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Original Article

Apical Micro-cracks Following Root Canal Preparation, Obturation, and Retreatment with Rotary and Reciprocating Instruments: An In-Vitro Study

Ahmed Osama [a], Nelly Abdulsalam [a], Marwa Sharaan [a]

[a] Department of Endodontics, College of Dentistry, Suez Canal University, Egypt

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CORRESPONDENCE

Marwa Sharaan
Professor of Endodontics, Department of Endodontics, College of Dentistry, Suez Canal University
E-mail: marwa_sharaan@dent.suez.edu.eg

CLINICAL SIGNIFICANCE

Both continuous rotation and reciprocating systems can be used without a notable difference in dentinal integrity, providing flexibility in clinical decision-making.precise application protocols.

ABSTRACT

Objectives: This study aims to evaluate apical cracks occurring after root canal preparation and retreatment using different NiTi rotary systems with either continuous rotation or reciprocating motion.

Materials and Methods: A total of 40 freshly extracted single rooted teeth could were used in this study, teeth were divided into 2 main groups (n=20) for each. Group A was prepared with continuous rotation motion (Revo-S). Group B was prepared with reciprocation motion (Wave One). Both groups were divided into two subgroups. Subgroup I was retreated by continuous rotation motion (R-Endo). Subgroup II was retreated by reciprocation motion (Wave One. All teeth were trimmed 1 mm apically then scanned by digital stereomicroscope preparation, after root canal preparation, after obturation and after retreatment procedure. Chi-square test was used to compare between two groups in non-related samples Friedman test was used to compare between more than two groups in related samples. Wilcoxon test was used to compare between two groups in related samples.

Results: No significant difference between continuous rotation motion and reciprocation motion in producing apical cracks during root canal preparation and retreatment procedure was found ($p>0.05$).

Conclusion: Reciprocating motion resulted in a slightly higher number of apical cracks than continuous rotation, but the difference was not statistically significant.

1. Introduction

Many factors before, during or after endodontic treatment may lead to deterioration of the tooth structure. These factors may include age-related structural changes, such as craze lines on enamel, chemo-mechanical preparation, intra-canal dressings, as well as obturation and restorative procedures.[1] The risk of root fracture is closely linked to the extent of apical canal preparation, the degree of canal enlargement, and the approach used to manage procedural errors, which often serve as focal points for stress accumulation.[2] It has been suggested that the progression of these dentinal defects may contribute to adverse outcomes, including the development of vertical root fractures.[3]

The Revo-S system (Micro Mega, Besançon, France) is a Nickel-Titanium (NiTi) rotary instrumentation system comprising six files: SC1, SC2, SU, AS30, AS35, and AS40. Its unique asymmetrical cross-sectional design enables a snake-like motion within the canal, which contributes to its high resistance to cyclic fatigue. This design also facilitates a brushing action against the lateral canal walls, aiding in effective circumferential preparation. Furthermore, the system is characterized by enhanced flexibility, superior centering capability, and minimal canal transportation.[4]

M-wire alloy NiTi material with superelastic wire has good flexible properties than that made from conventional NiTi wire. Thus, such flexibility of reciprocating file might have been contributed to the less number of dentinal defects formation as compared to rotation files.[5] Wave One (Dentsply Maillefer, Ballaigues, Switzerland) is a single file NiTi system made of M-wire alloy. It needs less time to prepare the root canal. It has a triangular or modified triangular cross-section. The clockwise and counterclockwise motions produce reciprocating motion which is responsible for decreasing cyclic fatigue and stress.[1]

The use of rigid stainless steel instruments in curved root canals has been associated with iatrogenic alterations to the original canal anatomy. To mitigate these risks, nickel-titanium (NiTi) instruments were introduced, offering shape memory and superelastic properties that enable safer and more effective navigation of curved canals.[6] Unfortunately, NiTi rotary file systems have also been associated with dentinal defects, including cracks, during shaping and retreatment procedures.[6,7] The potential for these defects varies depending on the kinematics of the instrument. Some studies suggest that reciprocating instruments may lead to fewer complete cracks compared to continuous rotation systems, though conflicting findings exist.[8,9] This raises concerns about the long-term integrity of root canal-treated teeth and highlights the need for further investigation into the effect of different NiTi systems on dentinal damage.[9]

By using a stereo microscope, researchers can accurately assess micro-apical cracks after root canal preparation, providing valuable insights into the effectiveness of different preparation techniques and instrumentation.[10]

To the best of knowledge, no published research investigated the apical cracks in the root canal walls during root canal preparation, obturation and retreatment using either rotating or reciprocating rotary systems. Our null hypothesis was that would be no statistically significant difference between rotating or reciprocating rotary systems during root canal preparation, filling, and retreatment in producing apical cracks within the root canal walls.

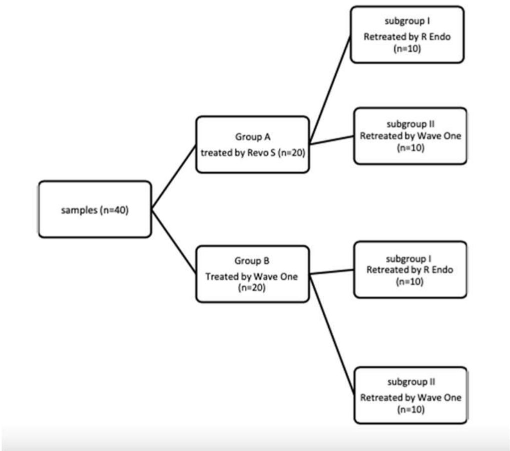

Fig. 1. Schematic diagram representing distribution of samples through groups and subgroups.

2. Materials and Methods

2.1. Sample Size Calculation & Selection

G* power statistical analysis software was used to determine sufficient sample size.[11] The sample size was determined on a sample population of 40 single straight rooted human teeth with an α error probability of 0.05, effect size f of 0.25, and a 0.97 power (1-β). The teeth used in this study were freshly extracted for periodontal, prosthodontic, or orthodontic reasons. Selection criteria included having a completely formed apex, absence of root caries, and no internal or external resorption to prevent structural loss during transverse sectioning. Only teeth that had not undergone prior endodontic treatment were included to ensure standardized instrumentation and obturation. Additionally, samples with visible cracks were excluded to prevent fracture during sectioning, and those with anatomical abnormalities, such as fusion or dilacerations, were not considered.

Maxillary canines were immersed in 2.5% sodium hypochlorite (Clorox; Household Cleaning Products of Egypt, Cairo, Egypt) for one hour for disinfection. The remaining external tissue fragments and calculus were removed from the external surface of teeth by scaling, and then they were washed and stored in distilled water at room temperature till time of use. Bucco-lingual and mesio-distal radiographs were taken to confirm the presence of a single canal.

2.2. Samples Preparation and Classification

Crowns of the collected teeth were decapitated at a standard length of 16-mm from the apical root end using tapered stone (Mani Inc., Japan) at high speed with water coolant for exposing orifice with a direct access to the root canal. One millimeter from the apex of each tooth was ground perpendicular to the long axis of the tooth using Isomet 4000 microsaw (Buehler, USA) with a diamond disc 0.6 mm thickness at speed 2500 rpm and feeding rate 10 mm/min under water cooling and the apical surface was polished. Patency to the canal was negotiated using#10 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) to its full length and passed 1 mm beyond the apex. The working length for root canal preparation was set 1-mm shorter than the apical foramen.[9]

A standard model for periodontal ligament simulation was made. Teeth were placed in melted wax up to 1 mm below the cervical end. After cooling, the teeth were being embedded in blocks filled with gypsum.[10] After setting, teeth were removed and the wax was cleaned from the root surface and "sockets" using warm water.[12] The "sockets" were then filled with a polyether impression material Impregum (3MESPE, St. Paul, MN, USA) using a molding syringe. Teeth were reinserted into the respective "sockets". The excess impression material was removed with a scalpel. The samples were classified into two main groups (n=20) according to the instrumentation technique used during chemo mechanical preparation (Fig.1).

2.3. Root Canal Preparation

2.3.1. Group A – Revo-S System (Continuous Rotation)

In this group, root canals were prepared using the Revo-S rotary system in accordance with the manufacturer's guidelines, employing continuous rotation. The procedure began with initial canal negotiation using a stainless steel K-file (#10, 21 mm) to gain preliminary tactile feedback regarding the canal's curvature and anatomy, complementing radiographic findings. Instruments were frequently withdrawn and cleaned with alcohol-soaked gauze to prevent dentin debris accumulation.

For shaping, Revo-S files were operated with the X-Smart IQ endodontic motor (Dentsply GmbH, Bensheim, Germany) at speeds ranging from 250 to 400 rpm. The SC1 instrument was advanced apically with a gentle, pressure-free, passive movement. SC2 was employed using a dynamic three-wave technique (repeated upward and downward motions), while the SU file was similarly advanced in a slow, pressureless, apical progression.[13] Apical patency was maintained between each file insertion using a small hand file.

Irrigation was performed with 5% sodium hypochlorite (NaOCl), delivered via a 27-gauge syringe needle, with a total of 10 mL used per canal. A chelating agent (MD; Meta Biomed Co., Ltd., Korea) was applied as a lubricant and to aid in debris removal. Final apical shaping was achieved with the SU file, expanding the apical portion to a 6% taper, in continuity with prior preparations.

2.3.2. Group B – WaveOne System (Reciprocating Motion)

Samples in this group were instrumented using the WaveOne file system, following the manufacturer's protocol involving reciprocating motion. Initial canal exploration was performed using a conventional stainless steel K-file (#10, 21 mm) to assess the internal canal anatomy in conjunction with pre-operative radiographs. Instruments were regularly withdrawn and wiped with gauze moistened with alcohol to remove dentinal debris.

The WaveOne Primary file, with a tip size of ISO 25 and a variable taper that begins with 8% apically and decreases coronally, was used to prepare the canals to the full working length. Throughout the procedure, canals were irrigated with 5% NaOCl using a 27-gauge syringe needle. A total volume of 10 mL of irrigant was used per canal. MD chelating agent was utilized to facilitate lubrication and enhance removal of smear layer and debris.

2.4. Root Canal Obturation

All specimens underwent obturation using gutta-percha cones (Dentsply, Maillefer, Ballaigues, Switzerland) in conjunction with an epoxy resin-based sealer, AH Plus (Dentsply DeTrey, Konstanz, Germany), following the cold lateral compaction technique. The master cone was fitted to the full working length, after which a size 30, 2% taper finger spreader (Dentsply, Maillefer, Ballaigues, Switzerland) was inserted parallel to the master cone, stopping 1 mm short of the working length. The spreader was maintained in position for approximately 10 to 60 seconds before being withdrawn, allowing the subsequent placement of accessory gutta-percha cones to ensure lateral compaction.

Following obturation, the coronal portion of each canal was sealed using a temporary restorative material, Cavit (Dentsply, Maillefer, Ballaigues, Switzerland). All samples were then stored in an environment of 100% humidity at 37°C for a period of two weeks to allow for sealer setting and material stabilization.

2.5. Root Canal Retreatment Procedure

Each experimental group was further divided into two subgroups (n = 10) based on the instrumentation method employed during the retreatment phase.

2.5.1. Subgroup 1 – R-Endo System (Continuous Rotation)

In this subgroup, removal of root canal filling materials was carried out using the R-Endo file system (Micro-Mega, Besançon, France), following the manufacturer's recommended continuous rotation protocol. Instrumentation was performed at a rotational speed of 300 to 400 rpm using a torque-controlled electric motor.

The procedure began with the Endo Flare file, which was used to eliminate gutta-percha material from the canal orifice to approximately 3 mm apically. Sequentially, the R1 file was used to clean the coronal third, R2 for the middle third, and R3 for the apical third of the canal. Throughout the process, 5% sodium hypochlorite (NaOCl) was used as the irrigant, delivered via a 27-gauge syringe needle, with a total volume of 10 mL per canal.

2.5.2. Subgroup 2 – WaveOne System (Reciprocating Motion)

In this subgroup, canal fillings were removed using the WaveOne system in reciprocal motion, in accordance with the manufacturer's guidelines. For larger canals, the WaveOne Large file (ISO size 40, taper 8% decreasing coronally) was utilized. Irrigation was similarly performed using 5% NaOCl (10 mL per canal), administered with a 27-gauge needle.

2.5.3. Common Protocol for All Subgroups

Retreatment was considered complete when the instruments no longer carried visible remnants of gutta-percha or sealer, and canal walls appeared smooth upon inspection. Radiographic imaging was employed to confirm the thorough removal of filling materials. A torque- and speed-regulated endodontic motor was used for all instrumentation steps.

Each file was used to treat a single canal only. Additionally, sterile distilled water (5 mL) was used to irrigate the canal after every three pecking motions, using a 27-gauge needle attached to a disposable plastic syringe. The needle tip was passively inserted to a depth 1 mm short of the working length and was never forced into the canal wall during irrigation to ensure safety and efficacy.

2.6. Detection and Evaluation of Apical Cracks

All specimens (n = 40) were carefully extracted from their simulated alveolar sockets and thoroughly rinsed under running water. Apical root surfaces were examined using a digital stereomicroscope (Guangdong, China) at 80× magnification. Each sample was evaluated at four distinct stages of the endodontic procedure: prior to instrumentation, after canal preparation, following obturation, and after the retreatment phase. Digital images were captured using image analysis software (Scope Capture 1.1.1.1 Ltd. Co.) to facilitate documentation and crack assessment.

The primary aim was to detect the presence or absence of apical cracks. High-resolution images of the apical root surfaces were recorded and inspected for structural defects.[15] The evaluation focused on the apical third of the root, specifically at a horizontal cross-section located 1 mm from the apex, using the same digital stereomicroscope (80×10 magnification).

To ensure objectivity, all assessments were conducted in a blinded fashion by two independent examiners who were unaware of the procedural details or the study's purpose. Each sample was evaluated twice to confirm intra-examiner reliability.

The following classification system was applied [12,16]:

Score 0 – No Crack: Specimens showed intact root dentin with no visible cracks or craze lines on either the internal canal wall or the external root surface.

Score 1 – Crack Present: A crack was identified as any visible line extending either from the canal lumen toward the dentin or from the external root surface inward.

2.7. Statistical Analysis

All data were collected from digital images results analysis, tabulated, and statistically analyzed. The mean and standard deviation values were calculated for each group. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed non-parametric (not normal) distribution. Chi-square test was used to compare between two groups in non-related samples. Friedman test was used to compare between more than two groups in related samples. Wilcoxon test was used to compare between two groups in related samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

3. Results

The mean apical crack scores across all groups significantly increased from baseline (before preparation) through each subsequent treatment step, indicating progressive dentinal damage during root canal procedures ($p<0.05$). Specifically, significant within-group differences were noted for both main groups and their respective subgroups from baseline to after retreatment ($p<0.05$). Additionally, substantial differences were observed when comparing all subgroups collectively ($p < 0.001$) (Table 1).

Group B, particularly subgroup 2 (Wave One preparation and

Table 1. The mean ± standard deviation (SD) and P values of apical crack score of all groups during different root canal steps.

Groups	Treatment Steps	Mean ± SD	Median	Within each group	Within each subgroup	Within all subgroups
Group A and subgroup 1	Before Preparation	0.00±0.00	0	0.015*	<0.001*	<0.001*
Group A and subgroup 1	After Preparation	0.30±0.48	0			
Group A and subgroup 1	After Obturation	0.40±0.52	0			
Group A and subgroup 1	After Retreatment	0.50±0.53	0.5			
Group B and subgroup 1	Before Preparation	0.00±0.00	0	0.004*		
Group B and subgroup 1	After Preparation	0.40±0.52	0			
Group B and subgroup 1	After Obturation	0.50±0.53	0.5			
Group B and subgroup 1	After Retreatment	0.60±0.52	1			
Group A and subgroup 2	Before Preparation	0.00±0.00	0	0.017*	<0.001*	
Group A and subgroup 2	After Preparation	0.30±0.48	0			
Group A and subgroup 2	After Obturation	0.30±0.48	0			
Group A and subgroup 2	After Retreatment	0.50±0.53	0.5			
Group B and subgroup 2	Before Preparation	0.00±0.00	0	0.001*		
Group B and subgroup 2	After Preparation	0.60±0.52	1			
Group B and subgroup 2	After Obturation	0.60±0.52	1			
Group B and subgroup 2	After Retreatment	0.70±0.48	1			

Friedman Analysis, Group A: Treatment with Revo S, Group B: Treatment with Wave One, Subgroup 1: Retreatment with R Endo, Subgroup 2: Retreatment with Wave one

Table 2. Comparison of apical crack scores between different groups.

Comparison	Comparison	Treatment Steps	P-value
Group A and Subgroup 1	Group B and Subgroup 1	Before Preparation	1.000
Group A and Subgroup 1	Group B and Subgroup 1	After Preparation	0.648
Group A and Subgroup 1	Group B and Subgroup 1	After Obturation	0.661
Group A and Subgroup 1	Group B and Subgroup 1	After Retreatment	0.661
Group A and Subgroup 2	Group B and Subgroup 2	Before Preparation	1.000
Group A and Subgroup 2	Group B and Subgroup 2	After Preparation	0.189
Group A and Subgroup 2	Group B and Subgroup 2	After Obturation	0.189
Group A and Subgroup 2	Group B and Subgroup 2	After Retreatment	0.374
Subgroup 1	Subgroup 2	Before Preparation	1.000
Subgroup 1	Subgroup 2	After Preparation	0.602
Subgroup 1	Subgroup 2	After Obturation	1.000
Subgroup 1	Subgroup 2	After Retreatment	0.752

Wilcoxon Rank test, Group A: Treatment with Revo S, Group B: Treatment with Wave One, Subgroup 1: Retreatment with R Endo, Subgroup 2: Retreatment with Wave one

crack scores, culminating at 0.70 ± 0.48 post-retreatment, whereas Group A exhibited comparatively lower scores at corresponding treatment stages (Table 1).

The comparison of apical crack scores between groups revealed no statistically significant differences at any treatment step. Specifically, when Group A (Revo S) and Group B (Wave One) were compared within Subgroup 1 (R-Endo retreatment) or Subgroup 2 (Wave One retreatment), no significant differences were detected before preparation, after preparation, obturation, or retreatment ($p>0.05$). Additionally, comparisons between Subgroup 1 and Subgroup 2, irrespective of preparation instruments, also showed no significant differences at any treatment phase ($p>0.05$) (Table 2).

After the preparation phase, cracks were observed in 30% of samples treated with Revo S (Group A) and 50% of samples treated with Wave One (Group B). However, this difference was not statistically significant ($p = 0.202$). Despite a higher frequency of crack formation in the Wave One group, the observed differences between the two treatment methods did not reach statistical significance (Table 3).

Representative images of apical cracks formed during root canal preparation and retreatment procedures using continuous rotation (Revo-S, R-Endo) and reciprocating motion (Wave One) are presented in Fig. 2

4. Dicussion

One of the fundamental objectives of chemo-mechanical root canal preparation is the thorough elimination of microorganisms, necrotic pulp tissue, and debris, while simultaneously shaping the canal to accommodate obturation materials.[17] However, overly aggressive instrumentation can compromise the integrity of root dentin, potentially inducing dentinal defects such as microcracks, fissures, or vertical root fractures—conditions that may contribute to long-term treatment failure.[18] These adverse events are often linked to factors such as the instrument's design features, including its cross-sectional shape, size, taper, and the physical properties of the alloy from which it is manufactured.[19]

This study utilized maxillary canines with single, straight roots containing one root canal to minimize anatomical variability. Teeth exhibiting deviations in the position of the major apical foramen relative to the canal axis were excluded to prevent potential confounding factors in crack formation and to enhance standardization. To further control variables and facilitate

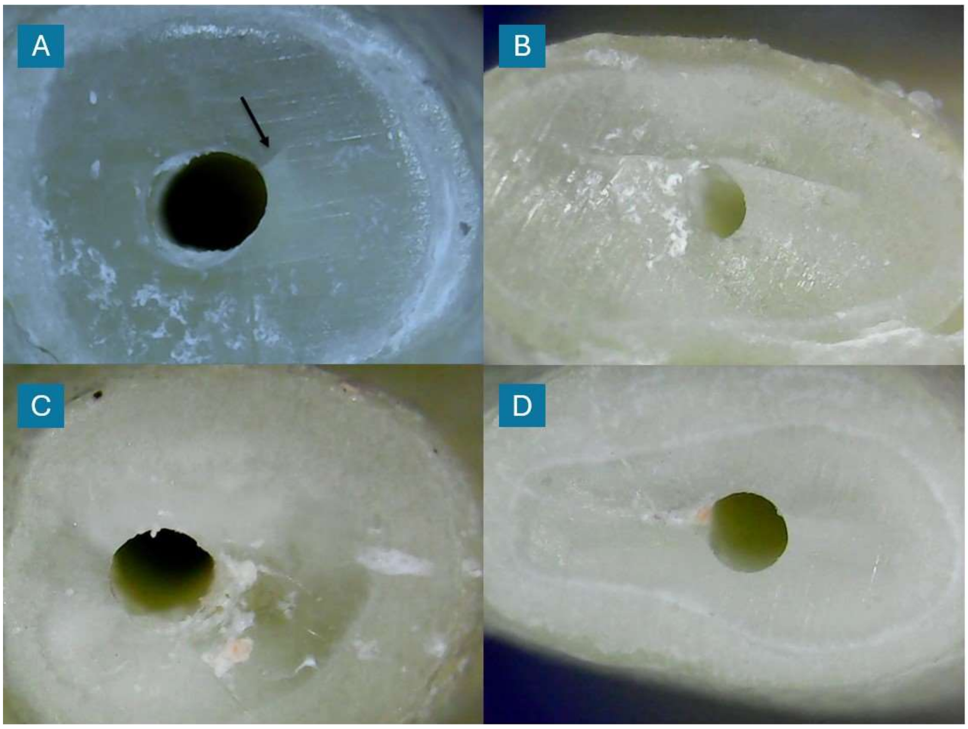

Fig. 2. (A) Apical crack after root canal preparation using continuous rotation motion (Revo-S). (B) Apical crack after root canal preparation using reciprocating motion (Wave One). (C) Apical crack after root canal retreatment using continuous rotation motion (R-Endo). (D) Apical crack after root canal retreatment using reciprocating motion (Wave One). Arrows indicate the presence of visible cracks.

Table 3. The frequencies of cracks in main 2 groups (After preparation).

Group	Crack status	n	%	p-value
Group A (treated by Revo S)	No cracks	14	70%	0.202
	Cracks	6	30%	
Group B (treated by Wave One)	No cracks	10	50%	
	Cracks	10	50%	

consistent evaluation, the apical 1 mm of each root was sectioned. This decision was based on the frequent occurrence of periapical pathology that can compromise the anatomical apex and apical constriction. Additionally, the presence of apical delta ramifications in the terminal 1 mm of the root can resemble cracks, potentially confounding microscopic analysis. Trimming the apex also created a flat surface, which improved the clarity of crack detection and allowed accurate monitoring of crack initiation and propagation under stereomicroscopic observation throughout the procedures.[20]

While it is acknowledged that sectioning of root apices may theoretically introduce structural damage or initiate crack formation, the findings of the present study do not support this concern. No cracks were identified in either Group A or Group B during the pre-treatment evaluation phase. This observation aligns with previous research, which similarly reported an absence of crack formation following root sectioning procedures.[20]

Apical cracks were examined using a digital stereomicroscope at 80× magnification. All images were assessed independently by two blinded evaluators. In instances where discrepancies arose between the observers, the samples were reanalyzed jointly until a consensus was reached.[16,21]

In this study, the null hypothesis was supported, as no statistically significant difference was found between Group A (rotational motion) and Group B (reciprocating motion) with respect to apical crack formation during root canal preparation. These findings are consistent with those reported by Yoldaş et al.[22], who also observed no significant differences between experimental groups. Their investigation noted the presence of apical cracks in 25% of specimens prepared with the Revo-S system, a proportion comparable to that observed in the current study. They proposed that the design of endodontic instruments plays a critical role in concentrating stress and strain at the apical third, thereby increasing the likelihood of dentinal defects and canal deviations. Such structural compromises can act as precursors to vertical root fractures, particularly following obturation and coronal restoration, which may further propagate pre-existing cracks.

In the present study, the lowest incidence of defects was recorded in Group A, instrumented with the Revo-S system. Although no prior studies specifically addressing the performance of this file system in crack formation were found in the literature, the manufacturer claims that the Revo-S file induces less stress on dentin. This is attributed to its asymmetrical cross-sectional design and extended coronal cutting portion, which collectively enhance flexibility and reduce dentinal strain during instrumentation.

Moreover, the WaveOne system, being a single-file technique, necessitates repeated entry into the root canal using the same instrument to achieve the full working length. This repeated engagement may contribute to increased mechanical stress on the canal walls, potentially resulting in a higher incidence of crack formation compared to the Revo-S system.

The findings of the present study are consistent with those reported by Bruklien et al.[23], who also observed no statistically significant difference between the experimental groups. In their investigation, apical cracks were identified in 55% of the samples instrumented with the WaveOne system—a percentage that closely aligns with the outcomes of our study. The variation in the incidence of dentinal defects between the Revo-S and WaveOne systems may be attributed to differences in their mechanical action and instrument geometry. Specifically, the WaveOne file features a triangular or modified triangular cross-sectional design, which may limit its cutting efficiency and reduce chip space. These characteristics can lead to increased stress accumulation at the apical third, thereby elevating the risk of crack formation.

Conversely, some studies have reported conflicting results regarding the impact of continuous rotational versus reciprocating motion on dentinal crack formation. Liu et al.[24] demonstrated that reciprocating systems, such as Reciproc files, induced fewer dentinal cracks compared to continuous rotation systems like ProTaper. In their study, continuous rotation instruments—OneShape and ProTaper—resulted in apical cracks in 35% and 50% of samples, respectively, whereas the Reciproc system, operating in a reciprocating motion akin to the balanced force technique, produced cracks in only 5% of specimens. The authors suggested that reciprocating motion may reduce torsional and flexural stresses, limit canal transportation, and offer enhanced resistance to cyclic fatigue. Although variations in cross-sectional design were noted, the reduced incidence of dentinal damage observed with reciprocating systems could be attributed, at least in part, to the kinematics of the instrumentation technique.[25]

In contrast to the findings of the present study, Kansal et al.[20] reported a lower incidence of dentinal defects when using instruments with reciprocating motion compared to those utilizing continuous rotation. Their results indicated that both the WaveOne file and the single F2 ProTaper file, when operated in reciprocating motion, produced significantly fewer cracks than the conventional ProTaper system in continuous rotation. The authors attributed this to the fact that continuous rotation tends to generate concentrated stress along the canal walls, increasing the likelihood of crack initiation. In contrast, reciprocating systems maintain better centering within the canal and, through alternating clockwise and counterclockwise movements, allow the file to disengage periodically when it binds to the canal walls during instrumentation. This motion not only facilitates smoother shaping but also reduces both flexural and torsional stresses by minimizing the time the cutting blades remain in contact with dentin, thereby lowering the risk of crack formation.

Several studies concluded that continuous rotational systems were associated with a higher incidence of dentinal crack formation compared to reciprocating systems.[26-28] Their findings suggested that the continuous application of rotational force and consistent torque by NiTi rotary instruments can exert substantial mechanical stress on the canal walls, thereby increasing the likelihood of crack development. In contrast, the reciprocating motion of WaveOne was reported to facilitate intermittent stress release, allowing the instrument to disengage before advancing further into the canal, which may help reduce the incidence of dentinal damage.

In further contrast to the findings of the present study, De-Deus et al.[29] found no causal relationship between dentinal crack formation and the biomechanical preparation of root canals using Reciproc, WaveOne, or BioRace systems. Their micro-computed tomography (micro-CT) based investigation revealed that all dentinal defects observed in the postoperative scans were already present in the corresponding preoperative images, indicating that no new cracks were induced as a result of the instrumentation procedures. The study employed high-resolution micro-computed tomography to assess dentinal integrity before and after canal enlargement using both rotary and reciprocating systems, providing a nondestructive and reliable method for defect detection.

In the present study, no statistically significant difference in dentinal crack formation was observed during the obturation phase. However, Shemesh et al.[30] reported a higher incidence of dentinal defects following root canal filling using the lateral compaction technique compared to the passive compaction approach. This discrepancy may be explained by methodological differences, particularly in the application of the spreader. In the current study, careful and controlled use of the spreader likely minimized the wedging effect—a known mechanical stressor implicated in crack initiation during lateral compaction—thereby reducing the potential for crack formation during obturation.

The lack of a significant difference between the R-Endo and WaveOne systems during retreatment in the present study aligns with findings by Citak et al.[31], who also reported no statistically significant differences among various NiTi systems. They concluded that crack formation was unrelated to file design or motion type but rather linked to mechanical stress during filling material removal. Other studies[30,32] similarly attributed crack occurrence during retreatment to the additional stress imposed by repeated instrumentation.

This study presents several limitations that warrant consideration. Firstly, as an in vitro investigation, it cannot fully replicate the complexity of clinical conditions, where factors such as masticatory forces, the biomechanical function of the periodontal ligament, and biological responses may significantly influence the development and progression of dentinal cracks. Although efforts were made to simulate intraoral conditions by maintaining humidity, the absence of physiological dynamics limits the extrapolation of the results to clinical practice.

Secondly, the sample size was relatively limited (n = 40), and only single-rooted teeth were included. This restricts the generalizability of the findings to multi-rooted teeth or those with more complex anatomical variations. Another important limitation involves the methodology used for crack detection. The stereomicroscopic examination of sectioned samples, while widely employed, may introduce or exacerbate dentinal defects, thereby confounding the accuracy of the observations.

The use of more advanced, non-invasive imaging techniques—such as micro-CT, optical coherence tomography, or infrared tomography—could have enabled a more precise and artifact-free evaluation of dentinal integrity. Additionally, the scope of the current study was limited to immediate crack formation following canal preparation, obturation, and retreatment. The potential for crack propagation over time, under the influence of functional occlusal loads or restorative procedures, remains unaddressed. Future investigations should consider longitudinal in vivo studies and clinical trials to evaluate the long-term effects of endodontic procedures on root structural integrity under realistic clinical conditions.

5. Conclusion

Within the limitations of this study, both continuous rotation and reciprocating NiTi systems were found to induce apical cracks during root canal preparation and retreatment. However, no statistically significant difference was observed between the two kinematic motions in terms of crack formation. These findings suggest that both techniques can be used without a notable difference in dentinal integrity.

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Conflict of Interest

The authors declare that no conflict of interest is available

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