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Dentinal crack formation during root canal preparations by three different reciprocating single file systems: An *in vitro* study

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Abstract
Introduction: The purpose of this study was to compare the formation of microcracks after canal preparation performed with three different reciprocating single-file systems: Reciproc (VDW, Munich, Germany), Wave One (Dentsply Maillefer, Ballaigues, Switzerland), and Wave One Gold (Dentsply Maillefer).
Methods: Sixty extracted mandibular central incisors (40–60 y) were selected and divided into 3 experimental groups (n = 15 teeth) and a control group (unprepared teeth, n=15); Control, Reciproc (group 1) Wave One (group 2), and Wave One Gold (group 3). Roots were then sectioned at 3, 6, and 9 mm from the apex, and the surface was observed under a stereomicroscope. Data were analyzed using logistic regression (P<.05).
Results: No cracks were observed in the control group. All the systems tested caused cracks, mainly in the apical section (3 mm). Wave One Gold (53.3%) showed fewer microcracks than other experimental groups (P<.01). There was no significant difference among Reciproc and Wave One experimental groups (P >.05).
Conclusions: All the instruments tested created dentinal cracks. Within the limitations of this study, the flexibility of nickel-titanium instruments because of heat treatment seems to have a significant influence on dentinal crack formation. Wave One Gold caused less microcracks than the other instruments tested.

Keywords: Micro cracks, single-file system, wave one gold

Introduction

Vertical root fracture (VRF) in endodontically treated teeth is one of the most frustrating complications of root canal therapy [1]. Several factors including dentin thickness, obturation strains, post placements and dentinal microcracks have been investigated as major causes of VRF [2-5]. Instrumentation with rotary nickel-titanium (NiTi) instruments could potentially cause dentinal cracks [1-9], which may have the potential to develop into fractures [9]. Cracks after canal instrumentation were detected either in horizontal sections cut at different levels along roots [1-5] or at the apical root surface [6-9]. It seems useful to examine the root surface and dentin at multiple levels to determine the development of cracks

Several factors of nickel-titanium (NiTi) files such as different heat treatments, designs, cross-sectional shape, and kinematics may influence the generation of cracks [8, 10]. Recently, a new generation of NiTi files has been introduced with a variable cross-sectional design and a different working motion (reciprocation), which completes canal preparation with only one instrument [11].

Reciproc (Rec) (VDW, Munich, Germany), Wave One (WO) (Dentsply Maillefer, Ballaigues, Switzerland), and the recently marketed Wave One Gold (WOG) (Dentsply Maillefer) are the main examples of commercially available single-file reciprocating systems [12, 13].

Reciproc & Wave One, are made of M-Wire NiTi alloy subjected to an innovative thermal treatment process to increase flexibility of the instruments. The Reciproc files have an S-shaped cross-section, 2 cutting blades, and a continuous taper (8%) over the first 3 mm of their working part followed by a decreasing taper until the shaft. Wave One has Apical cross section which is modified convex triangular & coronal cross section is convex triangular and has Fixed taper (8% for primary) from d1-d3 & increasing taper from d4-d16 [13]. Reciproc &

Wave One files are used in a reciprocating motion, which reduces the risk of cyclic fatigue caused by tension and compression [14].

WOG uses the same reciprocating kinematics (‘‘Wave One ALL’’) as WO. According to the manufacturer, the instrument is repeatedly heat treated and cooled, giving the file a distinctive gold color and providing increased flexibility and cyclic fatigue resistance. WOG has off-centered parallelogram design cross section and variable taper (7% taper at D0-D3) [15].

To date, there are few studies in the literature regarding the occurrence of microcracks when using these single-file systems. Thus, the purpose of this study was to investigate the formation of Microcracks after canal preparation performed with these different single-file systems.

Materials and Methods

Mandibular central incisors with mature apices from 40- to 60-year-old patients extracted for periodontal reasons were collected from Department of Oral & Maxillofacial Surgery Govt Dental College Srinagar. Teeth were stored in distilled water. Proximal radiographs of the teeth were taken, and only single-rooted teeth with a single straight canal ($<5^0$) were included in the study.

The coronal portions of all teeth were removed using diamond disc at low-speed under water cooling, leaving roots approximately 13 mm in length. All the roots were inspected with a stereomicroscope with 45x magnification to detect any pre-existing external defects or cracks. Teeth with such defects were excluded from the study and replaced by similar teeth. Determination of sample size with an α-error of 5% and power of 80% it was estimated that 13 teeth would be needed in each group. However, to enable detection of potential variations and avoid potential errors 15 teeth were included in each group In all teeth, the canal width near the apex was compatible with a size 10 K-file (Dentsply Maillefer). The buccolingual and mesiodistal widths of the canals were measured at 9 mm from the apex on radiographs. The homogeneity of the 4 groups with respect to the canal width at the 9-mm level was assessed by using analysis of variance ($P = 1.000$). fifteen teeth were left unprepared as the control group.

The working length was established by subtracting 1 mm from the length of a size 10 K-file inserted into the canal until the tip of the file became visible at the apical foramen. The periodontal ligament was simulated using addition silicone impression and fixing the teeth in blood sample collecting tubes with it [11]. A working jig (fig 1) was constructed to hold the tubes containing teeth to standardize the instrumentation.

Root Canal Preparation

Root canal shaping procedures were performed with 3 different single-file systems (Rec, WO, and WOG) according to the manufacturers’ instructions of each system. A new file was used to shape each canal. All instruments were activated using programmed reciprocating motion generated by the X-Smart plus motor (Dentsply Maillefer). The R25 Reciproc file (tip size = 25, apical taper = 0.08) was used in the ‘‘RECIPROC ALL’’ mode. The Wave One Primary file (tip size 25, 0.08 taper from d1-d3) & Wave One Gold Primary file (size 25,.07 taper d0-d3) were used in ‘‘WAVEONE All’’ mode. The files were used in a slow pecking motion and light apical pressure (amplitude less than 3 mm, 3 pecks). If some resistance was felt that would have required more apical pressure, the instrument was removed, and the flutes were cleaned. This was repeated for each file until the working length was reached. After each instrument insertion, the teeth were irrigated with 2 mL 3% sodium hypochlorite using a syringe and a 30-G Endo Irrigation Needle single side vent placed 1 mm from the working length. After completion of the procedure, canals were rinsed with 2 mL distilled water. To avoid any artefact by dehydration, all roots were kept moist in distilled water throughout all the experimental procedures.

The mean preparation time (in seconds) was recorded for each file using a digital stopwatch. The same expert operator performed all root canal preparations, and 2 blinded operators checked the presence of dentinal defects or no defects.

Microscopic Examination

All the roots were horizontally sectioned at 3, 6, and 9 mm from the apex with diamond disc at low-speed under water cooling. The slices were then analyzed using a stereomicroscope (Kyowa Getner, Japan). The samples were photographed with a reflex camera (Nikon D90; Nikon Tokyo, Japan) attached to the stereomicroscope at a magnification of 24x and 80x to determine the presence of Microcracks

Definition of Defects

A crack was defined as only defects originating from the inner root canal space. All other defects that did not originate from the canal wall as craze lines were not considered cracks (Fig. 2). Roots were classified as cracked if at least 1 of the 3 sections obtained from each root showed even 1 crack [16].

Statistical Analysis

Stastical software (SPSS ver.20.0) and GRAPH PAD (prism 5.00) was used to carry Stastical analysis of data. Logistic regression was used to ascertain the effects of canal preparation by 3 different file systems on the likelihood of crack formation. Pair-wise comparison (Tukey least significant difference) was conducted if a significant difference was found. Moreover, the number and percentage of defected roots in each group were evaluated. The level of significance was set at.05.

Results

The distribution of Microcracks per group and section level as well as the total cracked roots and their relative percentage per group are shown in Table 1. No cracks were observed in the control group. All the single files tested caused dentinal cracks. The logistic regression model was statistically significant (P<.001). Pair-wise comparison revealed a significant difference between the control group and all the experimental groups (P<.05). Logistic regression analysis revealed no significantly different roots with Microcracks between Reciproc and WO (P>.05). However, WOG showed statistically fewer roots with Microcracks compared with the other experimental groups (P<.05)

The apical section (3 mm) showed the major number of microcracks for all of the tested instruments. Regarding the different sections, Reciproc and WO produced a similar amount of microcracks (P >.05), which was significantly higher than the other experimental group (WOG) at 3, 6, and 9 mm (P<.01).

No significant difference was observed between the experimental groups (Reciproc & WO) at each section level (P >.05). There was no statistically significant difference in preparation time for all of the tested instruments (P>.05).

Discussion

Root canal preparation with rotary nickel-titanium instruments can damage the dentine and create defects on root canal walls [17]. This was confirmed by the current experiment because of the significant increase in the appearance of defects after preparation alone, when compared to the control group which did not undergo any treatment. Studies on dentinal crack formation present some limitations. The patient age may play an important role in the presence of dentinal cracks [7] consequently, we selected teeth from a limited age group (40–60 y). In addition, silicone impression material was used to simulate periodontal ligament, as reported in previous studies [5]. Periodontal ligament simulation is important because it acts as a major stress absorber and should influence the outcome of such studies [5]. In this study, the roots were distributed among the groups equally according to their root canal diameter at the 9-mm level [5]. Standardization was achieved in the groups by including only teeth with a canal width near the apex compatible with a size 10 K-file and leaving all the roots approximately 13 mm in length [18]. Preparation time could influence the results obtained. However, in this study, no difference in preparation time was observed for all of the tested instruments, probably because of the easy canal configurations (mandibular central incisors) of the tested teeth as well as the use of only single-file techniques (no sequences of files) to shape root canals. In this study, teeth were sectioned at different levels, looking for microcracks using a stereomicroscope. The sectioning method has a significant disadvantage related to its destructive nature and possible microcracks induced by the sectioning [19]. However, in our study, we speculated that it did not happen because no microcrack defects were found in the control group.

All 3 single-file systems used in this study created microcracks. This finding is in agreement with previous reports [20].

The tip design of rotary instruments, cross-sectional geometry, constant or variable pitch and taper, and flute form could be related to crack formation [10]. Although all instruments used in this study have different geometric features, this parameter seems to not affect the incidence of microcracks significantly as there was no significant difference in microcrack formation between Reciproc and wave One groups which clearly have different geometrical features. For this reason, the incidence of microcracks could be influenced by other features such as NiTi alloy and kinematic.

Previous studies reported higher flexibility of the rmomechanically treated files than those made from conventional NiTi wire or M-Wire [21, 22]. In Wave One Gold, The metallurgy of the files was changed from M-wire to a ***gold alloy***, which provides greater flexibility than NiTi and M-wire files [23]. The high flexibility of WOG may have contributed to the small number of cracks observed in this study. In addition, this result is probably caused by the synergistic effect of less taper of WOG compared with Reciproc & Wave One [23].

Regarding kinematics, some studies suggested that the motion of a shaping technique could influence microcracks [5, 18]. However, in this study WOG produced less microcracks than WO even if the same reciprocating movement was used to activate both of these instruments. Therefore, these results suggest that shaping motion has no or at least a limited and unpredictable role on microcrack formation. Moreover, it is reasonable that the synergistic effect of kinematic and other factors such as NiTi alloy and geometric features influence microcracks.

In this study major number of microcracks were observed in the apical section (3 mm) for all tested file systems, which is in agreement with previous studies [18]. The variable taper of Reciproc, WO, and WOG may explain the reduced number of microcracks in the middle and coronal teeth sections

Table 1: Number of Microcracks at Different Levels and the Number and Percentage of Roots with Microcracks per Group

Group	Number of Micro cracks			Roots with Microcracks Per group (%)
	3mm	6mm	9mm	
Control	0^a	0^a	0^a	0^a
Reciproc	13^b	6^b	6^b	$12\ (80)^b$
Wave One	15^b	7^b	8^b	$15\ (100)^b$
Wave One Gold	8^c	2^a	3^a	$8(53.3)^c$
P value	.01	.01	.01	.001

Similar lowercase superscript letters in the same column indicate no statistically significant differences (*P* >.05).

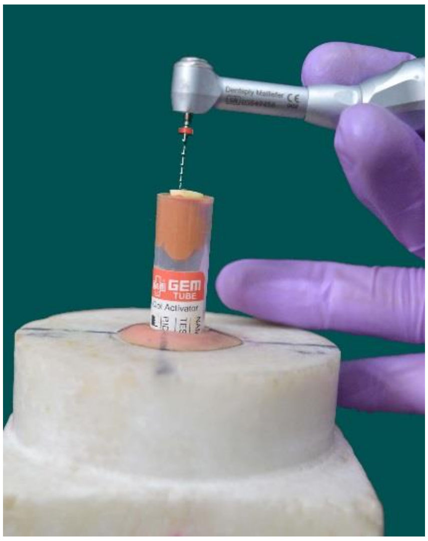

Fig 1: Simulation of periodontal ligament by silicone impression (blue arrow) material and customized jig for standardization of instrumentation (white arrow)

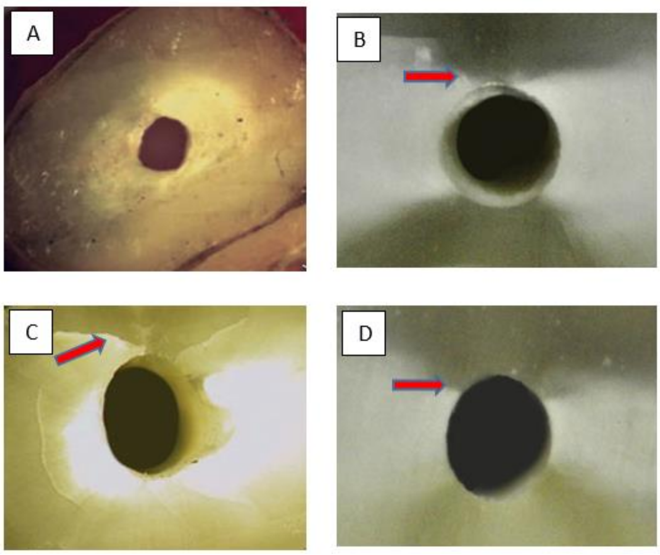

Fig 2: Microscopic cross sections from each experimental group at the 6-mm level (A–D) at 80Xmagnifications. Red arrows indicate dentinal defects. (A) Control, (B) Reciproc (C) WO Primary, (D) WOG.

Conclusion

Within the limitations of this study, it could be concluded that multiple factors cause dentinal cracks, but the flexibility of NiTi instruments because of heat treatment seems to influence the incidence of microcracks more than other factors. In particular, WOG caused less microcracks than other single file systems

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