roots were left unprepared. **Group II**: Canals were prepared using Ni-Ti 2 shape system up to TS2 file (#25/0.06). **Group III:** Canals were prepared using Ni-Ti ProTaper Next system up to X2 file (#25/0.06). **Group IV:** Canals were prepared using Ni-Ti Race system up to file (#25/0.06). Each root was sectioned horizontally using Isomet saw to give three sections: coronal,middle and apical with total of 120 sections and observed by Stereomicroscope and scanning electron microscope (SEM) to detect dentinal cracks.*
Results: *There is more dentinal cracks in the ProTaper Next group than 2 Shape ,Race and control groups as there was statistically significant difference present (P<0.05).There were no Statistically significant difference between the apical ,middle and coronal sections. (P=0.536).*
Conclusion*: ProTaper Next group showed high percentage of dentinal cracks incidence followed by Race, 2 Shape and control groups regardless the root canal cross section and the highest percentage of dentinal cracks incidence were in the apical third followed by middle and coronal thirds regardless of the Ni-Ti system*
Keywords:*2 Shape,Dentinal cracks, Nickel Titanium,ProTaperNext,Race.*

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I. Introduction

The aim of endodontic treatment is to completely remove micro-organisms, pulp tissue and debris and achieve a three dimensional seal of the root canal system by enlarging the diameter of original canal anatomy to a more desirable canal shape to obtain proper coronal and apical seal[1].

When biomechanical preparations are carried out, endodontic instruments don't act on the entire canal wall rather they act only on the central body of root canal[2].Instrumentation alone could produce dentinal damage in the apical region which in turn make risk of crack initiation, and there is a higher incidence of production of dentinal cracks when larger files are used in root canal preparation[3]. The more amount of dentin removed the more there is incidence for root fracture by formation of more small craze lines which will later propagate to vertical root fracture if the tooth are subjected to repeated stresses from endodontic or restorative procedures[4].

In the last decade there is a huge advancement in Nickel-Titanium (Ni-Ti) rotary systems with various files differing in their design features as cross section, flute depth and rake angle. Therefore these variables may affect dentin removalin the biomechanical preparation leading to cleaning and shaping mishaps as different craze lines formation and cracks generation[5].

Defect is referred as presence of craze line or microcracks or even complete crack that extend from the inner root canal space all the way to outer surface of root5.So in order to minimize dentinal cracks and other mishaps during root canal instrumentation, different Ni-Ti rotary systems are always introduced and developed to improve the efficiency and clinical outcomes of root canal treatment[6].

There are various methods to detect dentinal cracks such as micro CT, optical coherence topography and vibro-infrared but Stereomicroscope and scanning electron microscope are preferred in direct visual detection of cracks unlike other methods[7].

II. Material and methods

Forty freshly extracted, nearly straight, mature human mandibular premolars with single root canals were collected. Approval for this research was obtained from Faculty of Dentistry, Tanta University, Research Ethics Committee. The purpose of the present study was explained to the patients and informed consents were obtained to use their teeth on the research according to the guidelines on human research published by Research Ethics Committee at Faculty of Dentistry, Tanta University.

Study Design: DirectObservational study
Study location:Faculty of Dentistry, Tanta University
Study duration:December 2018 to December 2019
Sample size:4 groups (30 sample/ each) with total of 120 samples

All collected teeth were rinsed by tap water and cleaned from soft tissues and calculus using hand periodontal curette and stored in 10% buffered formalin phosphate solution1 at room temperature until used[8].

All teeth were decoronated perpendicular to the long axis of the tooth by using low speed diamond disc (Dica, Dendia, USA) under copious amount of water coolant system, leaving roots approximately 12±1 mm in length to ensure standardized root length for all samples[9].Blocks were made using a 5 ml plastic polyvinyl syringe with 15 mm length and internal diameter 10 mm which will act as a mold to hold the roots in it. The coronal surfaces of the roots were fixed onto a glass slap using a sticky wax for stability and centralization of the roots within the block without any root inclination.

Canal patency were established by using hand K-type stainless steel (#10/0.02) (#15/0.02) files till the full working length then 1 ml were shortened to the final working length and radiograph were taken to verify it to ensure complete patency and to standardize the initial canal diameter[10].Then roots were randomly divided into 4 groups (n=10) according to the Ni-Ti rotary file system being used in root canal preparation:

Grouping:
Group I (control group):
10 root canals were left unprepared by any rotary file to serve as a control group(11).
Group II(2 Shape group):
Root canals were prepared by 2 Shape (Micro Mega™, Besancon, France) system at 350 rpm and torque at 2 N.cm respectively according to manufacturer instructions in crown down manner by first introducing TS1 Ni-Ti file (#25/0.04) to shape the coronal two thirds then TS2 Ni-Ti file (#25/0.06) was carried to the full working length until the file passively reaches the apical limit..
Group III(ProTaper Next):
Root canals were prepared by ProTaper Next(Dentsply™Maillefer; Ballaigues, Germany) system at 300 rpm and torque at 4 N.cm respectively in crown down manner by first introducing SX Ni-Ti file (#19/0.04) to shape the coronal two thirds then X1 file (#17/0.04) and X2(#25/0.06) to the full working length.
Group IV(RaCe):
Root canals were prepared by RaCe (FKG™ Dentaire, La Chaux-de-Fonds, Switzerland) system at 600 rpm and torque at 1.5 N.cm respectively in crown down manner by first introducing files in the following sequence (#15/0.04), (#20/0.04), (#25/0.04),(#25/0.06) to the full working length.
In all samples irrigation was made with 5.25% sodium hypochlorite,saline and 17% EDTA solution throughout the cleaning and shaping after each file and whenever there is a blockage in the root canal due to debris Also Each (Ni-Ti) system was coated with glide file lubricant (Ethylenediaminetetraacetate 17% concentration Vista,USA)throughout the whole procedure of cleaning and shaping.

ProcedureMethodology:
Preparation of roots for sectioning

Sectioning of each block were carried out in horizontal plane perpendicular to the long axis of the tooth at 3,6 and 9 mm from apex where the most apical 2-3 mm was discarded and the remaining length was divided into 3 equal sections of 3 mm in length[6].

The 1mm in thickness slices were taken from the middle of each section to represent mid-apical, mid-middle and mid-coronal root canal thirds by using water cooled low speed Isomet saw (Buehler Ltd., lake bluff, Il, USA), and three 1mm in thickness slices were accurately measured using digital caliper (AR instrumented Germany) obtained from each specimen[12].

Evaluation of dentinal cracks:

The digital images were taken using a stereomicroscope with X40 magnification with the aid of external high definition camera connected to computer to enhance the resolution of the root sections images..Total of 120 digital images (30 images/group) were examined for the presence of cracks [12] and root Defects were classified as "no defect, complete cracks and other defects according to *Wilcox et al*[13].

Scanning Electron Microscope (SEM):

Random samples from each group were obtained and prepared for scanning electron microscope evaluation to confirm the results obtained from stereomicroscope as Images of each section with cracks were taken at X50, X100, X350 and X500 magnifications as the baselines using scanning electron microscopy[14].

Statistical analysis:

Statistical analysis was performed using SPSS (Chicago, IL, USA, version 18.0) .Kruskal Wallis and Mann–Whitney tests were used for pairwise comparisons between all Ni-Ti groups at each third and all Ni-Ti groups regardless third and between all the thirds regardless of Ni-Ti group[15].Whenever statistically significant difference was recorded among the levels, Mann–Whitney pair- wise comparison test was then performed to compare between each two tested levels. All tests analysis was performed at a significance level of P value less than or equal to (0.05).

III. Results

All of rotary file systems used in this study induce dentinal cracks.Regarding group I showed no dentinal cracks,(Fig.1) There is more dentinal cracks in Group II followed by group IV then group II as there was statistically significant difference present (P<0.05).(Fig.1) and (table 1).

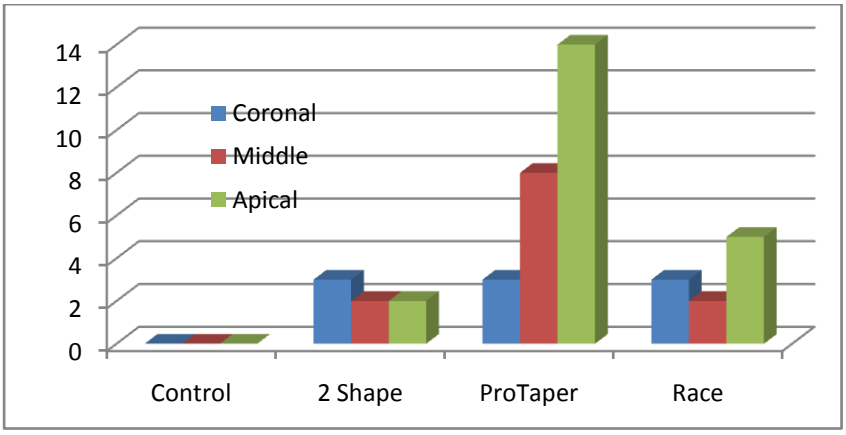

Fig1: Bar chart showing Number of specimens with cracks at different cross section levels and their total percentages within each third

Groups	N	Mean Rank	Chi-Square	df	*P* value
Group I (control)	30	47.00	17.579	3	0.001
Group II (2 shape)	30	59.83			
Group III (ProTaper)	30	74.43			
Group IV (Race)	30	60.73			

Table 1: Kruskal Wallis non-parametric test for the different groups and their statistical value.

Regarding groups,according to the kruskal Wallis test which was made to determine the different percentages of cracks in the three sections of each tooth, revealing that the apical third has the highest mean (64.13) and percentage of dentinal cracks formation and also a non-statistical significance difference was found between the root sections(P=0.536) as shown in (Fig.3)and (table 2)

Position	N	Mean Rank	Chi-Square	df	*P* value
Coronal	40	58.28	1.247	2	0.536
Middle	40	59.10			
Apical	40	64.13			

(Table 2): Kruskal Wallis non-parametric test for the different types of cracks and their statistical value in different cross sections.

Comparison between different groups were performed revealing no statistically significant differences between all groups except between groups I,III (P=0.888).and groups II, III where (P=0.063) as shown in (table 3).

	I vs II	I vs III	I vs IV	II vs III	II vs IV	III vs IV
Mann-Whitney U	332.000	443.000	345.000	345.000	255.000	345.000
Z	-2.092	-0.141	-2.791	-1.858	-4.004	-2.787
P value	0.036	**0.888**	0.005	**0.063**	0.000	0.005

(Table 3): Mann-Whitney U non-parametric test for two group comparison and their statistical significance.

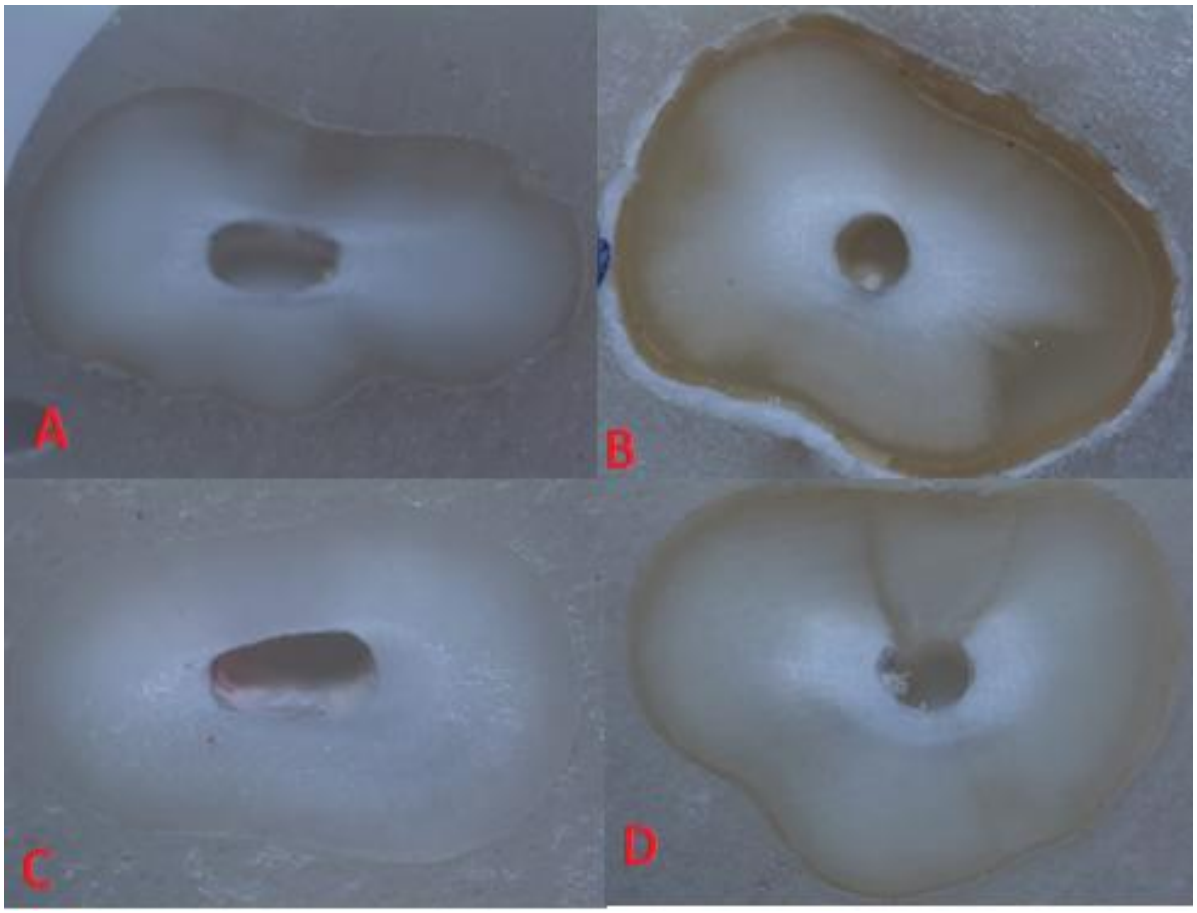

Fig 2: Samples of control group **(a,b)**showing absence of cracks ,Samples instrumented with ProTaper Next system**(c,d)** with no cracks presence of cracks.

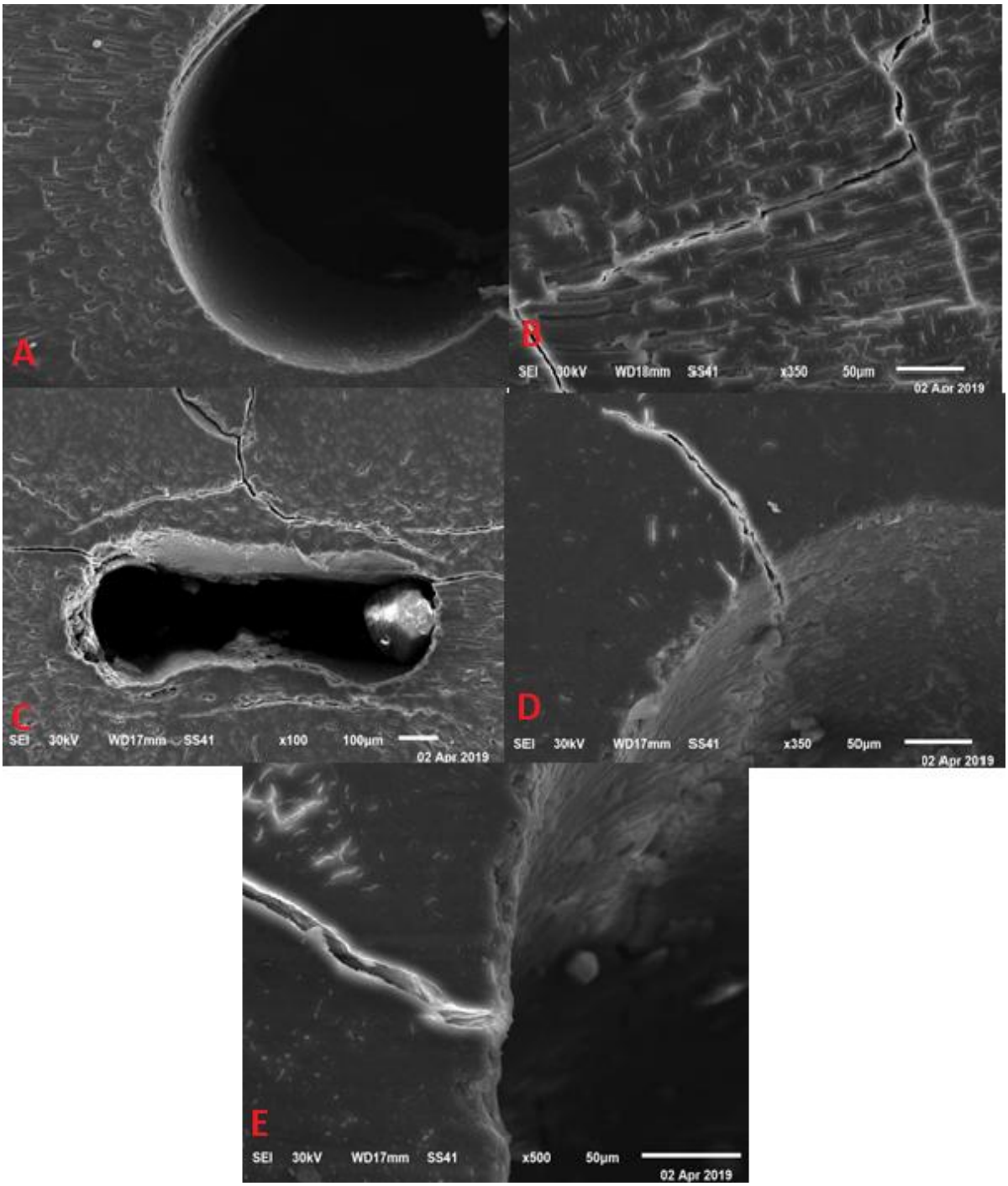

Fig 3: (a) SEM at x50 showing negative signs of dentinal cracks in apical section,**(b)**SEM at x350 showing dentinal cracks in apical section in 2 shape group,**(c)**SEM at x100 showing multiple dentinal cracks around the root canal in middle section in ProTaper Next group,**(d)**SEM at x350 showing dentinal cracks originating from inside the root canal in middle section in race group,**(e)**SEM at x500 showing dentinal crack originating from inside the root canal in middle section and propagating toward the surface in race group.

IV. Discussion

Proper and adequate biomechanical preparation (BMP) is the most important step in endodontics as it greatly helps to achieve uniform hermetic three dimensional obturation of the root canal system[16]and prevent re-invasion of the bacteria as it may proliferate in crack lines and dentinal cracks that might be created during cleaning and shaping, furthermore establishing biofilms on the root surface and consequently failure of the whole procedure of endodontic treatment [17]according to *Singh et al*[11].

After the instrumentation procedure 35% or more of the canal surface as lateral canals, deep apical areas and other irregularities remains intact and uninstrumented according to *Peter et al*,[18].So they provide an excellent environment for bacteria to colonize and cause failure of root canal treatment [19].

In *Nazir et al* study Statistical significant difference was found between CBCT and SEM when the total number of each type of defect was calculated (14).Craze lines were observed and detected only in SEM images not in CBCT images due to the greater magnification power used (×35 and ×75 μm) in SEM as consented by *Cicek et al*[20] who found that craze lines (micro cracks) were more obviously seen and detected using high magnification power (×40 μm) and *Özer et al*[21] who found that CBCT scans showed failure in reading of fracture lines smaller than 0.2 mm.

The sectioning method has no effect on crack formation or propagation[22], which come in agreement with several studies as *Bier et al.*[4] ,*Yoldz et al.*[15] ,and *Hin et al*. [23], who stated that some dentinal cracks might have been existed internal and may not be visible on the outer surface of the root. However, there were no cracks or fracture formation in the negative control group in the previous studies. On the contrary to *Shemesh et al*[24] who found that the sawing action somehow could result in dentinal micro cracks.

According to *Tomar et al*. [25]direct visualization of the root canal system by using microscoping system would provide a better detection and understanding way of the distribution of the dentinal cracks or any defects so stereomicroscope is used to visualize the defects and has many advantages as it is cost effective ,most common,fastest,high definition tool and sensitive enough to identify small area of cracks on the canal wall with the aid of 30X magnification loops for stereomicroscopic analysis[26].

No dentinal cracks were found as seen in stereomicroscope and Scanning electron microscope coronal enlargement and pre-flaring are made using hand K-type stainless steel files #10 and #15 subsequently in what is called glide path creationwhich is needed to prevent excessive instrument binding in the canal and subsequently decreasing any mishaps during the biomechanical preparation procedure[27].

23% dentinal cracks were observed in stereomicroscope and Scanning electron microscope as it comes In agreement with study made by *Gündoğar et al* ,stated that there is direct relation between the dentinal crack formation and the number of cycles to fracture for Ni-Ti file and it was stated that Receiproc blue Ni-Ti files showed higher cyclic fatigue resistance than 2 Shape files, Moreover the increase in the angle of curvature negatively affects the cyclic fatigue resistance and consequently more mishap as microcracks that may even lead to excessive stresses on file and finally file fracture[28].

The current study revealed that ProTaper Next recorded higher dentinal cracks formation compared to other groups as (83%) dentinal cracks were observed in stereomicroscope and Scanning electron microscope. Which come in agreement with different studies regarding the Ni-Ti rotary files role in dentinal crack formation.as *Capar et al.*[29] ,*Karatas et al.*[30] and *Cicek et al*.[20] who reported the incidence of dentinal cracks due to use of ProTaper Next rotary Ni-Ti files in (28%), (33.3%) and (64.44%) of samples respectively.These results were agreed with results in a study conducted by *Salem et al*. that showed there is (21%) increase in dentinal cracks of ProTaper group and hand instrumentation as a control group[31].

In contrast to this findings no significant difference were observed in number of defects in dentin after preparation with four different rotary systems, HERO shaper, Revo-S, Twisted File and Protaper Next (60%), (25%), (40%) and (30%) respectively which was found by *Yoldas et al*.[15].Also*Burklein et al.*[32]did not find any significant differences in incidence of dentinal defects after root canal preparation by Ni-Ti rotary and reciprocal motion in any of the three sections between ProTaper(23.3%), Mtwo(18%)and Reciproc(33.3%), WavOne(30%).This controversy could be due to difference in groups methodology as these studies comparing both rotary and reciprocal motions and due to difference in apical preparation sizes #30 and #40 .

Similar study by *Ashraf et al*.[17] have founded that ProTaper Next and HyFlex CM Ni-Ti rotary files have fewer tendencies to create dentinal cracks when compared with ProTaper universal system which showed the highest percentage of dentinal cracks.

In another study by *Staffooli et al* , there was no significant differences in the centering ability induced by ProTaper Next and 2 Shape Ni-Ti files systems as they were subjected to the test in stimulated severely curved canals and both systems showed some degree of transportation and microcracks formation especially in the apical third which is considered a mishap[33].

Regarding group II ,stereomicroscope and Scanning electron microscope revealed that (33%) dentinal cracks were observed and this result comes in agreement with a study done by *Garg et al*. that showed (10%)

cracks were formed by Race files and they were less than K3 rotary files (16.7%).But this might be attributed to the difference in apical preparation in this study as it was performed till (#25/4%) not to (#40/4%)[34].

The current study revealed that the apical third is the most susceptible for dentinal cracks formation and propagation and it comes in agreement with *Nishad et al*[35]study results stating that ProTaper Next (PTN) and ProTaper universal (PTU) has higher percentage of dentinal cracks formation compared to ProTaper gold (PTG).

This finding is in agreement with the results obtained by *Adorno et al*,as dentinal cracks were seen in 70%, 60% at the apical part at the full working length (WL) and 40%, 20% at 1 ml above the working length (WL-1) [36, 37].

V. Conclusion

Within the limitation of the present in-vitro study, the results suggested that:

1-Rotary preparation technique gives superior results than hand preparation technique regarding time consuming, canal shaping and mechanical properties.

2-ProTaper Next group showed high percentage of dentinal cracks followed by Race, 2 Shape and control groups regardless the root canal cross section.

3-The highest percentage of dentinal cracks incidence were in the apical third cross section followed by middle and coronal thirds regardless of the Ni-Ti rotary system.

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Conflicts of interest

The authors deny any conflict of interest related to this study.

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