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COMPARATIVE EVALUATION OF DENTINAL MICROCRACK FORMATION FOLLOWING ROOT CANAL PREPARATION WITH HAND K-FILES AND THREE CONTEMPORARY NITI ROTARY SYSTEMS: AN IN VITRO STUDY

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ABSTRACT

Background: Root canal instrumentation may generate dentinal microcracks that weaken the root and increase susceptibility to vertical fracture. This study compared dentinal defects produced by stainless-steel hand K-files and three contemporary nickel–titanium rotary systems.

Methods: Seventy-five extracted single-rooted mandibular premolars were randomly allocated into five groups (n=15): uninstrumented control, hand K-file, Neoendo Flex, HyFlex EDM, and TruNatomy. Following canal preparation, roots were horizontally sectioned at 3, 6, and 9 mm from the apex. Sections were examined stereomicroscopically and classified as having no defect, an incomplete crack, or a complete crack. Intergroup comparisons were performed using the chi-square test.

Results: Dentinal defect distribution differed significantly among groups at the coronal (χ^2=20.66, p=0.008) and middle levels (χ^2=22.00, p=0.005). TruNatomy showed the most favourable results, with 80% of specimens remaining defect-free at both levels and no complete cracks. At the middle level, complete cracks occurred most frequently with hand K-files (80%), while HyFlex EDM predominantly produced incomplete cracks (80%). No significant intergroup difference was found at the apical level (χ^2=1.19, p=0.880), where no complete cracks were detected.

Conclusion: The instrumentation system influenced dentinal microcrack formation. TruNatomy demonstrated better preservation of root dentin, particularly in the coronal and middle thirds. However, the occurrence of defects in uninstrumented specimens indicates that extraction or specimen preparation may have influenced the findings.

KEYWORDS: dentinal microcracks; HyFlex EDM; Neoendo Flex; root canal preparation; stereomicroscopy; TruNatomy

INTRODUCTION

Successful endodontic treatment depends on thorough cleaning, shaping, and three-dimensional sealing of the root canal system. Biomechanical preparation removes infected tissue and debris while creating an appropriate canal form for effective irrigation and obturation.1 However, instrumentation may produce procedural complications such as ledge formation, canal transportation, perforation, and dentinal microcracks.2 These defects can weaken the root structure and may gradually propagate under repeated occlusal forces, ultimately resulting in vertical root fracture and treatment failure.3

The occurrence of dentinal defects may be influenced by the instrument's design, alloy, cross-section, taper, cutting action, and kinematics.4 Rotary nickel–titanium (NiTi) instruments provide greater flexibility, cutting efficiency, and faster canal preparation than conventional stainless-steel hand files. Nevertheless, their rotational movement, active cutting edges, and increased taper may generate friction and stress on canal walls, thereby contributing to microcrack formation.5 Conservative instrumentation systems have therefore been developed to preserve root dentin while maintaining adequate canal preparation.

TruNatomy is a heat-treated NiTi system manufactured from a slim 0.8-mm wire and designed for minimally invasive shaping with reduced dentinal removal.6 HyFlex EDM files are produced through electrical discharge machining, which improves flexibility, cutting efficiency, and resistance to cyclic fatigue.7 Neoendo Flex files undergo gold heat treatment

and have a triangular cross-section intended to provide flexibility and efficient cutting.8 In contrast, stainless-steel K-files are manually operated instruments that enlarge canals using filing or balanced-force movements.
Because different instrumentation systems may transmit varying levels of stress to root dentin, their potential to produce microcracks requires evaluation. Therefore, the present study aimed to compare dentinal microcrack formation following root canal preparation using stainless-steel hand K-files, TruNatomy, HyFlex EDM, and Neoendo Flex rotary systems.

MATERIALS AND METHODS

This in vitro experimental study was conducted in the Department of Conservative Dentistry and Endodontics, Mithila Minority Dental College and Hospital. Seventy-five freshly extracted, single-rooted human mandibular premolars were obtained from the Department of Oral and Maxillofacial Surgery. The teeth had been extracted for periodontal reasons and were vital at the time of extraction. Teeth with a closed apex, intact root, restorable structure, and no visible root fracture were included. Grossly carious teeth and those with an open apex, root resorption, severe root curvature, or dilaceration were excluded. Immediately after extraction, adherent soft-tissue remnants, debris, and blood clots were removed. The specimens were disinfected using sodium hypochlorite, processed through ascending concentrations of alcohol for 8 hours, washed under running water, and stored in normal saline until use.

Sample size

The sample size was calculated using G*Power version 3.1.9.7, based on the proportions of dentinal cracks reported for hand files (6.7%) and another instrumentation system (66.7%) in the reference study. With a two-sided α error of 0.05, power of 80%, and equal allocation, the minimum requirement was 11 specimens per group. This was increased to 15 specimens per group, providing a total sample of 75 teeth across five groups.
Specimen preparation and grouping
All teeth were decoronated at the cementoenamel junction using a diamond disc under water cooling to standardize the root specimens. The samples were randomly allocated into five groups of 15 teeth each:

- Group I: uninstrumented control
- Group II: stainless-steel hand K-files
- Group III: Neoendo Flex rotary files
- Group IV: HyFlex EDM rotary files
- Group V: TruNatomy rotary files

Group I received no canal instrumentation. In the experimental groups, access preparation was performed using an Endo Access bur. Canal patency and working length were established using a size 10 K-file, followed by glide-path preparation up to a size 15 K-file. Group II canals were prepared sequentially with stainless-steel K-files from sizes 15 to 40. Group III was instrumented with Neoendo Flex files up to size 25/.06, Group IV with HyFlex EDM files up to size 30/.04, and Group V with TruNatomy files up to size 36/.03. Rotary instruments were operated with an endodontic motor according to their respective prescribed sequences (Figure 1).
During preparation, canals were irrigated with 5.25% sodium hypochlorite, with intermittent flushing using normal saline. A final rinse with 17% ethylenediaminetetraacetic acid was performed, after which the canals were rinsed and dried using absorbent paper points.
Stereomicroscopic evaluation
Each root was horizontally sectioned under continuous water cooling at 3, 6, and 9 mm from the apex, representing the apical, middle, and coronal thirds, respectively. Digital images of every section were obtained using a stereomicroscope and examined for the presence or absence of dentinal microcracks (Figure 2).
Statistical analysis
Data were analysed using IBM SPSS Statistics version 26.0. Frequencies and percentages were used to summarize dentinal microcracks. The chi-square test was applied to compare crack occurrence among the five groups at each root level. A p-value <0.05 was considered statistically significant, while $p<0.01$ was considered highly significant.

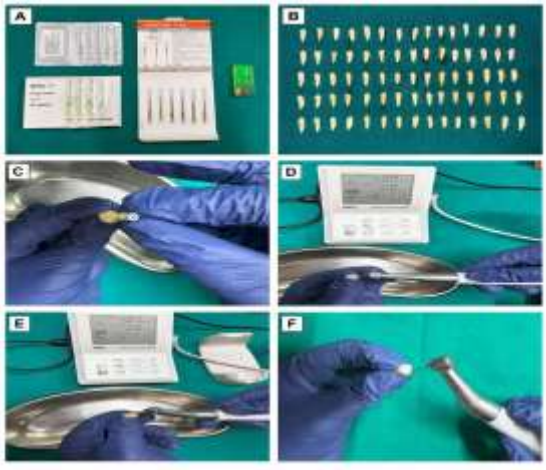

Figure 1. Specimen selection and root canal instrumentation..

(A) Seventy-five extracted single-rooted mandibular premolars selected for the study. (B) Different hand and rotary file systems used for canal preparation. (C) Manual instrumentation using Dentsply K-files from sizes #15 to #40. (D) Root canal preparation using the Neoendo Flex rotary file system. (E) Root canal preparation using the HyFlex EDM rotary file system. (F) Root canal preparation using the TruNatomy rotary file system.

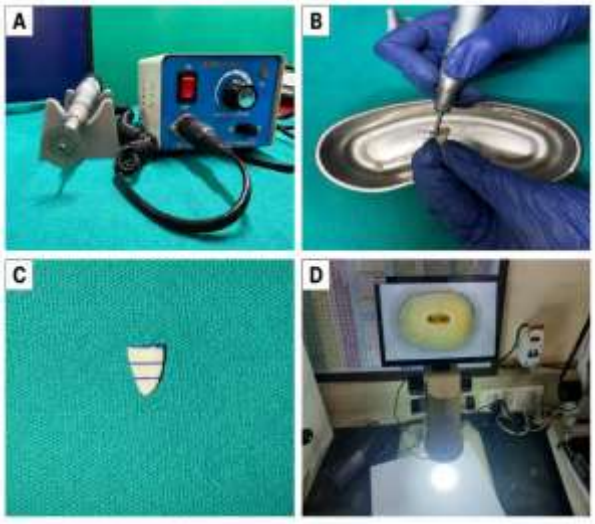

Figure 2. Preparation, sectioning, and stereomicroscopic examination of the specimens.

(A) Micromotor with a straight handpiece, mandrel, and diamond disc used for specimen preparation. (B) Decoronation of the tooth at the cementoenamel junction. (C) Decoronated root marked for sectioning at the coronal, middle, and apical thirds. (D) Examination of a sectioned root specimen under a stereomicroscope.

RESULTS

The distribution of dentinal defects differed significantly among the five groups at the coronal level (χ^2=20.66, df=8, p=0.008). TruNatomy demonstrated no defect in 80.0% of specimens and produced no complete cracks. In comparison, complete cracks were observed in 80.0% of the control, hand K-file, and Neoendo Flex groups and in 60.0% of the HyFlex EDM group.

A significant difference was also found at the middle root level (χ^2=22.00, df=8, p=0.005). No defects were observed in 80.0% of TruNatomy specimens and 60.0% each of the control and Neoendo Flex specimens. Complete cracks were most frequent with hand K-files (80.0%), followed by HyFlex EDM (20.0%). At the apical level, the distribution did not differ significantly among the groups (χ^2=1.19, df=4, p=0.880), and no complete cracks were identified.

Table 1. Distribution of dentinal defects according to instrumentation group and root level

Root level	Dentinal finding	Control n (%)	Hand K-file n (%)	Neoendo Flex n (%)	HyFlex EDM n (%)	TruNatomy n (%)	χ^2	p-value
Coronal	No defect	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	12 (80.0)	20.66	0.008
	Incomplete crack	3 (20.0)	3 (20.0)	3 (20.0)	6 (40.0)	3 (20.0)		
	Complete crack	12 (80.0)	12 (80.0)	12 (80.0)	9 (60.0)	0 (0.0)		
Middle	No defect	9 (60.0)	0 (0.0)	9 (60.0)	0 (0.0)	12 (80.0)	22.00	0.005
	Incomplete crack	6 (40.0)	3 (20.0)	6 (40.0)	12 (80.0)	3 (20.0)		
	Complete crack	0 (0.0)	12 (80.0)	0 (0.0)	3 (20.0)	0 (0.0)		
Apical	No defect	9 (60.0)	9 (60.0)	12 (80.0)	12 (80.0)	12 (80.0)	1.19	0.880
	Incomplete crack	6 (40.0)	6 (40.0)	3 (20.0)	3 (20.0)	3 (20.0)		
	Complete crack	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)		

Chi-square test was used for intergroup comparisons. A p-value <0.05 was considered statistically significant.

DISCUSSION

Cleaning and shaping are essential for removing infected tissue and facilitating irrigation and obturation of the root canal system.9 However, instrumentation inevitably removes dentin and may create stress concentrations within the root. Because fracture resistance is closely related to the amount and quality of remaining dentin, excessive preparation can increase susceptibility to crack initiation and propagation.10 Preserving radicular and pericervical dentin is therefore an important objective of contemporary endodontic treatment.

Stainless-steel K-files remain useful because of their affordability, tactile control, and role in canal negotiation. Their rigidity, however, may increase contact with canal walls and produce uneven stress, especially in narrow or curved canals.11 Rotary nickel–titanium instruments improve flexibility, canal centring, and preparation efficiency, but their continuous rotation and interaction with dentin may generate frictional and torsional stresses.3 The effect of instrumentation on root dentin is influenced by several factors, including alloy treatment, cross-sectional geometry, taper, pitch, cutting action, rotational speed, and the area of contact between the instrument and canal wall.12

In the present study, dentinal defects differed significantly among the groups in the coronal (p=0.008) and middle thirds (p=0.005). TruNatomy demonstrated the most favourable findings, with 80% of specimens remaining defect-free at both levels and no complete cracks being detected. This performance may be related to its slim 0.8-mm NiTi wire, regressive taper, reduced core diameter, and off-centred parallelogram cross-section. These characteristics limit file engagement with the canal wall and support conservative dentin removal, thereby reducing the stress transferred to the root.13 The findings support the minimally invasive shaping concept associated with TruNatomy.

At the coronal level, complete cracks were observed in 80% of the control, hand K-file, and Neoendo Flex groups and in 60% of the HyFlex EDM group. In the middle third, complete cracks were most frequent with hand K-files, whereas Neoendo Flex produced no complete cracks and left 60% of specimens defect-free. The flexibility provided by heat treatment may explain the relatively favourable middle-third performance of Neoendo Flex.14 HyFlex EDM mainly produced incomplete cracks in the middle third. Although its controlled-memory alloy and electrical discharge machining improve flexibility and cyclic fatigue resistance, its cutting action and canal-wall contact may still transmit stress to dentin.15

No significant intergroup difference was observed at the apical level (p=0.880). Most specimens were defect-free, and no complete cracks were detected. This may reflect the smaller instrument taper and more limited dentin removal in the apical third. Nevertheless, irrigation with sodium hypochlorite and EDTA may alter dentin properties and potentially influence its susceptibility to mechanical damage.

The presence of complete cracks in uninstrumented control specimens, particularly in the coronal third, suggests that some defects may have existed before preparation or may have resulted from extraction, storage, decoronation, or sectioning. Although water cooling was used, the destructive sectioning method cannot distinguish newly formed cracks from pre-existing defects. Other limitations include the in vitro design, small group size, absence of periodontal ligament simulation, and different file sizes, tapers, speeds, and torque settings. Within these limitations, TruNatomy preserved dentinal integrity better than the other tested systems, particularly in the coronal and middle thirds.

CONCLUSION

Within limitations of present study, instrumentation system significantly influenced dentinal microcrack formation. TruNatomy produced the fewest defects, particularly in coronal and middle thirds, supporting conservative dentin preservation. HyFlex EDM mainly caused incomplete cracks, whereas Neoendo Flex and hand K-files showed more defects, including complete cracks. Apical findings were minimal and comparable across groups. As microcracks may progress to vertical root fracture, selecting an instrument that limits dentinal stress may improve the structural durability and long-term prognosis of endodontically treated teeth.

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