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Impact of glide path preparation and instrument motion on dentinal crack formation after root canal preparation

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Abstract

Objective: This study investigated the effect of glide path preparation and different instruments in creating dentinal cracks during root canal instrumentation.

Methods: Eighty maxillary molars were divided into four groups (n=20). The mesiobuccal root canals were prepared using two rotary systems (Group 1: Hyflex EDM and Group 2: ProTaper Gold) and two reciprocating systems (Group 3: WaveOne Gold and Group 4: Reciproc Blue R25). In each group, ten specimens were prepared using the designated glide path files. Methylene blue dye was injected into the root canals to highlight dentinal cracks. The samples were then sectioned and examined under a microscope to count the number of dentinal cracks at the apical, middle, and coronal thirds. The data were analyzed using the Kruskal-Wallis and Mann-Whitney U tests ($P<0.05$).

Results: When glide path files were not used, the number of cracks was comparable across the groups in coronal, middle and apical sections ($P>0.05$). Among the samples prepared with glide path files, those instrumented with WaveOne Gold showed a significantly higher number of dentinal cracks in the coronal section compared to ProTaper Gold ($P<0.05$), and in the middle section compared to both HyFlex EDM and ProTaper Gold ($P<0.05$). In the apical section, no significant difference in the number of cracks was observed among the groups ($P=0.627$).

Conclusions: Glide path preparation with rotary systems (ProTaper Gold and HyFlex EDM) resulted in fewer dentinal cracks in the mesiobuccal root canals of maxillary molars compared to a reciprocating system (WaveOne Gold).

Keywords: Dental pulp cavity, Path file, Reciprocal systems, Root canal preparation, Root canal therapy, Tooth crack

Introduction

Dentinal cracks can weaken the tooth structure and jeopardize its structural integrity, making it more vulnerable to vertical root fractures (1). Cracks can also create pathways for bacteria, leading to reinfection and subsequent failure of the root canal treatment (2). Dentinal crack formation during root canal instrumentation is influenced by various factors, including the type and design of instruments, file kinematics, and the irrigation and preparation techniques used (3, 4).

Currently, endodontists use two types of systems for root canal preparation: rotary and reciprocating file systems. Rotary files, typically constructed from the nickel-titanium alloy, are made through precise machining and heat treatment processes, which enhance their flexibility and strength. The HyFlex EDM (HEDM; Coltene/Whaledent, Altstätten, Switzerland) is a single-file rotary system produced by electro-discharge machining technology. It has an 8% taper at the apical portion that shifts to 4% towards the coronal aspect, and it functions with continuous rotary motion (5). ProTaper Gold (PTG, Dentsply Maillefer, Ballaigues, Switzerland) is a multi-file rotary system that features a convex triangular cross-section. This system is particularly effective in navigating curved and calcified canals (5).

Reciprocating files use a back-and-forth motion that reduces the risk of file separation and improves control during canal preparation (6). Their design focuses on minimizing lateral pressure against the canal walls, theoretically decreasing the likelihood of dentinal cracks. WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) is a single-file reciprocating system that employs a heat treatment process to improve flexibility and reduce stress during canal preparation. It has a 25/.07 taper and a modified triangular cross-section (7). The Reciproc Blue R25 (VDW, Munich, Germany) is another single-file reciprocating system that

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incorporates a proprietary heat treatment process to improve its flexibility and fracture resistance. It features a 25/.08 taper and a special S-shaped cross-section that enhances cutting efficiency (8).

A glide path is defined as a smooth radicular tunnel that extends from the root canal orifice to its physiological terminus. It can be prepared using stainless steel hand files or engine-driven rotary files (5). Glide path files, being smaller in diameter, facilitate the creation of a smooth pathway for larger endodontic instruments.

The HyFlex EDM Glidepath is a single-file option with a #10 tip size and a 5% taper. This file is designed to preserve the apical canal curvature and is used along Hyflex EDM (5). The ProGlider is used along with ProTaper Gold and manufactured from M-wire NiTi alloy. It has a square cross-section and a progressive taper ranging from 2% to 8%. This file operates with continuous rotational motion (5).

WaveOne Gold Glider is used along with WaveOne Gold and manufactured with a unique heat treatment process that optimizes its mechanical properties and enhances its resistance to cyclic fatigue (9). The R-Pilot (size: 12.5, taper: 0.04) effectively prepares glide paths in curved canals and is used along with the Reciproc Blue R25 file system (9).

While some studies propose that glide path files reduce dentinal crack formation by enabling controlled and less traumatic canal preparation, others reported that their impact may not be significant (10). The present study aimed to evaluate the incidence of dentinal crack formation following canal preparation using reciprocating and rotary file systems, with and without the utilization of glide path files.

Materials and method

Study design

The present in vitro study was approved by the ethics committee of Mashhad University of Medical Sciences (code: IR.MUMS.DENTISTRY.REC.1399.172).

Eighty maxillary first molar teeth were selected for the study based on the following criteria for the mesiobuccal root canals: having an apical diameter corresponding to file #10, exhibiting an average curvature radius of the root between >4 mm and ≤8 mm, a curvature angle of the root canal between 10° and 20° according to Schneider (11), and a total root length between 19 and 22 mm. Periapical radiographs were taken to assess calcification, root resorption, root fractures, and canal curvature. Samples with root resorption, fractures, or calcified canals were excluded. The teeth were immersed in 2.5% sodium hypochlorite for 48 hours and then stored in a saline solution until use.

Sample preparation

Teeth were not decoronated to avoid stress and crack formation in the coronal section. Previous restorations and caries were removed and a standard access cavity was prepared using a long flat-end fissure bur (No. 856; Intensive SA, Switzerland) and a high-speed handpiece under air and water spray. The working length was determined with a #10 K file (Mani, Tochigi, Japan).

Grouping

Eighty maxillary molars were randomly assigned into four groups (n=20). The mesiobuccal canal of the samples was prepared using rotary systems in groups 1 and 2, and reciprocating systems in groups 3 and 4. The study groups were as follows:

Group 1: Hyflex EDM (HEDM; Coltene/Whaledent, Altstätten, Switzerland).

Group 2: ProTaper Gold (PTG, Dentsply Maillefer, Ballaigues, Switzerland).

Group 3: WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland)

Group 4: Reciproc Blue R25 (VDW, Munich, Germany).

In each group, half of the samples (n=10) were prepared using the following glide-path files:

- HyFlex EDM Glidepath for Hyflex EDM system
- ProGlider for ProTaper Gold system
- WaveOne Gold Glider for WaveOne Gold system
- R-Pilot for Reciproc Blue R25 file system

Each file was used to prepare three root canals. For each canal, the file was inserted into the canal and three gentle in-and-out strokes were applied. The file was then withdrawn and wiped clean with gauze to remove debris. This cycle of three strokes followed by cleaning was repeated until the file reached the predetermined working length. In cases where instruments fractured during use, the samples were replaced. During the instrumentation, the canals were thoroughly irrigated with 2 mL of 5% NaOCl solution and 1 mL of 17% ethylenediaminetetraacetic acid (EDTA). Finally, the root canals were rinsed with 2 mL of normal saline.

Sectioning and microscopic examination

To visualize instrumentation-induced cracks, a dye penetration technique was used with 0.5% methylene blue. The dye was injected into the canal using an insulin syringe fitted with a 31-gauge needle and was activated with a #10 K-file to enhance penetration, particularly in

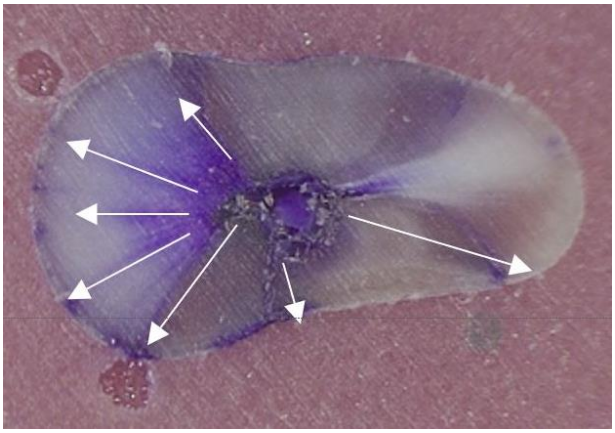

Figure 1. Examining the crack formation (white arrows) in the coronal third of the root dentin

the apical region (12). The samples were kept in a humid environment at 37°C to allow sufficient dye penetration into the cracks.

Afterwards, the samples were embedded in acrylic blocks and sectioned at 3 mm, 6 mm, and 9 mm from the apex—corresponding to the apical, middle, and coronal sections—using a diamond disc on a low-speed handpiece under water cooling. The cut surfaces were then smoothed with soft sandpapers.

Each section was examined under a dental microscope at 16× magnification (Zumax, China) to identify and count complete and incomplete cracks originating from the inner canal wall and extending toward the outer surface (Figure 1).

Data analysis

Data analysis was performed using SPSS version 16, employing Kruskal-Wallis and Mann-Whitney U tests. Values lower than 0.05 were considered statistically significant.

Results

Table 1 presents the average number of cracks observed following instrumentation by various file systems with and without glide-path files. The Kruskal-Wallis test revealed no significant difference in crack numbers among the groups when glide path files were not used (P>0.05; Table 1). However, when glide path files were used, the number of cracks in the coronal and middle sections differed significantly among the systems (P<0.05; Table 1).

In the coronal section, samples prepared with WaveOne Gold (5.0 ± 0.8) exhibited a significantly higher number of dentinal cracks compared to samples prepared with ProTaper Gold (4.0 ± 0.5; P<0.05). In the middle section, samples prepared with WaveOne Gold (5.1 ± 0.9) showed a significantly higher number of dentinal cracks compared to those prepared with Hyflex EDM (3.9 ± 0.9) and ProTaper Gold (3.8 ± 0.8; P<0.05). In the apical section, no significant difference in the number of cracks was observed among the groups when glide path files were used (P=0.627).

The Mann-Whitney U test indicated that the use of glide path files did not significantly affect the number of dentinal cracks in any file system or root canal section (P>0.05; Table 1).

Discussion

The formation of dentinal cracks is an inevitable consequence of root canal instrumentation. This study compared the number of dentinal cracks produced after instrumentation using rotary and reciprocating file systems, with and without using glide path files. Various methods have been employed to evaluate dentinal cracks, including micro-CT, stereomicroscops, digital cameras, and dental microscopes (13, 14). In this study,

Table 1. Mean ± standard deviation (SD) of the number of dentinal cracks in the coronal, middle, and apical sections of samples prepared by different file systems, with and without employing glide path files

File system	Groups	Coronal section			Middle section			Apical section		
		With glide path Mean ± SD	Without glide path Mean ± SD	P value	With glide path Mean ± SD	Without glide path Mean ± SD	P value	With glide path Mean ± SD	Without glide path Mean ± SD	P value
Rotary systems	Group 1: Hyflex EDM	4.1±0.7 [ab]	4.4±0.8	0.85	3.9±0.9 [ac]	4.4±0.7	0.18	3.3±0.7	3.9±0.7	0.07
	Group 2: ProTaper Gold	4.0±0.5 [a]	4.5±0.7	0.08	3.8±0.8 [a]	4.4±1.2	0.20	3.2±0.9	3.8±0.6	0.08
Reciprocating systems	Group 3: WaveOne Gold	5.0±0.8 [b]	5.3±0.8	0.14	5.1±0.9 [b]	5.2±0.9	0.79	4.0±0.7	4.2±0.8	0.56
	Group 4: Reciproc Blue R25)	4.7±0.5 [ab]	5.0±0.7	0.28	5.0±0.5 [bc]	5.2±0.8	0.51	3.7±0.8	4.0±0.8	0.41
	P value	0.007*	0.052		0.001*	0.096		0.086	0.627	

*Indicates a significant difference between groups at P<0.05 according to the Kruskal-Wallis test.
Different lowercase letters indicate statistically significant differences between groups.

a dye penetration technique and a dental microscope were used, consistent with some previous studies (10, 15-17). The methylene blue dye was applied after preparing the root canals to identify defects caused by instrumentation and sectioning of the sample (12).

In the present study, using the path files decreased the number of cracks in all file systems, but the effect was small and not significant in any group. This finding aligns with some previous studies (18-20). Aktemur Türker et al (18) found that glide path preparation before utilizing the ProTaper Next system did not significantly affect dentinal crack formation in the distal canals of mandibular molars with curvatures ranging from 25° to 35°. Similarly, Rodrigues et al (19) concluded that no correlation existed between the use of glide path files and the occurrence of dentinal defects during rotary instrumentation with Trunatomy files. Topçuoğlu et al (20) examined mandibular molars with curvatures between 25° and 35° and investigated the impact of glide path files on the incidence of apical cracks when using Reciproc, WaveOne, and ProTaper Next. Their findings indicated that glide path preparation did not alter the occurrence of apical cracks during canal preparation in curved canals.

In contrast to the findings of the present study, Kırıcı et al. (21) reported that the use of glide path files significantly reduced the number of dentinal cracks. However, their study focused on teeth with curvatures between 20° and 40°, whereas the present research evaluated teeth with curvatures between 10° and 20°. It has been suggested that the creation of a glide path is particularly important for reducing friction and minimizing crack formation in curved root canals (6). The present outcomes also imply that glide path preparation appears to have a minimal impact on crack formation in root canals with less curvature.

In the present study, no significant between-group differences were observed in crack numbers in any root sections when glide path files were not used. When glide-path files were employed, no significant difference was observed in the number of cracks among the groups in the apical section, but significant differences were noted in the coronal and middle root regions. In the coronal section, ProTaper Gold (a multi-file rotary system) demonstrated a significantly lower number of cracks compared to WaveOne Gold (a single-file reciprocating system). In the middle section, samples prepared with Hyflex EDM (a single-file rotary system) and ProTaper Gold exhibited a significantly lower number of dentinal cracks than those prepared with WaveOne Gold. Therefore, the use of glide path files may enhance the performance of rotary systems by enabling smoother canal preparation and reducing stress on dentin, as suggested previously (22).

The cross-section of the WaveOne Gold file is like a parallelogram with two leading edges angled at 85° (20). The increased number of dentinal cracks associated with the WaveOne Gold system may be due to its cross-sectional design (12). The increased number of cracks observed in some single-file systems may also be related to a larger amount of root dentin being removed in a shorter time (10). Conversely, multi-file systems tend to exert less stress on the canal walls due to a more gradual dentin removal process (10).

The outcomes of this study are consistent with the findings of Das et al. (14) who noted that rotary file systems, specifically Protaper NEXT and Hyflex Controlled Memory, produced significantly fewer dentinal cracks compared to reciprocating files such as WaveOne Gold. They assumed that the reciprocating motion may enhance debris transport towards the apical region and generate torsional forces, which can lead to the formation of dentinal defects (14). In contrast to the present findings, Katanek et al. (23) reported no dentinal defects, as detected by micro-CT, following root canal preparation using three different kinematic systems (vibration, reciprocation, and continuous rotation), each combined with its respective glide path file. Zhou et al. (24), noted that single-file and multi-file systems do not differ significantly in crack formation in larger canals. Rashid et al. (25) found that the multi-file ProTaper Universal system produced significantly more dentinal cracks than single-file systems utilizing rotary motion (OneShape) or reciprocal motion (Reciproc and WaveOne Gold). The difference in the findings of the present study and those of Rashid et al (25) can be attributed to the use of the ProTaper Gold system in the present study, which features a more refined cross-section compared to ProTaper Universal. This design minimizes dentin removal and allows for more conservative canal instrumentation (26).

No significant differences in the number of cracks were observed in the apical section among different groups utilizing glide-path files. This may be related to the higher pressure exerted in the coronal and middle thirds of the canal compared to the apical section (12, 27). Similar to the current study, Topçuoğlu et al. (20) reported that establishing a glide path before canal preparation with Reciproc, WaveOne, and ProTaper Next did not affect the occurrence of apical cracks during preparation.

In this study, using WaveOne Gold and Reciproc Blue R25 led to a comparable number of dentinal cracks in all sections. Gergi et al (28) reported that instrumentation with Reciproc R25 produced significantly more complete cracks than WaveOne Gold. This difference in findings may be due to the use of Reciproc Blue R25 in the present study, which has a finer structure, lower hardness, and greater flexibility and fracture resistance compared to Reciproc R25 (29).

The present study had some limitations. It is possible that the cracks formed were very small and not visible using the magnification. In addition, due to the laboratory nature of the study, the results cannot be simply generalized to clinical conditions. Furthermore, the absence of a periodontal ligament (PDL) can affect the forces on the teeth. It is suggested that elastomeric materials be used in future studies to simulate periodontal tissue during canal preparation.

Conclusions

Within the limitations of the current study, the following conclusions can be drawn:

- When glide-path files were not used, crack formation was not significantly different between the file systems.
- When glide-path files were used, the number of cracks in the coronal and middle sections was significantly lower in root canals prepared with rotary file systems (ProTaper Gold and HyFlex EDM) compared to those prepared with a reciprocating system (WaveOne Gold).
- The use of glide path files decreased the number of cracks in all file systems, but the effect was small and not significant in any group.

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Not applicable.

Conflict of interest

The authors declare that they have no conflict of interest.

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Ethical consideration

The present in vitro study was approved by the ethics committee of Mashhad University of Medical Sciences (code: IR.MUMS.DENTISTRY.REC.1399.172).

Author contributions

M.F. Contributed to the design and supervision of the research; M.G. assisted with the conceptualization of the study, data collection, and data analysis; and F.B. contributed to the research implementation and writing of the manuscript. All authors read and approved the final manuscript.

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