IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 7 Ser. 7 (July. 2025), PP 38-44
www.iosrjournals.org

Comparative Evaluation Of Dentinal Crack Propagation Using Multiple, Single Continuous, And Single Reciprocating File Systems: An In Vitro Study

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Abstract
Background: Root canal instrumentation can induce dentinal microcracks that may compromise tooth integrity. This study compares dentinal crack propagation using multiple- file, single continuously rotating, and single reciprocating file systems.
Methods: Sixty single-rooted human teeth were standardized to 13 mm in length and divided into six groups (n=10). Biomechanical preparation was performed using: TruNatomy, Hyflex CM (multiple-file); One Shape, Hyflex EDM (single continuous); and Wave One, Reciproc (single reciprocating). Sections at 3 mm, 6 mm, and 9 mm were examined under stereomicroscope (×25) for crack detection.
Results: TruNatomy showed the fewest cracks, followed by Hyflex CM, Hyflex EDM, Wave One, Reciproc, and One Shape. Significant variation across canal regions was noted in One Shape and Wave One groups.
Conclusion: Multiple-file systems produced fewer dentinal cracks than single-file systems. Among single-file systems, continuous rotation was associated with fewer cracks than reciprocating motion.
Keywords: *Dentinal cracks, rotary instrumentation, reciprocating files, stereomicroscopy, NiTi files*

Date of Submission: 13-07-2025 Date of Acceptance: 23-07-2025

I. Introduction

Root canal therapy relies on thorough cleaning and shaping of the root canal system to eliminate microorganisms and necrotic tissue while maintaining the integrity of the dentinal walls. However, the mechanical preparation involved in this process has been associated with the formation of dentinal defects and microcracks, which may predispose teeth to vertical root fractures (VRFs) in the long term [1-3].

Nickel-titanium (NiTi) alloys facilitated the advancement of rotary endodontic instruments due to their exceptional superelasticity and low elastic modulus.[4]

Advances in metallurgy, file design, and kinematics have led to the development of newer systems, including heat-treated NiTi files, which aim to enhance file flexibility and fatigue resistance while minimizing stress on canal walls [5-7].

Hyflex CM (Coltene/Whaledent AG, Altstatten, Switzerland) and TruNatomy (TN; Dentsply Sirona, Maillefer, Ballaigues, Switzerland) file systems are continuously rotating sequence file systems that have shown to cause fewer dentinal cracks as compared to traditional rotary files.[1,8]

Single file systems (SFS) only need one file to prepare the canal to an appropriate size and taper. When compared to various file systems, SFS not only shapes the canal but also decreases cross-contamination, and instrument fatigue without sacrificing cutting efficiency.[9] They are also considered cost-effective and time-efficient, as it requires fewer files compared to multi- instrument rotary canal preparation techniques.

One shape and Hyflex EDM are continuously rotating single file systems by Micro-Mega and Coltene respectively.

Continuously rotating rotary files tend to undergo cyclic fatigue in curved canals. This occurs due to alternating tensile and compressive stresses causing elastic deformation of the instrument. Reciprocating single file systems such as Reciproc (VDW, Munich, Germany) and WaveOne (Maillefer, Ballaigues, Switzerland) provide more flexibility of the M-wire Ni-Ti alloy, greater resistance to cyclic fatigue and better handling of narrow and curved canals than the traditional Ni-Ti instruments and they are widely used in endodontic treatment.[10,11]

There is limited research comparing dentinal crack propagation between single continuously rotating and single reciprocating file systems. Therefore, this study aims to evaluate and compare dentin crack formation among multiple-file systems, single continuous rotation, and single reciprocating rotary file systems using stereomicroscopy.

II. Aim Of The Study

The aim of this study is to compare dentin crack formation among sequence file systems, single continuously rotating and single reciprocating rotary file systems.

III. Materials And Methods

Sixty single rooted teeth with mature apices were collected, cleaned and stored in distilled water. All the teeth were decoronated apical to the cementoenamel junction to standardize the canal length to 13 mm with a diamond disc under water coolant. The root samples were then viewed under stereomicroscope to access any pre-existing external defects or cracks.

Working length of all samples were established by subtracting 1mm from the length of a size 15 K-file inserted into the canal until the tip of the file become visible at the apical foramen.

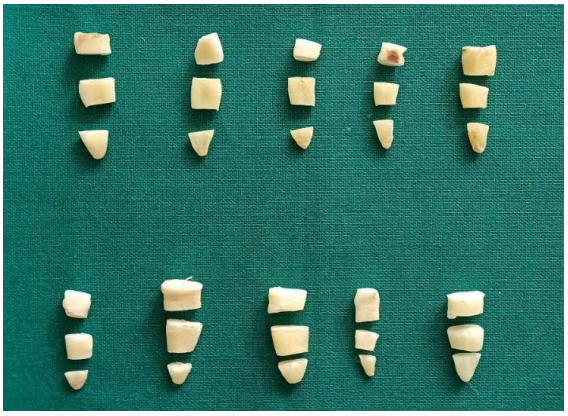
The samples were randomly divided into six experimental groups based on the instruments used for the canal preparation (n= 10 in each group). For each rotary file the individual torque limit and rotational speed recommended by the manufacturer was used. All the single file systems were first enlarged with their corresponding glide path files. The reciprocating files were used in reciprocating working motion.

During instrumentation 1ml of 3% sodium hypochlorite (NaOCl) was used for irrigation. To maintain patency of apical foramen, the canal was recapitulated by 15K file after each file.

Ethylene diamine tetra acetic acid gel (EDTA gel) was used as a lubricant with each file. The canal was rinsed with distilled water after the completion of the procedure to avoid dehydration. Irrigating solutions were delivered using a 30-gauge side vented needle (Dentsply Maillefer, Ballaigues, Switzerland). The root canals of each tooth were dried with paper points.

The groups were as follows:
GROUP 1 A: Instrumentation with TruNatomy (Dentsply Sirona) rotary files up to file 26/.04 GROUP I B: Instrumentation with Hyflex CM (Coltene) rotary files up to file 25/.06
GROUP II A: Instrumentation with One Shape (MicroMega) single continuously rotating rotary file 25/.06
GROUP II B: - Instrumentation with Hyflex EDM (Coltene) single continuously rotating file 25/~
GROUP III A: - Instrumentation with Wave One (Denstply) single reciprocating file 25/.07 GROUP III B: - Instrumentation with R25 Reciproc (VDW) single reciprocating file 25/.08

After the completion of biomechanical preparation, all the roots were horizontally sectioned at 3 mm, 6 mm, and 9 mm from the apex and viewed under a stereomicroscope determine the presence and extent of cracks in the dentin surrounding the instrumented root canals.



Teeth horizontally sectioned into Coronal, Middle and Apical thirds

IV. Results

This study assessed and compared dentinal crack formation induced by six different endodontic file systems—TruNatomy, Hyflex CM, Hyflex EDM, Wave One, Reciproc, and One Shape—at three levels of the root: coronal, middle, and apical thirds. Statistically significant differences were observed among the groups in all three regions, as determined by the Kruskal-Wallis test ($p < 0.001$).

In the coronal third, the TruNatomy group exhibited the lowest mean dentinal crack count (0.10 ± 0.32), indicating minimal structural damage. Hyflex CM demonstrated a slightly higher mean value (0.60 ± 0.52), followed by Hyflex EDM (1.20 ± 0.42), Wave One (2.30 ± 0.48), and Reciproc (2.80 ± 0.42). The One Shape system showed the highest mean crack count (3.90 ± 0.32), significantly greater than all other groups ($p < 0.001$). Dunn's post hoc analysis confirmed significant differences between most groups, with One Shape inducing substantially more cracks than all other systems, and TruNatomy significantly outperforming most other instruments in preserving dentinal integrity.

Similar trends were observed in the middle third, where TruNatomy and Hyflex CM recorded the lowest mean crack counts (0.10 ± 0.32 and 0.30 ± 0.48, respectively). In contrast, One Shape again exhibited the highest mean value (3.50 ± 0.53), followed by Reciproc (2.60 ± 0.52), Wave One (1.90 ± 0.57), and Hyflex EDM (1.20 ± 0.63). Post hoc comparisons revealed statistically significant differences among the majority of groups, particularly between One Shape and all other systems ($p < 0.001$). The TruNatomy group showed significantly fewer cracks than the reciprocating and most continuous rotary systems.

In the apical third, TruNatomy (0.10 ± 0.32) and Hyflex CM (0.40 ± 0.52) again demonstrated the most favorable outcomes in terms of dentinal preservation. The One Shape group recorded the highest crack formation (3.20 ± 0.42), followed by Reciproc (2.60 ± 0.52), Wave One (1.70 ± 0.68), and Hyflex EDM (1.30 ± 0.48). Multiple comparisons showed that One Shape caused significantly greater dentinal damage compared to all other systems, with the exception of Reciproc, where the difference was not statistically significant ($p = 0.06$). Comparisons between the remaining groups also yielded statistically significant differences in several instances.

Intra-group comparisons of mean dentinal crack counts across root levels revealed significant regional variation only in the One Shape ($p = 0.006$) and Wave One ($p = 0.04$) groups. In the One Shape group, significant differences were found between the coronal and apical thirds ($p= 0.004$), whereas in the Wave One group, the coronal third exhibited significantly more cracks than the apical third ($p = 0.02$). No statistically significant regional variation was noted for TruNatomy, Hyflex CM, Hyflex EDM, or Reciproc.

In summary, the TruNatomy system consistently resulted in the least dentinal damage across all thirds of the root, whereas the One Shape system produced the highest crack counts.

Reciprocating systems, particularly Reciproc and Wave One, showed greater crack formation than Hyflex CM and EDM but were less aggressive than One Shape. These findings highlight the influence of instrumentation design and motion kinematics on the incidence of dentinal defects.

Microscopic image of tooth filed with TruNatomy

Microscopic image of tooth filed with Hyflex CM

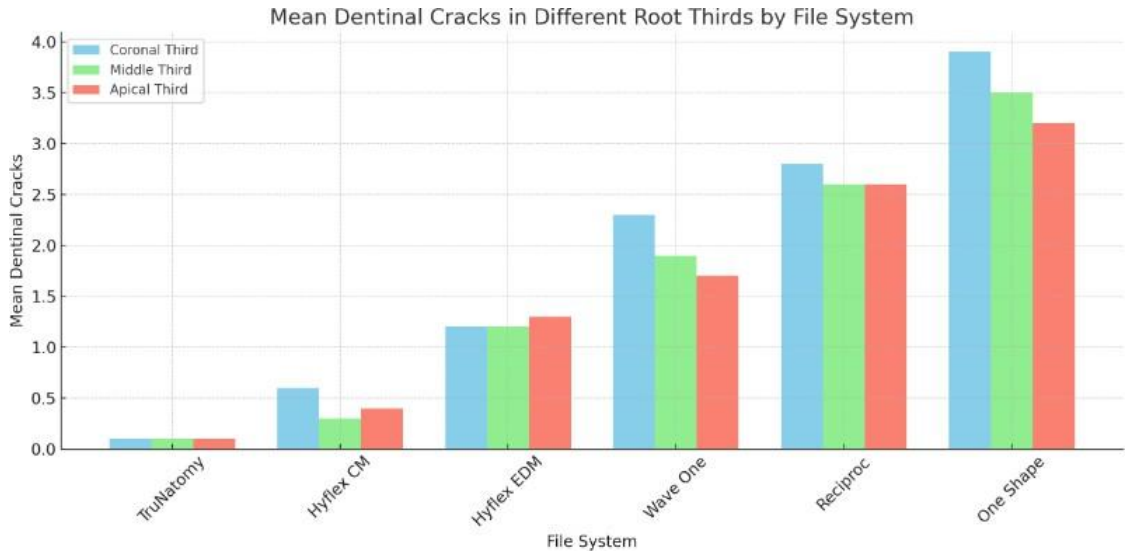
Microscopic image of tooth filed with One Shape

Microscopic image of tooth filed with Hyflex EDM

Microscopic image of tooth filed with Wave One

Microscopic image of tooth filed with Reciproc

Comparison of mean Dentinal Cracks b/w different regions in each group using Friedman's test followed by Wilcoxon Signed Rank Post hoc Test							
Groups	Region	N	Mean	SD	p-value [a]	Sig. Diff	p-value [b]
Trunatomy	Coronal 3rd	10	0.10	0.32	1.00	C vs M	..
	Middle 3rd	10	0.10	0.32		C vs A	..
	Apical 3rd	10	0.10	0.32		M vs A	..
Hyflex CM	Coronal 3rd	10	0.60	0.52	0.38	C vs M	..
	Middle 3rd	10	0.30	0.48		C vs A	..
	Apical 3rd	10	0.40	0.52		M vs A	..
One Shape	Coronal 3rd	10	3.90	0.32	0.006*	C vs M	0.11
	Middle 3rd	10	3.50	0.53		C vs A	0.004*
	Apical 3rd	10	3.20	0.42		M vs A	0.58
Hyflex EDM	Coronal 3rd	10	1.20	0.42	0.77	C vs M	..
	Middle 3rd	10	1.20	0.63		C vs A	..
	Apical 3rd	10	1.30	0.48		M vs A	..
Wave one	Coronal 3rd	10	2.30	0.48	0.04*	C vs M	0.11
	Middle 3rd	10	1.90	0.57		C vs A	0.02*
	Apical 3rd	10	1.70	0.68		M vs A	1.00
Reciproc	Coronal 3rd	10	2.80	0.42	0.28	C vs M	..
	Middle 3rd	10	2.60	0.52		C vs A	..
	Apical 3rd	10	2.60	0.52		M vs A	..



V. Discussion

The results of our study demonstrated that TruNatomy resulted in the fewest dentinal cracks across all root canal regions, followed by Hyflex CM and Hyflex EDM, suggesting these instruments are less damaging to dentin structure. In contrast, Reciproc, Wave One, and especially One Shape produced higher crack counts, with One Shape showing the most pronounced impact. While most systems exhibited consistent crack formation across the coronal, middle, and apical thirds, One Shape and Wave One showed regional variations, particularly with more cracks in the coronal third.

The superior performance of TruNatomy is attributed to its unique design and metallurgical properties. TruNatomy instruments are fabricated using a proprietary heat-treated NiTi alloy and feature a regressive taper, reduced core diameter, and an off-centred parallelogram cross-section. These design elements decrease the contact area with canal walls, reducing friction and lateral pressure on dentin, thereby enhancing flexibility and minimizing stress transmission to the dentinal walls. Such characteristics contribute to the reduced formation of dentinal microcracks during root canal preparation.[12,13] These results align with the observations of Shetty et al., who found that the TruNatomy file system caused fewer dentinal defects compared to other commonly used rotary file systems.[12]

Hyflex CM produced mean crack counts of 0.60 (coronal), 0.30 (middle), and 0.40 (apical), showing no significant regional variation and placing it second best in this study only beneath the TrNatomy file system. This system is known for its high flexibility and ability to return to its original shape after deformation, thereby reducing undue stress on canal walls, minimizing the potential for crack initiation.[14,15]. These findings are consistent with those of Çapar et al., who reported reduced dentinal defects with flexible file systems like Hyflex CM.[16]

The One Shape (MicroMega) system exhibited the highest mean dentinal crack counts across all root thirds. As a single-file system operating in continuous rotation, One Shape is constructed from conventional heat-treated NiTi and features a triple-cutting, asymmetric cross-section with a constant taper of approximately 0.06. This aggressive design may account for the increased stress applied to dentinal walls. Studies conducted by Kansal et al. in 2020, and Al Zaka in 2018 showed similar results concerning the One Shape file system.[15.17] The elevated incidence of cracks, particularly in the coronal third, suggests that One Shape's aggressive cutting efficiency may overload dentin, especially in wider canal regions.[18]

Hyflex EDM (Coltene), produced using Electrical Discharge Machining, demonstrated moderate levels of crack formation. The EDM process enhances surface hardness and fatigue resistance while retaining core flexibility. Its variable cross-sectional geometry and taper offer a balance between cutting efficiency and canal preservation.

Though the performance was inferior to TruNatomy and Hyflex CM, it was superior to One Shape, WaveOne, and Reciproc. These results support prior findings suggesting that EDM technology can improve file resilience while moderately limiting dentinal damage, namely studies conducted by Kfir et al in 2016 and Yared et al. in 2018.[19-21]

WaveOne Gold (Dentsply Sirona) and Reciproc (VDW) are single-file reciprocating systems. These reciprocating files systems showed the maximum amount of dentinal crack throughout the lengths of the roots, second only to the One Shape file system. Wave One Gold employs Gold-wire NiTi and features a variable taper and offset parallelogram cross- section. Its reciprocating motion (150° CCW / 30° CW) is intended to reduce

torsional stress on the instrument; however, repeated stress reversals may instead concentrate forces on the canal walls.[22]

Reciproc (VDW) is manufactured using M-Wire NiTi and designed with a high 0.08 constant taper and an S-shaped cross-section. It showed one of the highest levels of crack formation, second only to One Shape. The aggressive taper and reciprocating motion likely contribute to increased lateral pressure and dentinal damage.[93,94] These findings align with those of Kansal et al., who reported increased dentinal microcracks associated with reciprocating systems having high tapers.[15]

This study underscores the clinical importance of selecting minimally invasive instrumentation systems, as TruNatomy and HyFlex CM produced the fewest dentinal cracks, likely due to their heat-treated NiTi alloys and reduced tapers that minimize lateral stress and preserve critical dentinal structures such as the pericervical dentin. Clinically, these conservative systems may better maintain the biomechanical integrity of teeth, particularly in older patients or those with high occlusal loads. Conversely, aggressive systems like One Shape and Reciproc generated more cracks, especially in the coronal third, highlighting the need for cautious preparation in this region to avoid compromising structural resilience or the ferrule effect. While reciprocating files offer benefits such as speed and reduced instrument fatigue, their use should be tailored to canal anatomy and tooth condition, especially in structurally vulnerable roots. A case-specific, possibly hybrid, approach to instrumentation—combining conservative and reciprocating techniques—may provide an optimal balance between efficiency and dentin preservation.

VI. Conclusion

Under the limitations of this in vitro study, it can be concluded that the type of instrumentation significantly influences dentinal crack formation, with single-file systems— particularly reciprocating files and One Shape—producing the highest number of cracks along the entire root canal length, while sequential systems like TruNatomy and Hyflex CM resulted in substantially fewer defects. TruNatomy consistently exhibited the lowest crack counts across all root thirds, indicating its minimal impact on dentin integrity and suitability for conservative canal preparation. Hyflex CM and Hyflex EDM also showed relatively low to moderate crack formation, whereas Wave One and Reciproc demonstrated higher crack incidence, reflecting a greater potential to compromise dentinal structure. One Shape was the most aggressive, causing the highest number of cracks in all regions, particularly in the coronal third. While most instruments showed uniform effects across the root, regional variations were evident in One Shape and Wave One, which caused significantly more cracks in the coronal third compared to the apical third. These findings suggest that sequential rotary systems may pose a lower risk of dentinal damage compared to single-file systems and that both file design and motion kinematics must be carefully considered to preserve structural integrity during biomechanical preparation.

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