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Comparative Evaluation of Dentinal Microcrack Formation During Root Canal Preparation Using Different Rotary Files: An In Vitro Study

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Abstract:
Background*:The success of endodontic treatment depends on completely removing all vital and necrotic pulp tissue, microorganisms, and microbial toxins from the root canal. During the cleaning and shaping process, the canal is shaped through the interaction between instruments and the dentin walls. These interactions can create several temporary stress points within the dentin, which may lead to the development of dentinal defects, craze lines, or microcracks. As a result, the techniques employed for shaping root canals carry the risk of starting crack formation, which, under functional pressure, could progress into complete fractures. This study was aimed to compare and evaluate the incidence of dentinal microcrack formation during root canal preparation using ProTaper Universal, ProTaper Gold, NeoEndo Flex and Hyflex EDM files.*
Materials and Methods*: A total of 95 freshly extracted single rooted premolars with single straight canal were selected and stored in normal saline. Each specimen was examined using dental operating microscope to exclude cracked samples. Specimens then decoronated using a diamond disc and water as a coolant to a standardized length of 14 mm. Canal patency was determined by passing 10 K file passively and the working length was established 1 mm short of the file length at which the file become visible at the apical foramen. Canal was then enlarged upto15 k size file. Teeth samples were then divided into 5 groups having 19 teeth each. Group 1: Control Group (Uninstrumented teeth), Group 2 : Protaper Universal, Group 3 : Protaper Gold, Group 4 : NeoEndo Flex ,Group 5 : Hyflex EDM. After completion of cleaning and shaping procedure (to a standard apical diameter of 25), canal was rinsed with distilled water. Root was then horizontally sectioned at 3 mm, 6 mm and 9 mm from the apex with diamond disc at low speed under water cooling. All the sections were evaluated under stereomicroscope for presence of cracks and images were recorded. Cracks were observed as lines extending from the root canal lumen to the dentin or from the outer surface into the dentin.*
Results*: All the file systems used in this study showed dentinal microcracks. ProTaper Universal exhibited the highest percentage of dentinal defects, while Hyflex EDM displayed the lowest among the file systems used (ProTaper Universal, ProTaper Gold, NeoEndo Flex and Hyflex EDM). The defects were present more in the apical third (3 mm) as compared to 6 mm (middle third) and 9 mm (coronal third) sections.*
Key Words*: Dentinal Microcrack, Stereomicroscope, ProTaper Universal, ProTaper Gold, NeoEndo Flex, Hyflex EDM.*

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I. Introduction

The most important step in root canal treatment is the preparation of root canal system. The primary objective during cleaning and shaping is to remove microorganisms, pulp tissue, and debris from the root canal system, while also widening the root canal diameter to ensure ample space for the filling material.[1]

During cleaning and shaping, the canal undergoes shaping through the interaction of instruments with the dentinal walls. These interactions generate numerous transient stress points within the dentin. Such stress points have the potential to cause dentinal defects, microcracks, or craze lines.[1] These factors are linked to higher susceptibility to fractures because stresses from procedures like root canal filling, retreatment, and repeated chewing forces can significantly magnify at the ends of these defects, potentially initiating or spreading cracks. Additionally, bacteria can thrive within crack lines, forming biofilms on the root surface over time, which can pose clinical challenges.[2]

Root fractures in teeth that have undergone root canal therapy represent a highly frustrating complication, often leading to the extraction of the tooth due to its severe consequences. Given the catastrophic impact, it becomes crucial to identify the causative factors of root fractures to enhance preventive measures effectively.[3]

Over the past two decades, rotary nickel-titanium (NiTi) instruments have emerged as the predominant method for mechanically enlarging root canal spaces, addressing many limitations of traditional techniques. Several studies have highlighted that NiTi instruments can induce cracks in the dentin of root canals. The design characteristics of these instruments, including NiTi core diameter, cross-sectional shape, rake angle, and flute depth, vary among different file systems and can significantly impact their performance and the likelihood of crack formation.[1]

II. Material And Methods

A total of Ninety-five freshly extracted single-rooted premolars with single straight canals were chosen and stored in normal saline. The root surfaces were cleaned mechanically to remove soft tissues and calculus. Each specimen was carefully examined under a dental operating microscope to ensure no cracks were present. Subsequently, the specimens were decoronated using a diamond disc with water cooling, standardizing the length to 14 mm.

Canal patency was confirmed by passively inserting a size 10 K-file, and the working length was set 1 mm shorter than the length at which the file first became visible at the apical foramen. The canal was subsequently enlarged up to a size 15 K-file.

Then the root was wrapped with a single layer of aluminum foil and embedded in acrylic resin inside an acrylic tube. Subsequently, the root was removed from the tube, and the aluminum foil was peeled away. Silicone impression material was used to fill the space previously occupied by the foil, mimicking a simulated periodontal ligament. The root was then promptly repositioned.

Teeth samples were then divided into 5 groups having 19 teeth each.

Group 1 : Control Group (Uninstrumented teeth)
Group 2 : Protaper Universal
Group 3 : Protaper Gold
Group 4 : NeoEndo Flex
Group 5 : Hyflex EDM

After each instrumentation, the canal was irrigated with 2 ml of 3% Sodium Hypochlorite using a syringe. Following completion of the cleaning and shaping procedure, where the standard apical diameter was set to 25, the canal was flushed with distilled water. Subsequently, the root was horizontally sectioned at 3 mm, 6 mm, and 9 mm from the apex using a diamond disc at low speed under water cooling. All sections were examined under a stereomicroscope to detect any cracks, and images were captured. Cracks were identified as lines extending from the root canal lumen into the dentin or from the outer surface inward into the dentin.

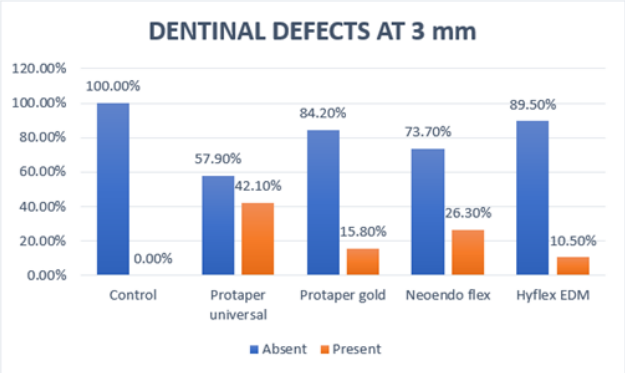
Statistical analysis

The collected data was entered into Microsoft excel sheet and analyzed using IBM, SPSS (Statistical Package for Social Sciences, IBM Co., Armonk, NY, USA) version 26 statistical software. Descriptive statistics was used to summarize the data. Chi square test was used for comparison of proportions among the groups. p value of <0.05 was considered statistically significant.

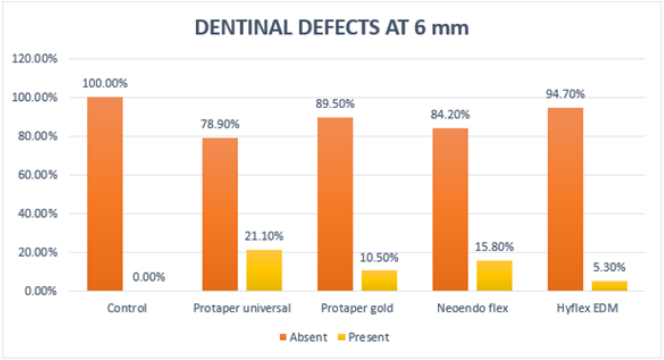
III. Result

All the file systems used in this study showed dentinal microcracks. ProTaper Universal exhibited the highest percentage of dentinal defects, while Hyflex EDM displayed the lowest among the file systems used (ProTaper Universal, ProTaper Gold, NeoEndo Flex and Hyflex EDM). The defects were present more in the apical third (3 mm) as compared to 6 mm (middle third) and 9 mm (coronal third) sections.

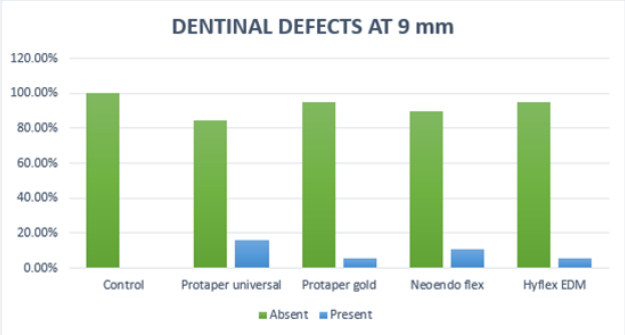
			DENTINAL DEFECTS		Total	P value
			absent	present		
DENTINAL DEFECTS AT 3 mm	Control	n	19	0	19	0.013*
		%	100.0%	0.0%	100.0%	
	Protaper universal	n	11	8	19	
		%	57.9%	42.1%	100.0%	
	Protaper gold	n	16	3	19	
		%	84.2%	15.8%	100.0%	
	Neoendo flex	n	14	5	19	
		%	73.7%	26.3%	100.0%	
	Hyflex EDM	n	17	2	19	
		%	89.5%	10.5%	100.0%	



			DENTINAL DEFECTS		Total	P value
			absent	present		
DENTINAL DEFECTS AT 6 mm	Control	n	19	0	19	0.22
		%	100.0%	0.0%	100.0%	
	Protaper universal	n	15	4	19	
		%	78.9%	21.1%	100.0%	
	Protaper gold	n	17	2	19	
		%	89.5%	10.5%	100.0%	
	Neoendo flex	n	16	3	19	
		%	84.2%	15.8%	100.0%	
	Hyflex EDM	n	18	1	19	
		%	94.7%	5.3%	100.0%	
	Control	n	18	1	19	
		%	94.7%	5.3%	100.0%	



			DENTINAL DEFECTS		Total	P value
			absent	present		
DENTINAL DEFECTS AT 9 mm	Control	n	19	0	19	0.41
		%	100.0%	0.0%	100.0%	
	Protaper universal	n	16	3	19	
		%	84.2%	15.8%	100.0%	
	Protaper gold	n	18	1	19	
		%	94.7%	5.3%	100.0%	
	Neoendo flex	n	17	2	19	
		%	89.5%	10.5%	100.0%	
	Hyflex EDM	n	18	1	19	
		%	94.7%	5.3%	100.0%	



IV. Discussion

The success of endodontic treatment depends on completely removing any remnants of both living and necrotic pulp tissue, and efficiently eliminating microorganisms and their toxins from the root canal.[4] The critical phase in root canal treatment is the preparation of the root canal system, which involves utilizing both manual and rotary instruments with continuous irrigation. This process is aimed at removing inflamed and necrotic tissue, as well as eliminating microbes, biofilms, and debris from the root canal space. The primary goal of this procedure is to ensure comprehensive irrigation, effective disinfection, and proper filling of the canal afterward.[1]

During the cleaning and shaping procedure, the canal is shaped as instruments interact with the dentin walls. These interactions create transient stress points within the dentin, potentially causing the formation of dentinal defects, craze lines, or microcracks. There is a likelihood that stresses originating from within the root canal propagate through the root to its surface, potentially exceeding the cohesive strength of the dentin. As a result, root canal shaping techniques pose a risk of initiating cracks, which under functional pressure could progress to complete fractures.[1] Dentinal defects as a consequence of canal preparation were first reported by Onnink et al.[5]

Vertical root fracture (VRF) is characterized by a longitudinal fracture within the root, either complete or incomplete, that can initiate at any level and progress towards the crown. This condition has received considerable attention in the field of endodontics due to its significant potential impact on the tooth's long-term health.[6] Therefore, this presents challenging complications in root canal treatment, often requiring the extraction of the tooth.[1]

The evolution of nickel-titanium (NiTi) instruments has introduced a new dimension to root canal therapy.[6] In the last twenty years, rotary nickel-titanium-based preparation has become the primary method for mechanically expanding the root canal space, effectively addressing several limitations associated with traditional preparation techniques.[2] Different characteristics of NiTi files, such as specific heat treatments, metallurgical compositions, file designs (including NiTi core diameter, cross-sectional shape, rake angle, and flute depth),[2] and motion patterns, can impact the occurrence of dentinal microcracks. These microcracks are frequently seen as the initial phase in the onset of vertical root fractures (VRFs)[6].

Shemesh et al. found that rotary Ni-Ti file usage during canal preparation led to notable dentin defects such as fractures, craze lines, and incomplete cracks. Similarly, Bier et al. reported that Ni-Ti files used for canal preparation caused significantly more dentinal defects compared to hand files.[7]

The use of multiple NiTi file systems has become increasingly common to address the varied anatomical complexities encountered during root canal treatment. However, the extended instrumentation time required by these systems can impose heightened stress and mechanical forces on the dentin. Moreover, the utilization of

different file sizes and designs in multiple-file systems may lead to uneven stress distribution within the root canal system, potentially increasing the risk of dentinal defects.

The periodontal ligament exhibits a nonlinear and viscoelastic response to external stress, effectively dissipating stress in clinical scenarios. In this research, silicone impression material with comparable properties was used to mimic the bony socket and stabilize the specimens during canal preparation, thereby dispersing the applied forces. Mandibular premolar teeth, known for their susceptibility to forces during root canal procedures due to their smaller size and thin dentin walls, were chosen for this study. To maintain hydration and prevent artifacts, the specimens were consistently stored in a hydrated environment.[8]

Glidepath establishment was accomplished to preserve the canal anatomy and reduce instrument binding during the procedure. This method aims to decrease the potential for dentinal defects that may result from excessive binding of instruments and prolonged contact between the file and dentin.

Sodium hypochlorite (NaOCl), due to its alkaline nature, can alter the chemical structure and mechanical properties of dentin, including elastic modulus and flexural strength. This can potentially reduce dentin microhardness and influence crack propagation.[8] However, despite the use of 3% sodium hypochlorite for irrigation in all teeth in this study, no dentinal defects were observed in the control group. Therefore, it can be concluded that irrigation with sodium hypochlorite did not appear to contribute to the occurrence of dentinal defects in this particular study.

All specimens were decoronated using a diamond disc with water coolant. This method ensures consistency in variables such as coronal anatomy and root canal access, thereby improving the reliability of comparisons between various endodontic treatment techniques. Dentinal defects can potentially result from sectioning procedures. However, since no defects were found in the control group, it can be inferred that any observed defects were not attributable to the sectioning process.[8]

Stereomicroscope was used in the present study to evaluate dentinal microcracks. This optical instrument enables two-dimensional analysis of objects through imaging at different magnifications. It is particularly useful for assessing dentinal microcracks and vertical root fractures. Unlike conventional microscopes that transmit light through an object, the stereomicroscope operates by reflecting light from the surface of the object. It employs two distinct optical paths with separate objectives and eyepieces, providing a three-dimensional view of the specimen under examination.[9]

File systems used in this study includes ProTaper Universal, ProTaper Gold, NeoEndo Flex and Hyflex EDM in rotation motion. The study's results indicated the presence of dentinal microcracks induced by all four file systems. Each of these systems achieved a final apical diameter of size 25, and this uniformity enhanced the reliability of the findings. Standardization within the groups was further ensured by selecting teeth with canal widths near the apex compatible with a size 10 K-file and maintaining all roots at a consistent length of approximately 14 mm.

ProTaper Universal rotary files exhibited a dentinal defect rate of 42.1%, contrasting with 15.8% for ProTaper Gold, 26.3% for NeoEndo Flex and 10.5% for Hyflex EDM at 3 mm from apex. This notable difference is likely due to the more rotations with progressively increasing taper with increasing number of files of ProTaper Universal with increased stiffness and active cutting. The F2 file of ProTaper, with a taper of 0.08, may contribute to the higher incidence of damage. Bier et al. noted cracks in horizontal sections of 16% of roots treated with the ProTaper system, while Liu et al. observed cracks on the apical root surface in 25% of roots treated with ProTaper. The ProTaper Gold rotary system shares the same architecture as ProTaper Universal but features a specific 2-stage transformation behavior and a high austenite finish temperature akin to controlled memory (CM) wire. These metallurgical characteristics provide increased flexibility and resistance to fatigue for the files.[8]

Hyflex EDM files, a single-file system utilizing continuous rotation, demonstrate reduced incidence of cracks in the apical, middle, and coronal thirds compared to other file systems (ProTaper Universal, ProTaper Gold, and NeoEndo Flex) employed in this study. This difference is attributed to their manufacturing process involving EDM technology and controlled memory (CM) treatment.

Electrical Discharge Machining (EDM), also known as spark machining or spark erosion, is a manufacturing technique used to achieve desired shapes through controlled electric discharges (sparks). The EDM process involves using electric sparks to erode metal from the workpiece, shaping it into the desired form. This metal removal is accomplished by applying pulsating high-frequency electrical currents through the electrode to the workpiece. The controlled erosion removes tiny particles of metal at a precise rate.The repeated application of sparks to the material causes melting or, in some cases, evaporation, altering the surface of the metal. This results in a distinctively textured surface that enhances the hardness of the material. The hardened surface from spark erosion significantly improves the cutting performance of the resulting tools. Therefore, EDM produces files that are highly flexible and resistant to fractures due to their unique surface characteristics.[10]

Hyflex EDM files primarily consist of martensite and R-phase, and their inherent shape memory allows them to adapt their spiral shape to conform precisely to the root canal anatomy during canal preparation. This adaptive feature helps mitigate stress, thereby minimizing the occurrence of microcracks and dentin defects. These files have a tip size of 25 and maintain a consistent taper of 0.08 mm in the apical 4 mm, which reduces to 0.04 mm in the coronal portion. They are characterized by three distinct cross-sectional zones: quadratic at the tip, trapezoidal in the middle, and triangular towards the shaft. This variable cross-sectional design has been observed to effectively reduce the formation of dentinal cracks.

Endodontic instruments with high flexibility are linked to fewer dentinal defects because the alloy's increased flexibility generates reduced stress on the root canal walls and less pressure during instrumentation. This observation aligns with the conclusions of Pedullà et al.,[11] Pereira et al.,[12] and Peters et al.,[13] who found in their studies that endodontic instruments made from M-wire alloy and CM NiTi are more flexible compared to traditional NiTi rotary instruments. Hyflex EDM instruments are crafted from M-wire alloy, ensuring high flexibility and likely contributing to fewer incidences of cracks.[8]

When assessing dentinal microcracks generated by various file systems in this study, it was observed that NeoEndo Flex produced greater number of cracks than ProTaper Gold and Hyflex EDM files, but fewer cracks than ProTaper Universal.

Neoendo Flex features a triangular cross-sectional design, ensuring that during biomechanical preparation, the file rotates in the canal with three-point contact between the instrument and the root canal wall. This contact transmits increased tensile stresses to the dentinal wall of the root canal, potentially resulting in dentinal microcracks.[14]

The majority of dentinal microcracks were found predominantly in the apical section (3 mm) across all tested samples. This occurrence is likely attributed to the highest stress concentration within the apical third of the root canals.[1]

The current study was limited to samples featuring teeth with straight, single root canals. Another limitation was the inability to standardize the force used during instrumentation. Within these constraints, it was observed that ProTaper Universal showed the highest percentage of dentinal defects, whereas Hyflex EDM demonstrated the lowest among the file systems tested (ProTaper Universal, ProTaper Gold, NeoEndo Flex, and Hyflex EDM files). Further research is necessary to assess dentinal defects in roots that are more susceptible and in curved canals.

V. Conclusion

Based on the conditions of this study, the following conclusions can be drawn:

1. ProTaper Universal exhibited the highest percentage of dentinal defects compared to ProTaper Gold, NeoEndo Flex and Hyflex EDM files.
2. Hyflex EDM demonstrated the lowest percentage of dentinal defects compared to ProTaper Universal, ProTaper Gold, and NeoEndo Flex files.
3. Dentinal defects were more prevalent in the apical third (3 mm) compared to the middle third (6 mm) and coronal third (9 mm) sections across all four file systems tested.

Within the limitations of this study, it can be inferred that various aspects of file systems contribute to dentinal damage. However, the flexibility of NiTi instruments due to heat treatment appears to have a greater influence on the incidence of microcracks compared to factors such as kinematics and geometric features. These findings are preliminary, and further studies with larger sample sizes are necessary to validate this research.

References

[1]. Jehan SS, Farooq R, Pura A, Ahmad F, Masoodi A. In Vitro Comparative Evaluation of Dentinal Microcrack Formation during Root Canal Preparation Using Reciprocating and Continuous Motion Single File Systems. Ann. Int. Med. Den. Res. 2020; 6(6):DE71-DE75.

[2]. Tomer AK, Ramachandran M, John AG, Jose T, Tirupathi P, Kumari S, Behera A. Comparative evaluation of dentinal crack formation during root canal preparation using ProTaper Gold, Hyflex EDM files. International Journal of Medical Science and Diagnosis Research, 2019 Jun; 3(6).

[3]. Tsesis I, Rosen E, Tamse A, Taschieri S, Kfir A. Diagnosis of vertical root fractures in endodontically treated teeth based on clinical and radiographic indices: a systematic review. Journal of endodontics. 2010 Sep 1;36(9):1455-8.

[4]. Chellapandian K. Recent Advancements In Endodontic Irrigation Systems. Journal of Positive School Psychology. 2022 Apr 28:3809-22.

[5]. Onnink PA, Davis RD, Wayman BE. An in vitro comparison of incomplete root fractures associated with three obturation techniques J Endod. 1994;20:32–7

[6]. Aggarwal A, Nawal RR, Yadav S, Talwar S, Kunnoth S, Mahajan P. Comparative Evaluation of Dentinal Microcrack Formation before and after Root Canal Preparation Using Rotary, Reciprocating, and Adaptive Instruments at Different Working Lengths—A Micro–computed Tomographic Study. Journal of Endodontics. 2021 Aug 1;47(8):1314-20.

[7]. Kulangara AT, Devadathan A, James B, Jacob J, Nair M. Comparative Evaluation of Dentinal Microcrack Formation by Single Reciprocating File Systems: An In Vitro Study. Group. 2020;4(5):9.

[8]. Devi TP, Kaur A, Priyadarshini S, Deepak BS, Banerjee S, Sanjeeta N. Microscopic assessment of dentinal defects induced by ProTaper Universal, ProTaper Gold, and Hyflex electric discharge machining rotary file systems–An in vitro study. Contemporary Clinical Dentistry. 2021 Jul;12(3):230.
[9]. Muthanandam S, Santhadevy A, Suganya R, Vezhavendhan N. A review on stereomicroscope. International Dental Journal of Students' Research. 2024 Jan 1;12(1).
[10]. Singh H, Kapoor P (2016) Hyflex CM and EDM Files: Revolutionizing the Art and Science of Endodontics. J Dent Health Oral Disord Ther 5(7): 00182.
[11]. Pedullà E, Genovesi F, Rapisarda S, La Rosa GR, Grande NM, Plotino G, et al Effects of 6 single-file systems on dentinal crack formation J Endod. 2017;43:456–61
[12]. Pereira ES, Peixoto IF, Viana AC, Oliveira II, Gonzalez BM, Buono VT, et al Physical and mechanical properties of a thermomechanically treated NiTi wire used in the manufacture of rotary endodontic instruments Int Endod J. 2012;45:469–74
[13]. Peters OA, Morgental RD, Schulze KA, Paqué F, Kopper PM, Vier-Pelisser FV, et al Determining cutting efficiency of nickel-titanium coronal flaring instruments used in lateral action Int Endod J. 2014;47:505–13
[14]. Guha A, Pandharikar R, Shivangi S, Rao RD, Verma M, Jain AK. Comparative evaluation of dentinal crack formation after root canal preparation with Neoendo Flex and Mani Silk files: An in vitro study. J Conserv Dent. 2020 Sep-Oct;23(5):468-472. doi: 10.4103/JCD.JCD_428_20. Epub 2021 Feb 10. PMID: 33911355; PMCID: PMC8066664.