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An In Vitro Comparative Assessment of Dentinal Cracks Progressions Evaluated at Different Root Regions and Thicknesses: A Scanning Electron Microscopy-Based Original Research Study

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KEYWORDS

Scanning Electron Microscopy (SEM), Dentinal Cracks, Biomechanical Preparation, Mtwo Files, Profiles GT Files, T Adaptive Files.

ABSTRACT:

Aim: The study aims to assess dentinal cracks in various root regions and thicknesses using scanning electron microscopy.

Materials and Methods: In this study, we analyzed 90 non-traumatic single-rooted premolars collected over three months. Teeth without carious lesions were cleaned and excluded if infected or previously treated. Roots were embedded in acrylic resin with access cavities created. Using a No. 15 K-file, we measured the working length, keeping it 1 mm short of the apical foramen. Cleaning and shaping were performed with three file systems: Mtwo (Group 1), ProFile GT (Group 2), and TF Adaptive (Group 3), each involving 30 mandibular first premolars. Dentinal cracks were measured in various root sections using Scanning Electron Microscopy (SEM).

Statistical Analysis and Results: Statistical evaluations using SPSS were performed on 90 mandibular first premolars, divided into three groups for biomechanical preparation with different rotary file systems: Group 1 (Mtwo files), Group 2 (Profiles GT files), and Group 3 (T Adaptive files). Dentinal cracks were assessed using Scanning Electron Microscopy (SEM) and analyzed with Pearson Chi-Square tests. Results showed Group 1 had the most cracks, particularly in the coronal and middle regions, with three teeth showing no cracks. Group 2 had 12 teeth without cracks, while Group 3 had the fewest, with 20 teeth exhibiting no cracks. Findings were summarized in Table 5 and analyzed using one-way ANOVA.

Conclusion: The study found that the Mtwo file system causes more dentinal cracks than the Twisted File Adaptive (TFA) system and Profiles GT files. The TFA's hybrid motion reduces stress on tooth structure, lowering the risk of cracks. All file systems risk dentinal damage, but TFA's adaptive motion offers a significant advantage. Crack frequency also depends on tooth anatomy and operator experience.

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Introduction

The effectiveness of root canal therapy relies on meticulous cleaning, shaping, and complete sealing of the root canal system. Successful results are also dependent on the right restoration, as dental structures can weaken due to dentin loss from decay or injury.[1,2] Identifying and addressing dental cracks and fractures can be challenging, especially in the early stages. Cracks can range from minor craze lines to severe vertical root fractures, being the third leading cause of tooth loss after periodontal disease and tooth decay. Microcracks occur when tensile stress exceeds dentin's strength.[3,4] They are classified as 'completed' if they extend from the root canal lumen to the surface and 'incomplete' if they don't reach the other side. Treatment strategies depend on severity, making crack detection crucial for clinicians. It's important to understand crack types and symptoms for effective management, as using dental files can create additional dentinal cracks during root canal preparation. New endodontic instruments aim to address these challenges.[5,6] The Mtwo NiTi rotary system, for instance, offers a lower risk of instrument breakage while effectively cleaning and shaping curved root canals due to its S-shaped cross-section that allows efficient lateral cutting.[7] Additionally, the ProFile GT rotary system features tapered files designed for efficient flare creation, reducing the need for extra burs.[8] The TF Adaptive files, employing Adaptive Motion Technology, aim to enhance root canal shaping by automatically adjusting to stress during use, balancing the advantages of continuous rotation with reciprocation, thus minimizing file breakage and improving debris removal.[9-11] Scanning electron microscopy (SEM) is a widely utilized technique that provides high-resolution images of organic and inorganic materials at scales from nanometres to micrometres. SEM operates at magnifications of up to 300,000X and is enhanced by Energy Dispersive X-ray Spectroscopy (EDS), which yields qualitative and semi-quantitative data about specimen composition. The equipment can analyse samples up to 200 mm in diameter and 80 mm in height, and it is particularly valuable for assessing the structure of dental enamel.[12,13] This study specifically examines dentinal crack progression across three different root regions and thicknesses, employing three distinct file systems evaluated by SEM, underscoring the importance of accurate diagnosis and management in endodontic procedures.

Materials and Methods

In our research, we analyzed a carefully selected sample of 90 single-rooted premolar teeth, which were collected over a span of three months for non-traumatic dental reasons. The study was planned, designed and conducted in the Department of Conservative Dentistry and Endodontics of the institute. To maintain their integrity and prevent any dehydration during the course of the study, these teeth were stored in distilled water. Each tooth was extracted for periodontal-related issues and was confirmed to be free of carious lesions. Prior to examination, we meticulously cleaned the outer surfaces of the roots to remove any soft or hard debris, including calculus, utilizing an air-rotor hand piece in conjunction with specialized scaling instruments. It was essential to adhere to strict criteria for inclusion; therefore, any teeth exhibiting multiple foramina, signs of dilation, indications of infection, or having undergone previous endodontic treatment were excluded from our study to ensure the reliability of our findings. All root surfaces of the teeth were covered and embedded in acrylic resin for proper handling. To prepare the samples, the occlusal surfaces of the selected teeth were flattened using diamond rotary cutting instruments. Uniform access cavities were created in all samples, and the working length was determined. The working length was assessed using a No. 15 K-file, keeping it 1 mm short of the actual length, as detectable at the major diameter of the apical foramen. Conventional root canal cleaning, shaping, enlargement, and curving were executed using three different commercially available file systems are Mtwo Files (VDW Anteas, Munich, Germany), ProFile GT Rotary Files (Dentsply Sirona, Canada), and TF Adaptive Files (NiTi twisted files; Bio Switzerland). These three file systems were divided into three groups for cleaning, shaping, and enlarging the canals. Group 1 consisted of 30 extracted mandibular first premolars, where cleaning, shaping, and enlargement of the canals were performed using Mtwo files, and dentinal cracks were measured at the apical, middle, and coronal portions using Scanning Electron Microscopy (SEM). Group 2 consisted of 30 extracted mandibular first premolars, treated similarly with ProFile GT rotary files, and dentinal cracks were measured in the same

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regions by SEM. Group 3 included 30 extracted mandibular first premolars that underwent cleaning, shaping, and enlargement using TF Adaptive files, with dentinal cracks similarly measured. This study specifically examines the progression of dentinal cracks across inner to outer root regions and thicknesses, employing three distinct file systems evaluated by Scanning electron microscopy (SEM). This underscores the importance of accurate diagnosis and management in endodontic procedures.

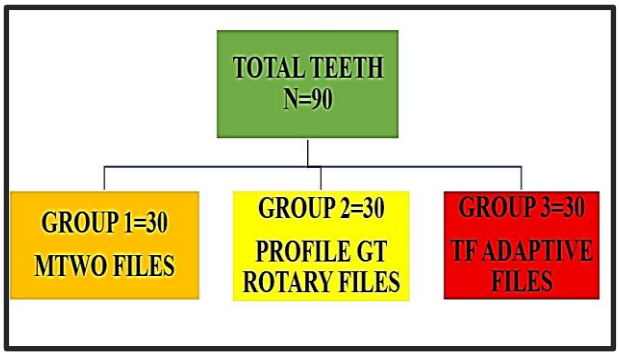
Statistical Analysis and Results

In this research, all statistical evaluations were conducted using SPSS software version 29.0, a robust tool specifically tailored for data analysis and statistical computing in the realm of social sciences. To assess the significance of our results, we employed the chi-square test, known for its effectiveness in analyzing differences in proportions among various groups. This method allowed us to conduct an in-depth and rigorous comparison of categorical data, ensuring that our results not only reflect, but also highlight the essential trends and interrelationships inherent within the dataset. By meticulously examining the various categories, we were able to uncover meaningful insights that contribute to a deeper understanding of the underlying patterns at play.

Results

The study involved a comprehensive analysis of 90 extracted mandibular first premolars, all gathered over one month for non-traumatic reasons. Each tooth underwent a meticulous access cavity preparation, with the working length carefully established to be 1 mm short of the apex. Following this initial phase, the 90 extracted teeth were subjected to biomechanical preparation utilizing three distinct commercial file systems. For clarity in analysis, the teeth were divided into three separate groups, each representing a different preparation method. In Table 1, the total number of teeth is categorized according to these three distinct groups. Moving to Table 2, we find Group 1, which is composed of 30 extracted mandibular first premolars prepared using Mtwo files. In this group, dentinal cracks were meticulously assessed at three specific regions: the apical, middle, and coronal portions, focusing on the transition from the inner to outer aspects of the roots. This assessment was conducted using Scanning Electron Microscopy (SEM) to ensure precision in the observation of dentinal integrity. A statistical evaluation of the data was carried out using the Pearson Chi-Square test to determine the significance of the findings. Table 3 details Group 2, which also includes 30 extracted mandibular first premolars, where biomechanical preparation utilized Profiles GT rotary files. Similar to Group 1, dentinal cracks were measured in the same regions, with a thorough statistical evaluation performed using the Pearson Chi-Square test. In Table 4, we find Group 3, which encompasses the final set of 30 extracted mandibular first premolars that underwent biomechanical preparation with T Adaptive files. The assessment of dentinal cracks in this group mirrored that of the previous groups, focusing on the apical, middle, and coronal regions, with corresponding statistical analyses conducted. Upon analyzing through Scanning electron microscopy (SEM) the results across the three groups, it was evident that Group 1, prepared with Mtwo files (N=30), exhibited a notable increase in dentinal cracks, particularly in the coronal and middle regions. Remarkably, three teeth in this group demonstrated no visible cracks. In contrast, Group 2, which utilized Profiles GT rotary files, showed a reduction in induced dentinal cracks, with 12 teeth displaying no cracks at all. Most significantly, Group 3 evidenced the least number of dentinal cracks, with an impressive 20 teeth showing no signs of cracks whatsoever. Lastly, Table 5 provides a comprehensive overview of the estimates among all studied groups, analyzed using a one-way ANOVA for comparative insights.

Table 1: The total number of samples has been categorized into three distinct groups



Journal of Chemical Health Risks
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Table 2: Group 1 (N=30) extracted mandibular first premolars, where biomechanical preparation was performed using Mtwo files. Dentinal cracks were measured at the apical, middle, and coronal portions from inner to outer regions using Scanning Electron Microscopy (SEM), along with statistical assessment using the "Pearson Chi-Square" test and level of significance

Dentinal Cracks Region	n	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Coronal								
1/3	6	1.15	0.895	0.268	1.97	3.682	1.0	0.80
2/3	5	1.13	0.494	0.155	1.56	2.381	1.0	0.02*
Full thickness	4	1.09	0.289	0.049	1.48	1.078	1.0	0.56
Middle								
1/3	3	0.07	0.056	0.019	0.036	1.078	1.0	0.06
2/3	2	0.05	0.026	0.016	0.034	1.008	1.0	0.13
Full thickness	1	0.02	0.015	0.011	0.020	0.036	2.0	0.46
Apical								
1/3	1	0.02	0.015	0.011	0.020	0.036	2.0	0.46
2/3	1	0.02	0.015	0.011	0.020	0.036	2.0	0.46
Full thickness	-	-	-	-	-	-	-	-
No cracks	7	2.07	0.06	0.049	0.396	1.678	1.0	0.09
*p<0.05 significant								

Table 3: Group 2 (N=30) extracted mandibular first premolars, where biomechanical preparation was performed using Profiles GT rotary files. Dentinal cracks were measured at the apical, middle, and coronal portions from inner to outer regions using Scanning Electron Microscopy (SEM), along with statistical assessment using the "Pearson Chi-Square" test and level of significance

Dentinal Cracks Region	N	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Coronal								
1/3	5	1.13	0.494	0.155	1.56	2.381	1.0	0.02*
2/3	3	0.07	0.056	0.019	0.036	1.078	1.0	0.06
Full thickness	3	0.07	0.056	0.019	0.036	1.078	1.0	0.06
Middle								

Journal of Chemical Health Risks
www.jchr.org
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1/3	3	0.07	0.056	0.019	0.036	1.078	1.0	0.06
2/3	2	0.05	0.026	0.016	0.034	1.008	1.0	0.13
Full thickness	1	0.02	0.015	0.011	0.020	0.036	2.0	0.46
Apical								
1/3	1	0.02	0.015	0.011	0.020	0.036	2.0	0.46
2/3	0	-	-	-	-	-	-	-
Full thickness	0	-	-	-	-	-	-	-
No cracks	12	2.14	1.095	1.348	2.45	6.078	1.0	0.80
*p<0.05 significant								

Table 4: Group 3 (N=30) extracted mandibular first premolars, where biomechanical preparation was performed using T adaptive files. Dentinal cracks were measured at the apical, middle, and coronal portions from inner to outer region using Scanning Electron Microscopy (SEM), along with statistical analysis using the "Pearson Chi-Square" test and the level of significance

Dentinal Crack Region	**n**	**Stat. Mean**	**Std. Dev.**	**Std. Error**	**95% CI**	**Pearson Chi-Square Value**	**Df**	**p value**
Coronal								
1/3	3	0.07	0.056	0.019	0.036	1.078	1.0	0.06
2/3	2	0.05	0.026	0.016	0.034	1.008	1.0	0.13
Full thickness	2	0.05	0.026	0.016	0.034	1.008	1.0	0.13
Middle								
1/3	2	0.05	0.026	0.016	0.034	1.008	1.0	0.13
2/3	1	0.02	0.015	0.011	0.020	0.036	2.0	0.46
Full thickness	0	-	-	-	-	-	-	-
Apical								
1/3	0	-	-	-	-	-	-	-
2/3	0	-	-	-	-	-	-	-
Full thickness	0	-	-	-	-	-	-	-
No cracks	20	2.30	2.196	1.506	1.06	8.067	2.0	1.10
*p<0.05 significant								

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(5), 2732-2739 | ISSN:2251-6727

Table 5: Estimation amongst all studied groups using one-way ANOVA

Variables	Degree of Freedom	Sum of Squares ∑	Mean Sum of Squares m∑	F	Level of Sig. (p)
Between Groups	3	1.420	1.537	1.3	0.001*
Within Groups	15	2.204	0.623	_	
Cumulative	104.13	07.644	*p<0.05 significant		

Discussion

Shemesh H et al reviewed in their study that the primary aim of root canal instrumentation is to effectively eradicate bacteria and debris while safeguarding the structural integrity of the root canal system. This crucial process of biomechanical preparation, while necessary, carries inherent risks, including the potential development of dentinal defects, such as craze lines and fractures. These compromises can significantly heighten the risk of tooth fractures, particularly under the pressures encountered during occlusion, the functional contact between opposing teeth. Several factors contribute to these detrimental defects, including the choice of instrumentation techniques, the materials used for filling, the anatomical characteristics of the tooth, and the procedures followed after treatment.[14,15] Goo HJ et al showed in their study that the introduction of advanced nickel-titanium (Ni-Ti) file systems has marked a transformative shift in root canal preparation, offering remarkable improvements in efficiency when compared to the traditional stainless steel (S.S.) hand files. However, the diverse designs of these files can sometimes amplify stress on the canal walls, leading to the formation of microcracks that increase the likelihood of fractures.[16,17] Kakoienejad M et al reviewed in their study shown the advantages of various file systems like Mtwo files are specifically designed to tackle the intricacies of complex root canal systems. Their unique taper and flute design empower clinicians to navigate through curvatures and irregularities with precision, ensuring effective shaping of even the most challenging canals. In contrast, Mtwo R files are designed for rapid and efficient material removal, making them suitable for clearing extensive tissue or debris.[18] Iqbal MK et al included in their study that their aggressive cutting action may lead to more canal wall fractures compared to ProTaper R files, which provide a gentler cutting mechanism that minimizes damage while effectively shaping. ProFile GT rotary files are well-regarded for their flexibility and strength, crafted from advanced materials to endure torsional stress. This durability enhances the life and efficiency of the instruments, ensuring safe performance during endodontic procedures.[19] Gambarini G et al reviewed in their study that the TF Adaptive system elevates root canal shaping by combining rotary and reciprocating motions, accommodating diverse canal anatomies. Its color-coded mechanism simplifies setting selection, offering clear visual guidance to optimize techniques based on tooth characteristics. This design improves operational effectiveness and enhances patient outcomes in root canal treatments.[20] Stewart AD at el included in their study that Scanning Electron Microscopy (SEM) plays a crucial role in dental research as it offers vital insights into bacterial leakage, biofilm formation, and fracture patterns in the realm of endodontics. Furthermore, SEM allows for thorough surface analysis of dentin following the use of various rotary instruments, thus reinforcing its significance in advancing knowledge and practices within the field.[21-23]

Conclusion

The findings of the study concluded that among the various file systems commonly employed in dental procedures, the Mtwo file system is associated with a notably higher occurrence of dentinal cracks compared to the Twisted File Adaptive (TFA) system and Profiles. This research suggested and concluded that the unique hybrid reciprocating motion utilized by the TFA system may play a crucial role in reducing stresses on the tooth structure during use, ultimately leading to a diminished incidence of crack formation. While it is important to

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JCHR (2025) 15(5), 2732-2739 | ISSN:2251-6727

acknowledge that all file systems inherently carry the risk of causing some degree of dentinal damage, the adaptive motion characteristic of TFA appears to provide a significant advantage in minimizing the potential for cracks. However, it is essential to keep in mind that the frequency of these cracks is influenced not only by the file system used but also by the specific anatomical characteristics of the tooth being treated and the level of experience possessed by the dental operator.

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Journal of Chemical Health Risks

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