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ORIGINAL ARTICLE

Incidence Of Apical Crack Initiation And Propagation During The Removal Of Root Canal Filling Material With Protaper And Mtwo Rotary Nickel-Titanium Re-Treatment Instruments And Hand Files: An In-Vitro Study.

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ABSTRACT
Introduction: The Re-treatment procedure requires mechanical instrumentation and further preparation of the canal. Today, it's the era of rotary files because of being less time-consuming in instrumentation. As many file systems are available for the re-treatment procedure, the aim of this study was to determine the effect of re-treatment procedure on the apical dentin by determining apical cracks initiation and propagation with three different file systems ProTaper, Mtwo and Hand files.
Materials and Methods: Untreated human mandibular premolars with single canal and Fully formed apices. The root surfaces of each tooth was observed under a stereo-microscope (Leica micro-systems) at ×40 magnification for evidence of fracture lines, open spices, or anatomic irregularities and were discarded if any of these characteristics were found. The apical 1 mm of the roots were grounded perpendicular to the long axis with waterproof 320-grit silicone carbide disk and was polished. A base-line image of the apical surface of each specimen was observed under stereo-microscope (Leica micro-systems). 30 teeth each served as control group, ProTaper re-treatment group, Mtwo re-treatment group and Hand files group. Root canal treatment, re-treatment and additional instrumentation was performed in each experimental group. The images were captured by a stereo-microscope(40X) (Leica micro-systems). Each specimen in the experimental group had 4 images taken [baseline, after instrumentation and obturation, after re-treatment and after additional instrumentation]. The images were then inspected for apical cracks initiation and Propagation and the data were analyzed.
Results: Ni-Ti rotary re-treatment instruments cause more crack initiation and propagation in apical root dentin after re-treatment procedures than do hand files. Root canal re-treatment with the ProTaper re-treatment system had a significant effect on the apical crack initiation and propagation. Additional instrumentation with Ni-Ti rotary instruments after re-treatment showed higher incidence of apical cracks initiation and propagation, but the hand file group showed none. It can be because both rotary instruments have an active rotating movement that may cause more friction between the files and canal walls inside the root canal.
Conclusions: This study shows that Root canal re-treatment with the ProTaper re-treatment system had a significant effect on the apical crack initiation and propagation. Ni-Ti rotary re-treatment instruments cause more crack initiation and propagation in apical root dentin than Hand files.
Key-words: Re-treatment, Apical cracks.

I. INTRODUCTION

Endodontic procedures, including biomechanical preparation, obturation and re-treatment, cause loss of tissue and put excessive pressure on the teeth. Mechanical instrumentation of the root canal system is an important phase of root canal treatment. However, it has been stated that root canal instrumentation has the potential to induce dentinal damage and generate cracks on the apical surface. [1,2,3]

Whenever initial root canal treatment fails, the first choice to eradicate or reduce microbial flora is Endodontic re-treatment. The goal of re-treatment of endodontically treated teeth is to eradicate persistent or emerged apical periodontitis and provide a favorable environment for healing. It aims to remove all filling materials from the root canal system, followed by chemo-mechanical disinfection and obturation.

Rotary systems are frequently used to prepare root canals because of being less time-consuming. However, they cause more dentinal micro-crack formation in root dentin because they have more taper as compared to 0.02 taper hand files. [2]**AviadTamse (2006)** [4] suggested that the most frustrating complication to root canal therapy is vertical root fracture. Cracks that occur during endodontic procedures can propagate with repeated stress application, and occlusal forces, rendering the tooth more susceptible to vertical root fracture. [4]

ProTaper re-treatment (DentsplyMaillefer, Baillagues, Switzerland) and Mtwo re-treatment (VDW, Munich, Germany) files are the two Ni-Ti rotary systems which have been designed for gutta-percha removal from the root canal system. The ProTaper re-treatment system consist of three instruments D1 (30/0.09), D2 (25/0.08) , D3 (20/0.07) files which are designed specially for removal of obturation from the coronal, middle and apical portions of root canals, respectively. [5,6,7,8,9,10]Mtwo re-treatment system consists of two instruments R1 (15/0.05), R2 (25/0.05) with cutting tips for efficient removal of gutta-percha obturation. [12]

However, very little data is available on the interrelation between re-treatment of the tooth with different file systems and crack formation. Currently, only four studies using sectioning method evaluated the incidence of cracks after re-treatment procedures in mandibular incisors and premolars. [31,33] In three studies [32,33], various re-treatment techniques, followed by different preparation and filling procedures, caused a high incidence of crack initiation and had a significant effect on crack propagation. Therefore, the purpose of this study was to evaluate the incidence of crack initiation and propagation in root dentin after re-treatment with two different commonly used rotary re-treatment systems ProTaper (DentsplyMaillefer, Baillagues, Switzerland), Mtwo (VDW, Munich, Germany) and Hand Hedström files (MANI INC., Japan) with additional instrumentation.

II. MATERIALS AND METHOD

The criteria for selection of teeth specimens was as follows-

Inclusion criteria-

All untreated human mandibular premolars with single canal with fully formed apices.

Exclusion criteria -

Root resorption, Root bifurcation, Open apices/Incomplete root formation, deviated apical foramen.

Radiovisiographs were taken from bucco-lingual as well as mesio-distal angles to verify the presence of single root canal. The root surfaces of each tooth was observed under a stereo-microscope (Leica microsystems) at ×40 magnification for evidence of fracture lines, open apices, or anatomic irregularities and were discarded if any of these characteristics were found. Teeth were then stored in purified distilled filter water (A.B.Enterprises, Mumbai) throughout the study. Collection, disinfection, storage and handling of extracted teeth was done according to the guidelines and recommendations by Occupational Safety And Health Administration (OSHA) and the Center Of Disease Control (CDC) (1993) .

The surfaces of all 120 teeth root were covered with silicon impression material Zetaplus (Zhermack, Italy) to simulate periodontal ligament space, the silicone impression material was removed from the apical 4 mm of the root to allow intraoperative image recordings. The apical 1 mm of the roots were grounded perpendicular to the long axis with waterproof 320-grit silicone carbide disk (DENTORIUM, New York, NY, USA). The apical surface was polished with waterproof silicone carbide abrasive paper (DENTORIUM, New York, NY, USA) to reduce the fine scratches and to obtain a clear, highly magnified image. A base-line image of the apical surface of each specimen was observed under stereo-microscope (Leica microsystems). The crowns of all teeth were removed at 2 mm above the proximal cemento-enamel junction to ensure straight line access. The resulting coronal surface provided a reference plane parallel to the apical surface. A size 10 k file was introduced into the canal until the file tip observed at the apical plane. The measurement was determined as the working length.

To ensure standardization, all 120 teeth roots were prepared by using Mtwo rotary files (VDW, Munich, Germany) up to size 35/0.6. The canals were irrigated with 2 ml 3% Sodium hypochlorite (DENTPRO, India) between each file size by using a syringe and a 23 gauge needle (PRICON, Iscon surgical ltd., Jodhpur, India). After completion of the preparation, the canals were irrigated with 5 ml 17% EDTA (CANALARGE, Amdent, India) for 1 minute and subsequently rinsed with 5 ml distilled water

(A.B.ENTERPRISES, Mumbai, India). After canal preparation all the 120 root canals were obturated with AH plus sealer (DentsplyMaillefer, Baillagues, Switzerland) and size 35/0.06 size gutta-percha points (DentsplyMaillefer, Baillagues, Switzerland) and the coronal opening of all specimens were sealed with Cavit (3M ESPE, Seefeld, Germany). Images of the apical portion of 120 roots were then, taken and crack initiation was checked. Computer generated randomization was used to make four groups. One control group with 30 teeth and the other three were experimental groups with 30 teeth in each group. All the specimens which showed crack formations were equally divided in the experimental groups.

Experimental groups and Re-treatment procedures:

Group1 - ProTaper re-treatment group (DentsplyMaillefer, Baillagues,Switzerland):[n=30]
In this group, the canal filling material was removed using ProTaper re-treatment instruments (DentsplyMaillefer). The re-treatment instruments were used at a constant speed of 500 rpm for D1 and 400 rpm for D2 and D3, with a torque of 3 N cm. The instruments were used in a brushing action with lateral pressing movements, according to the manufacturer's instructions: D1 (30/.09) in the coronal third, D2 (25/.08) in the middle third, and D3 (20/.07) throughout the entire working length. Stereo-microscopic images were taken after completion of re-treatment. Additional instrumentation was then performed by using an F4 ProTaper file (DentsplyMaillefer, Baillagues, Switzerland) at a speed of 300 rpm at working length.

Group 2- Mtwo re-treatment group (VDW, Munich, Germany) [n=30 teeth]
In this group, the canal filling material was removed using Mtwo R2 (25/.05) at a speed of 280 rpm and at a torque of 1.2 N cm. A brushing action was performed against the canal walls in a crown-down direction until the working length was reached. Stereo-microscopic images were taken after completion of re-treatment. Additional instrumentation was then performed by using the Mtwo instrument (40/.04) at a speed of 300 rpm and a torque of 1.6 N cm at the working length.
Group 3- Hand instrument group- [n=30 teeth]

In this group, gates glidden drills (DentsplyMailefer) size 3 and subsequent size 2 were used to remove coronal filling material. The canals were re-instrumented with Hedström files (Dentsplymaillefer) sizes 15, 20, 25 and 30, in a circumferential, quarter turn, push-pull filing motion to remove filling material until working length was achieved. Once working length was achieved with a size 15 file, sizes 20, 25, 30 and 35 were used at the working length. Stereo-microscopic images were taken after completion of re-treatment. Additional instrumentation was then performed by using a Hedström file (MANI INC., Japan) size 40 at the working length.

All the instruments were used with the speed control and torque recommended by the manufacture. The speed controlled endomotor X-Smart (DentsplyMaillefer, Baillagues, Switzerland) was used for the same. During re-treatment, canals were irrigated with 2 ml 2.5% NaOCL. When no gutta-percha or sealer was visible on the instrument surface, the process was considered complete. To avoid inter-operator variability, all procedures were performed by a single operator.

III. SCANNING AND IMAGING

Images were taken of each tooth in all experimental groups after Biochemical preparation and obturation, after re-treatment and after additional instrumentation. The images were captured by a stereo-microscope(40X) (Leica micro-systems). Each specimen in the experimental group had 4 images taken [baseline, after instrumentation and obturation, after re-treatment and after additional instrumentation]. Each image, was compared with the preceding image and any visible crack line on the apical surface that was not present in the preceding image were defined as a crack. The images were compared with the baseline image, and the presence of a new crack at any subsequent treatment or propagation of a crack in length occurring during procedures were noted.

IV. STATISTICAL ANALYSIS

Data obtained was compiled on a Microsoft Excel sheet (version 2010) and subjected to statistical analysis. Comparison of frequencies of specimens showing cracks at initiation & progression After re-treatment and After additional Instrumentation between all the groups was done using chi square test using Yates correction where required. $p<0.05$ was considered to be statistically significant, keeping α error at 5 % and β error at 20%, giving the power to study as 80%. The p value for this study was significant in

- Crack initiation after re-treatment.
- Crack propagation after re-treatment.
- Crack initiation after Additional instrumentation.
- Crack propagation after Additional instrumentation.

Table 1: Number of specimens showing cracks after Baseline stereo-microscopic images.

n/N
0/120

[n= Number of new cracks, N= Total number of specimens]

Table 2: Number of specimens showing cracks after Bio-mechanical Preparation and Obturation

n/N
27/120

[n= Number of new cracks, N= Total number of specimens]

Table 3: Number of specimens showing cracks after re-treatment.

	Initiation	Propagation
Groups	n/N	p/npct
Control	---	---
Hand file	2/30	2/09
ProTaper	7/30	5/09
Mtwo	5/30	3/09

[n= Number of new cracks, N= Total number of specimens, npct= Numbers of previous cracked teeth, P= Propagation of previous cracks]

Table 4: Number of specimens showing cracks after additional instrumentation.

	Initiation	Propagation
Groups	n/N	p/npct
Control	--	--
Hand file	0/30	0/11
ProTaper	5/30	6/16
Mtwo	3/30	2/14

[n= Number of new cracks, N= Total number of specimens, npct= Numbers of previous cracked teeth, P= Propagation of previous cracks]

Table 5: Chi-square test result of crack initiation after re-treatment

	Initiation	
Groups	n (%)	P *Value
Control	--	
Hand file	2 (6.7)	
ProTaper	7 (23.3)	**0.01**
Mtwo	5 (16.7)	
	30	

***- Chi-square test**

There was a statistically significant difference between number of specimens showing presence of crack initiation after re-treatment across all the groups (excluding control as it did not show any) $p<0.05$ with maximum cracks seen in ProTaper, followed by Mtwo.

Table 6: Chi-square test result of crack propagation after re-treatment

	Propagation	
Groups	n (%)	P* Value
Control	--	**0.03**
Hand file	2 (22.1)	
ProTaper	5 (55.6)	
Mtwo	3 (33.3)	
	9	

***- Chi-square test**

There was a statistically significant difference between no of specimens showing presence of crack progression after re-treatment across all the groups (excluding control as it did not show any) $p<0.05$ with maximum cracks propagation seen in ProTaper, followed by Mtwo.

Table 7: Chi-square test result of crack initiation after Additional instrumentation

	Initiation	
Groups	n (%)	P* Value
Control	--	**0.02**
Hand file	0 (0)	
ProTaper	5 (16.7)	
Mtwo	3 (10)	
	30	

***- Chi-square test**

There was a statistically non-significant difference between no of specimens showing presence of crack initiation after additional Instrumentation across all the groups (excluding control as it did not show any) $p<0.05$

Table 8: Chi-square test result of crack propagation after Additional instrumentation.

	Propagation	
Groups	n (%)	P* Value
Control	--	**0.003**
Hand file	0/11 (0)	
ProTaper	6/16 (37.5)	
Mtwo	2/14 (14.2)	

There was a statistically significant difference between no of specimens showing presence of crack progression after additional Instrumentation across all the groups (excluding control as it did not show any) $p<0.05$, with maximum cracks propagation seen in ProTaper, followed by Mtwo.

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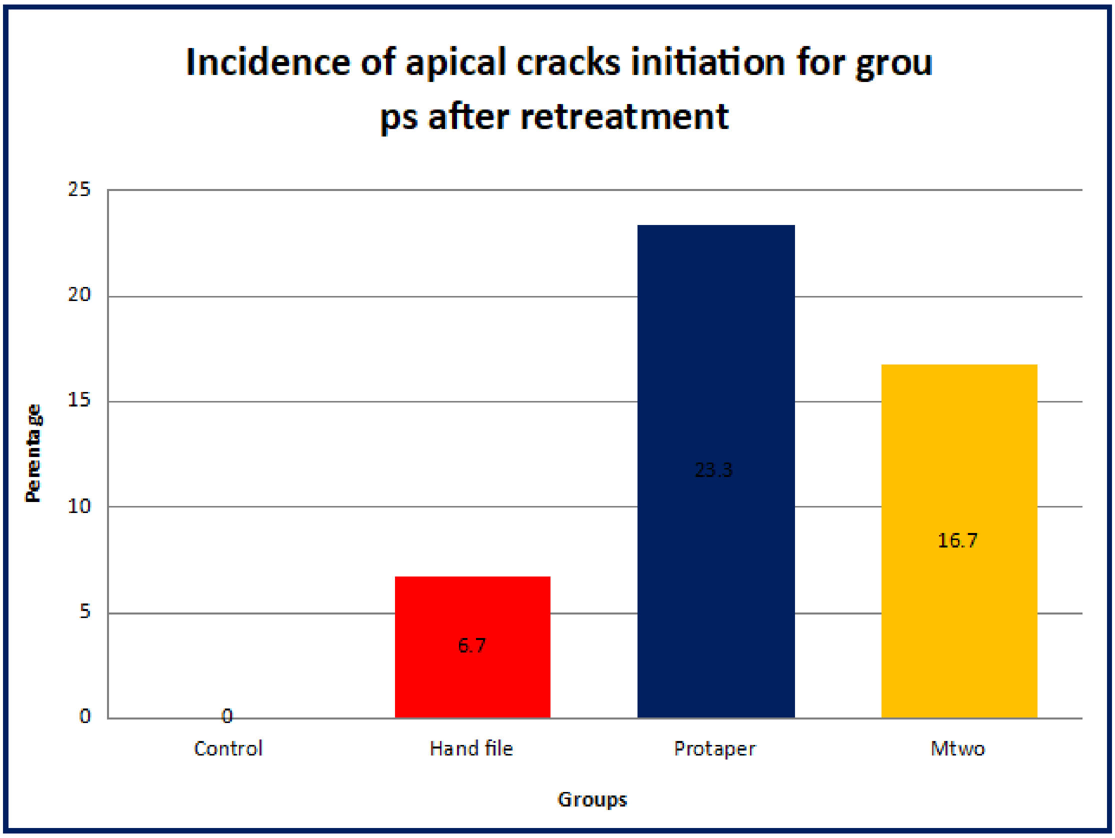
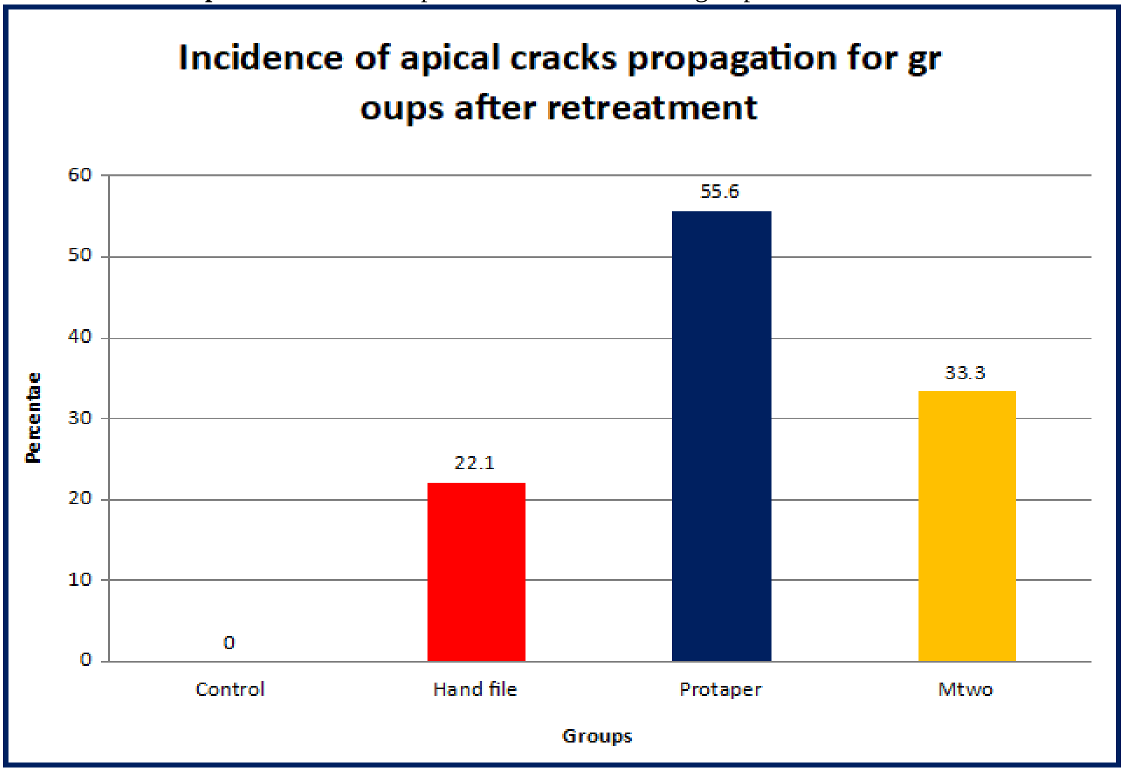


Graph 1: Incidence of apical cracks initiation for groups after re-treatment.



Graph 2: Incidence of apical cracks propagation for groups after re-treatment.

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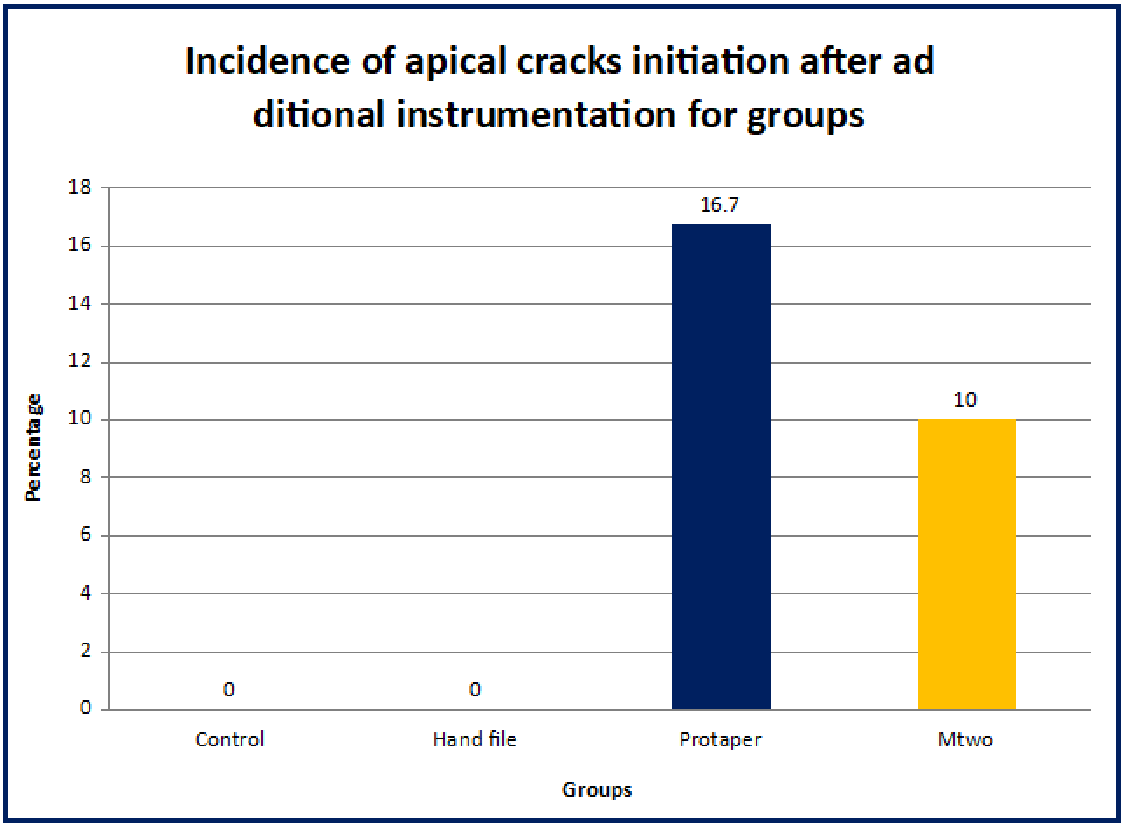
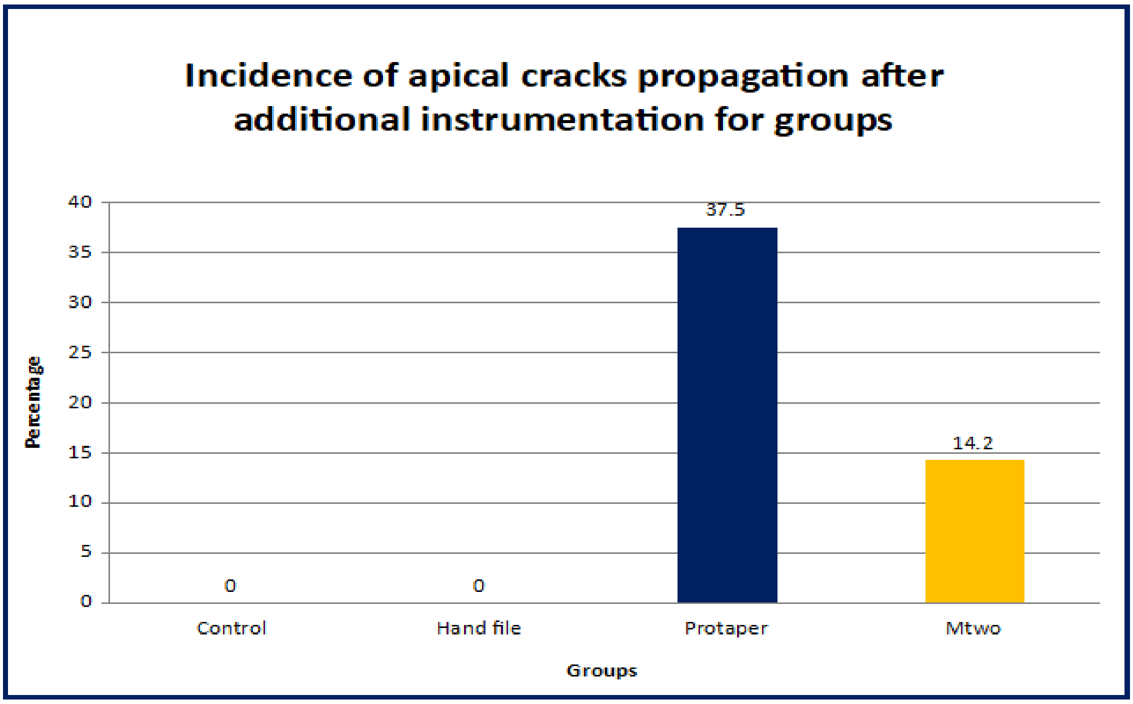


Graph 3: Incidence of apical cracks initiation for groups after additional instrumentation



Graph 4: Incidence of apical cracks propagation for groups after additional instrumentation.

V. DISCUSSION

Whenever initial root canal treatment fails, it becomes mandatory to do orthograde re-treatment for removal of microbial load and existing inflammation from the root canal system to save the tooth. The removal of gutta-percha by using hand files can be a tedious, time-consuming process, on the other side use of rotary Ni-Ti instruments in root canal re-treatment decreases patient and operator fatigue. Multiple rotary systems are available for removal of gutta-percha from the root canal during re-treatment. Many studies have been done to compare their efficacy in removing gutta-percha from the root canal system by assessing the gutta-percha left in the root canal after re-treatment, but the amount of stress they create on the dentin is still not investigated thoroughly.

Pitts et al. [28] **And Holcomb et al.** [27] reported for the first time the potential relationship between root canal procedures and dentinal micro-cracks, and since then this subject has gained much attention in the endodontic field. Although there has been awareness of the issue since the 1970s, it was only after the studies of **Bier et al. and Shemesh et al.** [3] that the relationship between micro-crack formation and biochemical preparation, obturation and re-treatment procedures received much more attention from the international endodontic community and the phenomenon of micro-cracks started to gain importance in endodontic research.

Nonsurgical endodontic re-treatment requires the removal of pre-existing obturation material to allow for adequate cleaning, disinfection, and filling of the root canal space after the failure of the previous root canal treatment. Although initial root canal therapy has been shown to be a predictable procedure with a high degree of success, failure can still occur. Lack of healing is attributed to persistent intra-radicular infection residing in uninstrumented canals, dentinal tubules, or the complex irregularities of the root canal system. [34] Previously treated teeth with persistent infection might be preserved with non-surgical re-treatment, which can re-establish healthy periapical tissues by regaining access to the root canal system through the removal of the obturation, further cleaning, and obturation. [35] Therefore, the removal of as much filling material as possible from an inadequately prepared and filled tooth is necessary to expose the remaining necrotic tissues and bacteria that might be responsible for periapical inflammation and, thus, post-treatment disease. [36]

The new rotary files coming into the market for re-treatment purpose needs to be evaluated for how much stress it creates on the dentinal wall which can be assessed by dentinal cracks initiation and propagation, ultimately giving idea about which file creates the least stress on root dentin and is safe to remove gutta-percha during re-treatment procedure. The presence of craze lines and incomplete cracks after instrumentation has been reported previously **(Bier et al. 2009, Shemesh et al. 2009, Adorno et al. 2011).** [2,3,11] These defects in dentin may become high stress concentration areas, from where the crack may gradually propagate to the root canal surface when an external force (re-treatment) is applied. [15] Crack growth requires cyclic stressing, whereas at constant or no stress, the cracks in the dentin become blunted and require higher stresses to advance. Cyclic loading will allow the crack to sharpen and blunt alternatively, allowing the crack to advance. The sharpness of the crack tip will determine the stress concentration, which will focus strain energy on the next susceptible bond during crack propagation. Root canal preparation with rotary Ni-Ti instruments can damage the dentin and can create defects on root canal walls. Undergoing this procedure two times during root canal treatment and for an endodontic re-treament may increase the number of defects. Clinically, bacteria may establish bio-films on the root surface after proliferating in crack lines. Moreover, localized crack lines may develop into root fractures through propagation of the cracks after long term functional loads. In this situation, a complete crack might contribute to leakage, which may result in the recurrence of periapical infection.

Previously, numerous methodologies have been used to evaluate the influence of endodontic procedures on root dentin. These include stress distribution measurements [15], finite elemental analysis [24], tests of fracture strength [22,25], observations of the existence of cracks in different sections [20,21,26], and evaluation of crack initiation in the apical surface and subsequent propagation. [14,23] The sectioning method has a significant disadvantage related to its destructive nature and possible micro-cracks induced by the sectioning. [18,19] However, in the present study, we speculated that it did not happen because no micro-crack defects were found in the baseline images. [16,17] Evaluation of the cracks in the apical surfaces of the root dentin eliminates the risks associated with cutting procedure that may cause new cracks in the root dentin. Thus, crack initiation and propagation was assessed in the apical surfaces and the apical 1 mm of roots was trimmed to more clearly assess

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crack initiation and propagation during all procedures.

In the current study, the effect of re-treatment procedures on propagation of existing cracks was evaluated because the cracks occurred as a result of initial canal preparation which can propagate further after re-treatment and additional instrumentations. The finding showed that NiTi re-treatment instruments caused more new apical cracks and propagation of cracks than did hand files. These could be attributed to the less aggressive movements of hand files in the canal compared with engine operated Ni-Ti re-treatment rotary files.

The tip design of rotary instruments, cross-sectional geometry, constant or variable pitch and taper, and flute form could be related to crack formation. [13] Bier et al.(2009) [29] stated that the taper of the Ni-Ti files could be a contributing factor in the generation of dentinal cracks, due to the fact that it causes increased stress on the canal walls. Additionally, Kim et al. (2010) [30] stated that the file design affected apical stress and strain concentrations during instrumentation, which were both linked to an increase in the number of dentinal cracks. The tip designs of ProTaper D3 and Mtwo R2 re-treatment instruments are non- cutting and active cutting respectively. Moreover, their tapers are also different (.07 for ProTaper D3 and 0.05 for Mtwo R2). It was found in this study that ProTaper re-treatment files causes more apical crack initiation and propagation than Mtwo re-treatment files. It shows connection of instrument taper on dentinal crack formation.

The statistical analysis showed that for both Re treatment and Additional instrumentation Hand files were better than Rotary Ni-Ti re-treatment files and between rotary Ni-Ti re-treatment files Mtwo rotary Re-treatment files were better than ProTaper rotary re-treatment files.

VI. CONCLUSIONS

Within the limitations of this study, it can be concluded that,

-- Ni-Ti rotary re-treatment instruments cause more crack initiation and propagation in apical root dentin after re-treatment procedures than do hand files. Root canal re-treatment with the ProTaper re-treatment system had a significant effect on the apical crack initiation and propagation.

-- Additional instrumentation with Ni-Ti rotary instruments after re-treatment showed higher incidence of apical cracks initiation and propagation, but the hand file group showed none. It can be because both rotary instruments have an active rotating movement that may cause more friction between the files and canal walls inside the root canal.

-- There is connection between the tip design and taper of Ni-Ti rotary re-treatment instruments used in this study and formation of apical crack initiation and propagation during re-treatment, the files with larger taper causes more crack formation compared to smaller taper.

-- Clinicians should always consider the risk of causing apical cracks during re-treatment procedures, when assessing the outcomes of nonsurgical endodontic re-treatment and the prognosis of re-treated teeth,

-- The hand file group both in re-treatment and additional instrumentation showed the least effect on dentinal wall, after additional instrumentation since there was no crack initiation or propagation, and after re-treament the crack initiation and propagation was least proving that re-treatment with hand files is better than using Ni-Ti rotary instruments.

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Conflicts of interest
There are no conflicts of interest.

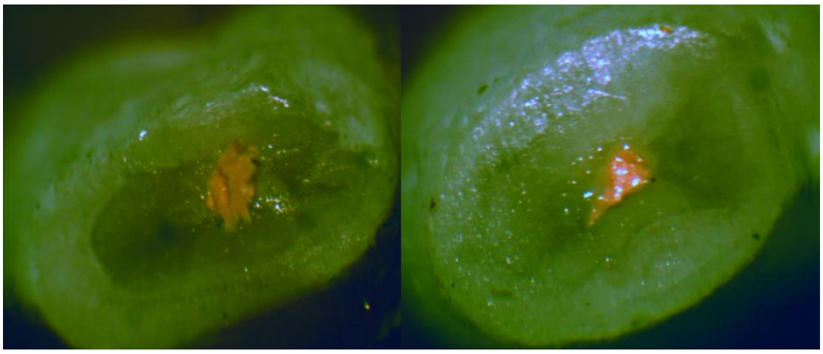

Image 1: Stereo-microscopic images of the specimen after Obturation

After Obturation **After Re-treatment** **After Additional instrumentation**

Yellow Arrow- Starting point of crack

Red Arrow- End of crack

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