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Abstract- Aim and Objectives: This study aims to compare the incidence of dentinal microcracks produced by Max Wire Technology (XP Endo Shaper-single files), Adaptive Pitch (Hero shaper – multiple files) and Controlled Memory (Hyflex – multiple files) files during root canal procedures in single- rooted teeth using a stereomicroscope.

Materials and Methods: Sixty four single-rooted mandibular premolars with similar sizes and completed apices were selected. All specimens were decoronated using a diamond- coated bur with water cooling, leaving roots approximately 15 millimeter in length. Silicone impression material was used for covering the external surface of roots to simulate periodontal ligament space, and specimens were then embedded in the alginate impression material.

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Influence of Metallurgy and File Design in Micro Crack Formation in Root Canals- An in Vitro Study

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Materials and Methods: Sixty four single-rooted mandibular premolars with similar sizes and completed apices were selected. All specimens were decoronated using a diamond-coated bur with water cooling, leaving roots approximately 15 millimeter in length. Silicone impression material was used for covering the external surface of roots to simulate periodontal ligament space, and specimens were then embedded in the alginate impression material. Randomly divided the teeth into four groups of sixteen each. Sixteen teeth were left unprepared and served as controls, and divided the remaining forty-eight teeth into three groups. Hero Shaper, Hyflex CM, and XP Endo Shaper. Sectioned the roots at 3, 6 and 9 mm from the apex, and observed the cut surface under stereomicroscope (8X) to detect dentinal microcracks. We expressed the results as the number and percentage of cracked roots in each group, and analyzed the data with a chi- square test. Any difference of $P < 0.05$ was considered as statistically significant

Interpretation and Conclusion: All rotary systems used in this in vitro study created dentinal cracks in root canals at all three levels, whereas XP ENDO SHAPER (max wire technology) presented with minimal dentinal microcracks but no significant difference was noticed.

Keywords: cracks, controlled memory, dentinal damage, xp endo shaper, hyflex cm, hero shaper, max wire technology, adaptive pitch, controlled memory, root canal instrumentation, root fracture, rotary nickel-titanium instruments.

I. Introduction

The irrevocable aim of endodontics is to create a three-dimensional flawless seal of the root canal system. [(1)] During endodontic treatment procedures, roots are susceptible to develop dentinal damage, quantity of which are influenced by numerous factors like physical properties of teeth, [(2)] preparation technique or various endodontic instruments that used, etc. The American Association of Endodontists classifies the longitudinal tooth fractures as five different types: [(3)] Craze lines, Cuspal fractures, Cracked tooth, Split tooth,Vertical root fracture.

Shemesh [(4)] et al. defined dentinal defects as all lines that appeared to disrupt the integrity of the dentin on the root end surface that extended either from the external root surface onto the resected dentin surface or from within the root canal lumen onto the resected root surface.

Despite the technological advancements, microcrack formation and vertical root fracture remain as significant problems during root canal shaping and cleaning procedures using Ni-Ti instruments [(5)]

Rotary systems are classified into single and multi-file systems. Preparation of the entire root canal using one single Ni-Ti instrument has many advantages, such as being cost-effective, decreasing cross-contamination, and reducing instrument fatigue. But it might be speculated that more stress will be generated during instrumentation when using only one instrument, thereby increasing the frequency of microcracks [(6,7)]

Hero Shaper [(8)] (HS; Micro-Mega, Besancon, France) is a multiple file system with a triple helix cutting edge and a safe ended tip with variation in the helical angle from the tip to the shank. Controlled memory (CM) wire (Coltene/ Whaledent, Altst€atten, Switzerland) made with thermally treated NiTi alloy has been introduced a few years back. Because of the austenite/martensite transformation as a result of heat treatment, CM wire has a stable martensitic microstructure at body temperature [(9)]

A recently introduced single file system known as the XP-endo Shaper[(10)] (XP) (FKG Dentaire, La Chaux-de-Fonds, Switzerland) uses a rotary Ni-Ti snake-shaped instrument. The Max Wire® and Booster Tip technologies combine to make the XP-endo Shaper a "One File Shaper." It has an initial taper of .01 in its M phase when it is cooled. Upon exposure to body temperature (35^{0}C), the taper changes to .04 according to the molecular memory of the A phase. XP achieves a final minimum canal preparation of 30/.04 when using this instrument alone. It applies minimal stress to the dentin walls, thereby minimizing the risk of microcracks

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in the dentin. XP can adapt to canal irregularities and has excellent resistance to cyclic fatigue

Till now, no study has evaluated the incidence of dentinal microcracks that result from the use of the XP system against Heroshaper and Hyflex CM. Hence, the purpose of the present study was to inspect the effects of using Hyflex CM, Hero Shaper, and XP files on the incidence of dentinal defect formation using a stereomicroscope.

II. Materials and Methods

Sixty-four single-rooted, human noncarious mandibular premolar teeth with similar anatomy and closed apices were selected. Using an ultrasonic scaler, soft tissues and calculus were removed from the root surfaces. Buccolingual and mesiodistal radiographs were taken from the specimens to verify the presence of single canal in each root. The teeth were temporarily stored in 4 °C distilled water till further use. All the roots were inspected with transmitted light and stereomicroscope under 8X magnification to detect any pre-existing craze lines or cracks. Teeth with anomalies were excluded from the study and replaced by intact teeth. Covered the external surface of roots with silicone impression material to simulate periodontal ligament space, and specimens were then embedded in the alginate impression material. Canal patency was established with a size no-: 15 K-File (Dentsply Maillefer, Ballaigues, Switzerland). The working length of the canals was determined by inserting a size 15 K-type file into the root canal terminus and subtracting 1 mm from this measurement.

III. Root Canal Preparation

Tooth were randomly divided into 3 experimental groups (Groups 1-3) and one control group with 16 teeth in each group. All teeth were measured and the crowns were sectioned with a high-speed bur under copious water spray in order to obtain equal lengths of the roots.

- Group I: No preparation

Sixteen teeth were left unprepared and served as controls.

- Group II: Teeth prepared with a single file system (XP ENDO SHAPER)((FKG Dentaire SA Switzerland)

In XP groups, root canals were enlarged with a K-file until #25 by manufacturers' recommendations. The XP file was first placed in 35^{0}C water and then placed in the root canal in order to enable phase transformation. Preparation time was one minute at a speed of 800 rotations per minute and 1- Newton cm torque according to the manufacturer's recommendations.

- Group III: Teeth prepared with multiple rotary file system (Hyflex CM rotary file)

A gentle in-and-out motion with a rotational speed of 500 rotations per minute, and 2.5 Newton cm torque was used to operate the HyFlex files. The sequence used was 20/0.04 (till two-thirds of the working length), 25/0.04, 30/0.04 (till full working length).

- Group IV: Teeth prepared with multiple rotary file systems (Heroshaper rotary file)

In the HeroShaper group, HeroShaper NiTi files were used in a crown-down sequence to file #30 at 450 rotations per minute at a torque of 1.2Newton cm. The order used was 20/04, 25/04, 30/04.

In all the groups, between each instrument, irrigants used were 3% sodium hypochlorite and 0.9% w/v Sodium Chloride. A total volume of 12 mL of sodium hypochlorite was required. EDTA in gel form was used as a lubricant.

a) Sectioning and Microscopic Examination

Sectioning of all the roots was performed perpendicular to the long axis at distance of 9, 6 and 3 mm from the apex using a diamond-coated disc under water cooling. Digital images of each section were captured using a digital camera attached to a stereomicroscope (Nippon SM 225) at a magnification of 8X. Two operators checked each specimen for the presence of dentinal defects (microcracks).

''No defect'' is defined as root dentin devoid of any craze lines or microcracks either at the external surface of the root or at the internal surface of the root canal wall.

''Defect'' is defined if any lines, microcracks, or fractures are present in root dentin.

IV. Results and Statistical Analysis

Determination of the number of teeth having microcracks

Presence of crack --- 1

Absence of crack ----0

No defects in all the three sections of the control group.

Comparison of Microcrack Formation Using Different Rotary File Systems

	HEROSHAPER	HYFLEX CM	XP ENDO SHAPER	CONTROL
CORONAL(9MM)	12	10	3	0
MIDDLE(6MM)	8	6	2	0
APICAL(3MM)	1	1	0	0

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V. Statistical Analysis

Table 1: Descriptive statistics for microcrack formation among different rotary groups

Chi-square Contingency Table Test for Independence				
	HEROSHAPER	HYFLEX CM	XP ENDO SHAPER	Total
CORONAL(9mm)	12	10	3	25
MIDDLE(6mm)	8	6	2	16
APICAL(3mm)	1	1	0	2
Total	21	17	5	43
	.33	chi-square		
	4	df		
	.9879	p-value		

Chi-square Contingency Table Test for Independence					
		HERO SHAPER	HYFLEX CM	XP ENDO SHAPER	Total
CORONAL (9mm)	Observed	12	10	3	25
	% of row	48.0%	40.0%	12.0%	100.0%
	% of column	57.1%	58.8%	60.0%	58.1%
MIDDLE (6mm)	Observed	8	6	2	16
	% of row	50.0%	37.5%	12.5%	100.0%
	% of column	38.1%	35.3%	40.0%	37.2%
APICAL (3mm)	Observed	1	1	0	2
	% of row	50.0%	50.0%	0.0%	100.0%
	% of column	4.8%	5.9%	0.0%	4.7%
Total	Observed	21	17	5	43
	% of row	48.8%	39.5%	11.6%	100.0%
	% of column	100.0%	100.0%	100.0%	100.0%
		.33	chi-square		
		4	Df		
		.9879	p-value		

We examined the association of rotary files with section with the help of the chi-square test, and the chi-square value is 0.33 and p-value (0.9879)(p>5%), which is not statistically significant. There is no association between different rotary files and crack formation.

VI. Discussion

Vertical root fracture (VRF) is one of the most common complications associated with biomechanical root canal preparation, which usually leads to tooth loss. Numerous Ni-Ti instruments with different design were introduced, but all of them causes incomplete cracks or even VRF. Bier et al. suggested that craze lines occurred in 4% to 16%, which may progress into fractures during retreatment procedures or after long-term functional stresses such as chewing. Fractures or craze lines can occur after root canal preparation with NiTi rotary systems and every following additional procedure in endodontics like obturation and retreatment.[11]

The imperative goal in endodontics is resistance to tooth fracture as such fractures might cause a decrease in the long-term survival rate. It is crucial to find out which rotary instrumentation system is safer to use regarding dentinal micro-crack generation.[12]

Many new NiTi rotary instruments have been developed and introduced by various manufacturers in the latest years.[13]

Rotary instrumentation need only less time to prepare root canals compared to hand instrumentation while it results in significantly more rotations of the instruments inside the root canal. It creates more friction between the files and the canal walls.[14] Tip design, cross-section geometry, constant or progressive taper type, variable pitch, and flute form determine the extent of such a defect formation[15]. Canal micro-cracks

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originate inside the root canal, and may or may not reach the external root surface. File design is also likely to affect the shaping forces on the root dentin [16]. Several studies have evaluated the stress applied to dentin and micro-crack formation in the use of rotary systems. However, studies comparing XP EndoShaper, Hyflex CM, and Heroshaper are limited. Thus, the current study assessed and compared dentinal crack formation following the use of this system.

The taper of the preparation and the files could be a contributing factor in the generation of dentinal defects. Wilcox et al. concluded that a root fractures if more root dentin is removed [16]. Hence, in the present study, a uniformed tapered preparation (0.04) was attempted in all groups.

In this study, teeth were sectioned at different levels, which has a significant disadvantage related to the detrimental effect of sectioning procedure. However, in the present study, this might not have been the situation as no microcracks defects were observed in the control group.

The specialty of endodontics has evolved and got revolutionized over the years [17]. The modern endodontic specialty practice has little resemblance to the traditional endodontic practice [18]. Conventional multiple rotary file system were now replaced with single file systems. However, crack formation in the root canal walls is a concern in the use of single - file systems.

In the present study, XP Endo Shaper (single-file system) causes fewer dentinal cracks as compared to multiple rotary file systems (Hero Shaper and Hyflex CM). Similar results were obtained in a study by Ekta et al.[19] As a supposed evolutionary procedural evolvement of multiple file system (Hero Shaper and Hyflex CM), single file system (XP Endo Shaper)facilitate the cleaning and shaping, comprising one single sterile file for root canal shaping (ISO 30 tip and 4% taper). MaxWire® and Booster Tip technologies together make the XP-endo Shaper a “One File Shaper.” It works with continuous rotation. Max wire technology (Martensite-Austenite electropolish-fleX) was used in the manufacture of the files. The metallurgical alloy gives the instrument high flexibility. Its “snake” shape, superelasticity and extreme flexibility combined with continuous rotation at high speed (800 rpm) and minimal torque (1N) ensure: Minimal stress is applied to dentine walls and due to support from the spring action against the walls; minimizes the risk of micro-cracks in the dentine.

In the present study, the use of Hero Shaper files [20] resulted in the highest incidence of defects compared to Hyflex CM and XP Endo Shaper. The dentinal defect that arises in the root during the cleaning and shaping depends on the taper, design, and rotations per minute (rpm) of the instrument. Hero Shaper rotates at a speed of 450 to 600 rpm and torque of 1.2 N. In Hero Shaper, the helical angle of cutting edges varies from tip to the shank and adapted pitch, i.e., the pitch varies according to taper, positive rake angle, large inner core, which tend to engender more stress on the root walls and thereby possess relatively low flexibility. Increased stiffness with less flexibility of the HeroShaper may have contributed to a larger number of defects in the HeroShaper group in the present study.

The use of Hyflex CM produces a lesser number of defects as compared to Hero Shaper. It has a Speed of 500 rpm and a torque of 2.5 N cm. The reason for the lower incidence of cracks in HyFlex CM is due to its 300% more resistance to cyclic fatigue. This control memory metallurgy of the HyFlex CM file makes it more flexible but without the shape memory. Also, it contains a smaller percentage of nickel than other systems. The decrease of nickel content creates a softer metal with lower hardness .It also changes the metal properties, like the thermal changes, which arise during the processing of the HyFlex CM file. It results in a martensitic metal phase [21,22] which is a more flexible form that outcomes in superior elasticity and enhanced resistance to cyclic fatigue[22].

The results of the present study revealed that there was no significant difference between the groups in the formation of dentinal microcracks. Hence, the null hypothesis is accepted.

Cracks in the coronal portion were more than cracks in the apical region, similar to results obtained by Adorno et al. [23] and Liu [24] et al.

All rotary systems used in the study have a similar apical taper design (tip diameter of 0.30 mm), and this could be the reason for the comparable results in the apical third. The slighter incidence of microcrack formation in apical third could be associated with the size and taper of the master apical file. The standardization of speed and torque settings for various file systems is a drawback of the current study. It was tough to homogenize the downward force used throughout every instrumentation.

Gambarini [25] stated that when the torque of an instrument gets beyond a definite limit the risk of intracanal fracture is increased. Even though XP Endo Shaper has a high rotational speed, fewer cracks may be due to its minimal torque.

Some of the defects seen did not connect with the pulp space. During preparation with rotary files, internal stress is generated in the canals. According to Wilcox [27] et al. the stress is transmitted through the dentin towards the surface and often exceeds the force holding the dentin together. Onnink [28] et al. speculated that a fracture contained within the dentin in one section could communicate with the canal space in an adjacent segment.

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We selected mandibular premolars for the study because of the high prevalence of VRF as reported by Tamse[21] et al. Occlusal load on mandibular premolars during chewing is three times as high as the other teeth. Moreover, we selected teeth with only straight root canals thus anatomic complexities were not considered which did not mimic exact clinical presentation.[15]

One of the limitations of this study was the application of elastomeric material to simulate the periodontal ligament.[6] The clinical situation is more complicate because the presence of periodontal ligament influences the distribution of stresses.

All rotary systems used in this in-vitro study created dentinal defects in root canals. Overall, XP Endo Shaper caused the least number of cracks as compared to the other two groups but there is no significant difference among the three groups.

VII. Conclusion

1. Within the limitation of the study, it can be concluded that all the instruments induced dentinal defect irrespective of file design.
2. Control group showed no cracks.
3. Among rotary file systems, a single file system (XP ENDO SHAPER) induced fewer number of defects when compared to multiple file systems even though there was no statistically significant difference.
4. More cracks were noticed in the coronal and middle section as compared to the apical segment with no statistically significant difference.
5. Shaping ability, ability to eliminate smear layer and canal centering ability needs to be further evaluated.

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