Original Article ISSN (O):2395-2822; ISSN (P):2395-2814

In Vitro Comparative Evaluation of Dentinal Microcrack Formation during Root Canal Preparation Using Reciprocating and Continuous Motion Single File Systems

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Received: October 2020
Accepted: October 2020

ABSTRACT

Background: The purpose of this study was to compare and evaluate the incidence of dentinal microcrack formation after root canal preparation performed with single file systems in reciprocating motion Reciproc Blue (VDW, Munich, Germany) and Wave One Gold (Dentsply Maillefer) and continuous motion HyFlex EDM (Coltene/Whaledent) and One Curve(Micro-Mega). **Methods**: Eighty extracted mandibular first premolars were selected and divided into 4 experimental groups (n = 16 teeth) and a control group (unprepared teeth, n=16); Control, Reciproc Blue (group 1), Wave One Gold (group 2) HyFlex EDM (group 3) One Curve (group 4). Roots were then sectioned at 3, 6, and 9 mm from the apex, and the surface was observed under a stereomicroscope. Chi-square test was applied for comparing categorical variables. A P-value of less than 0.05 was considered statistically significant. **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 (50.0%) and HyFlex EDM (43.8%) showed fewer microcracks than other experimental groups . There was no significant difference between reciprocating and continuous motion file systems (p>.05)WOG and Hyflex EDM showed statistically significant difference with other other experimental groups (One curve and Reciproc Blue) at apical (3mmlevel) and middle section (6mmlevel) (p<.05). **Conclusion**: O 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. HyFlex EDM caused less microcracks than the other instruments tested.

Keywords: Micro cracks, single-file system, wave one gold, Reciproc Blue, dentinal defects, HyFlex EDM, reciprocation.

INTRODUCTION

Preparation of root canal system is recognized as the most important step in root canal treatment. The main goal of biomechanical preparation is to eliminate microorganisms, pulp tissue and debris from the root canal system and enlarging the root canal diameter to provide enough space for the filling material.[1] During biomechanical preparation, a canal is shaped by the contact between instruments and dentin walls. These contacts create many momentary stress concentrations in dentin. Such stress concentrations may induce dentinal defects and craze lines or microcracks.[2] Thus root canal shaping procedures have the potential to induce crack formation, which can extend to complete fractures under functional load and these vertical root fracture become frustrating complications of root canal treatment as they often result in tooth extraction.[3]

Initially, most of the nickel-titanium file systems used multiple files to shape the canal. Recently a new concept proposes use of "single use, single file system to shape the canal completely from start to finish" thus requiring less time than full sequence rotary systems.[4] The concept of using a single NiTi instrument has some advantages like technique simplification, reduced cross contamination and reduced instrument fatigue. Different heat treatments, design features, such as NiTi core diameter, cross-sectional shape, taper, rake angle, type of alloy affect the behaviour of these single file systems and, therefore, may influence the generation of cracks. However their bearing on the root canal wall is not fully elucidated.[5]

Single file systems can be used in two different motions, reciprocation and continuous motion. Regarding the kinematics some studies have found no difference on crack formation, but most of them agreed that rotary instruments with continuous motion produce significantly more cracks than reciprocating instruments.

The single-file system used in a reciprocal motion consisting of Reciproc Blue (VDW GmbH,

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Munich, Germany) the new generation of single-file Reciproc instruments and WaveOne Gold (WOG, Dentsply Maillefer) are the main examples of commercially available single-file reciprocating systems.[6,7] HyFlex EDM (Coltene/Whaledent AG, Altstatten, Switzerland) and One Curve(Micro-Mega, Besancon, Cedex, France),[8,9] are instruments designed and marketed to shape root canals using the single-file technique in continuous clockwise rotation.

Reciproc Blue has a S-shaped cross section, 2 cutting edges, and a noncutting tip(tip size 25 and an 8% (0.08 mm/ mm) taper over the first 3 mm from the tip)made of special NiTi alloy with innovative heat treatment.

Wave One Gold metallurgy was changed from M-wire to a gold alloy. The cross section of the file was modified to a parallelogram, having 2 cutting edges (tip size 25, 0.07 taper from d1-d3.

HEDM files are made of a controlled memory alloy using electrical discharge machining technology. Throughout the file shaft, HEDM uses 3 different cross sections: quadratic in the apical third, trapezoidal in the middle third, and almost triangular in the coronal third. (Tip size 25 with a variable taper from .08 at the tip up to .04 in the coronal part).

One Curve is exclusive C. wire heat treated with variable cross section all along blade, triangular in apical third and almost S-shape in coronol third(tip size size 25 with taper 6%).

To date, there are only few studies in the literature regarding the occurrence of microcracks when using these single-file systems in continuous motion and reciprocating motion. 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

Freshly extracted mandibular first premolars from the Department of Oral and Maxillofacial Surgery GDC Srinagar were used as the study samples. The total number of extracted teeth used for the study were 80 and stored in distill water. Proximal radiographs were taken and only single rooted teeth with single striaght canal (<50) were included in study. To standardise canal instrumentation, teeth were decoronated by diamond disc with water cooling, establishing a standardised root length of 14mm.

Each specimen was examined with dental operating microscope (DOM) (micro vision Dental Microscope) to exclude cracked samples for excluding teeth with any external defects. Teeth with such findings were excluded and replaced by similar teeth in the study. Determination of sample size with a α-error of 5% and power of 80% it was estimated that 16 teeth would be needed in each group (n=16). 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. Roots with comparable canal widths were finally selected. Sixteen 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. A working jig [Figure 1] was constructed to hold the tubes containing teeth to standardize the instrumentation.

Root Canal Preparation

Teeth in control group were left unprepared and stored in distill water. All instruments were activated according to the manufacturer's instructions for each instrument system. A new file was used to shape each canal. The Reciproc blue files were used in "RECIPROC ALL" mode and Wave one Gold primary files were used in "WAVEONE ALL" mode generated by X-smartTM plus (Dentsply Tulsa Dental). HEDM file and One Curve files were used in continuous rotation as suggested by the manufacturer with torque control endodontic motor (X smart plus Dentsply Maillefer). 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 artifact by dehydration, all roots were kept moist in distilled water throughout all the experimental procedures.

Sectioning and microscopic observation

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 25x to determine the presence of micro cracks.

Definition of Defects

The dentin surface was inspected and dentinal defects observed were categorized as follows:

0 = No defect – root dentin devoid of any craze lines, microcracks and fractures.

1 = other defects – incomplete cracks: a craze line– a line extending from the outer surface into the dentin, without reaching the canal lumen, or a partial crack – a line extending from the canal

Walls into the dentin without reaching the outer surface.
2 = Fracture - a line extending from the root canal space all the way to the outer surface of the root.
Roots were classified as cracked if at least 1 of the 3 sections obtained from each root showed even 1 defect.

Statistical analysis

The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Data were summarized as frequencies and percentages. Graphically the data was presented by bar diagrams. Chi-square test or Fisher's exact test, whichever appropriate, was applied for comparing categorical variables. A P-value of less than 0.05 was considered statistically significant. All P-values were two tailed.

RESULTS

No complete fracture was observed in any samples examined. All single files tested caused dentinal cracks. Except control group, for all other tested instruments, other defects were observed at all sections. The apical section (3mm) showed major number of microcracks. Hyflex EDM (43.8%) and Wave One Gold (50.0%) showed fewer microcracks than other groups. WOG and Hyflex EDM showed statistically significant difference with other other experimental groups (One curve and Reciproc Blue) at apical (3mmlevel) and middle section (6mmlevel) ($p<.05$).

Number of other defects at different Levels				Number and percentage of roots with other defects per groups
Group	3mm	6mm	9mm	
	No	No	No	
Control	0	0	0	0.0
Reciproc Blue	8	4	4	10 (62.5%)
Wave One Gold	5	3	3	8 (50.0%)
Hyflex EDM	7	2	2	7 (43.8%)
One Curve	13	9	6	13 (81.3%)

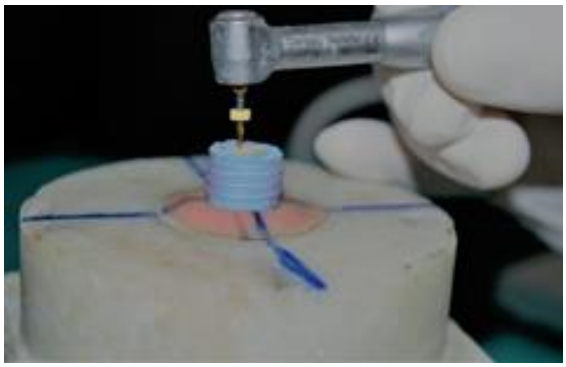

Figure 1: Simulation of periodontal ligament by silicone impression (blue arrow) material and customized jig for standardization of instrumentation (white arrow)

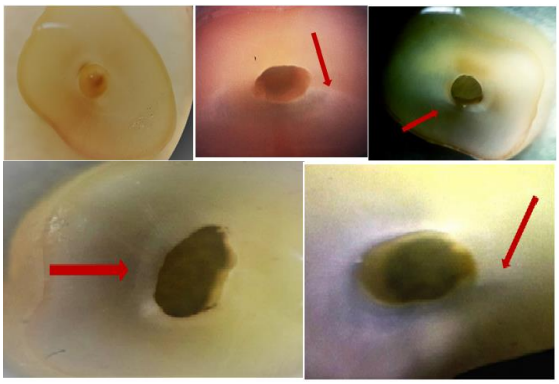

Figure 2: a) Control group, b) Reciproc Blue, c) Wave ONE Gold, d) Hyflex EDM, e) One curve. Microscopic cross sections from each experimental group at the 3-mm level

DISCUSSION

Root canal preparation preparation procedures can damage the root dentin, resulting in dentinal microcracks, crazelines and fractures.[10] These usually occur during canal preparation as a result of contact between instruments and dentinal walls and thus result in momentary stress concentrations. At these stress concentration points dentinal wall defects like crazelines and microcracks will devolop which eventually may propagate into complete fracture lines.[2] Vertical root fracture is end point of these dentinal defects when tooth is exposed to continual stress from any source. It seems likely that stresses generated from inside the root canal are transmitted through the root to the surface where they overcome the bonds holding the dentin together.[11]

Recent concept proposes use of single file systems to shape the canal completely as they can show equal or superior root canal cleaning efficiency and also save preparation time so they are preferred to multiple file systems.[4] However it might be speculated that using only one instrument for complete preparation more stresses will be generated that might result in increased incidence of dentinal defects. The kinematics of the file as well as different design, taper, cross-sectional geometry, heat treatment and type of alloy have a bearing on remaining root dentin. All of these factors may be related to generation of dentinal microcracks. These single file systems are used in continuous and reciprocating motion. Reciprocating motion was found to be more centered in the canal, and by repeating the clock wise (CW) and countert clock wise (CCW) rotation, reciprocating motion allows continuous release of the file when it is engaged in the inner surface of the root canal during the cutting and shaping procedure thus reducing stresses on root canal wall dentin.[12,13] Single file systems used in reciprocating motion such as Reciproc Blue and Wave One Gold and single file systems used in

continuous motion such as Hyflex EDM and One curve are recently introduced into market and it is claimed that the alloy and different heat treatments used in these systems enables high flexibility, fatigue resistance and superior adaptation of these files to the root canal walls.[14]

The results of the present study showed dentinal microcracks caused by all 4 single-file systems which is in agreement with other in vitro root canal instrumentation studies that have persistently shown such results.[15,16] The final apical diameter achieved with these four file system was similar (size 25) and this standardization improved reliability of the results. The methodology used was adapted from previous studies.[10,17,18] To enable better stress distribution during the shaping procedures, PDL simulation was done with silicon impression material because it acts as a major stress absorber.[18,19] The roots were distributed among the groups equally according to their root canal diameter at the 9-mm level. 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 14mm in length. In this study teeth were sectioned at different levels. The sectioning method has a significant disadvantage related to its destructive nature and possible microcracks induced by the sectioning.[20,21] However, in the present study control group revealed no defects and this implies that the methodology adopted did not induce dentinal damage.[7] In this study dentinal microcracks were produced by both reciprocating and continuous motion single file systems. However no statistical difference was observed among reciprocating files (Reciproc Blue, WaveOne Gold) and continuous motion files (Hyflex EDM and One Curve). Instead One Curve produced more microcracks then Hyflex EDM both used in continuous motion. Therefore, these results suggest that shaping motion has limited and unpredictable role on dentinal microcrack formation. These results are in accordance with results of some previous studies.[22-25]

The major number of dentinal microcracks were observed in the apical section (3 mm) for all tested instruments, which is in agreement with previous studies.[22,26] This may be due to maximum stress in the apical third of the root canals. For Hyflex EDM, WaveOne Gold, and Reciproc Blue the variable taper may explain the reduced number of micro cracks in the middle and coronal sections. Regarding One Curve, a constant taper and triangular apical cross-section with three point contacts resulting in lower cutting efficiency and less chip space may explain for more number of microcrack formations at apical and middle third which is statistically significant with Wave One Gold and Hyflex EDM. Higher flexibility of Hyflex EDM caused by the synergistic effect of the Controlled Memory wire and the electrical discharge machining manufacturing process are the reasons for Hyflex EDM producing less number of dentinal microcracks.[27] These results are in agreement to the results of study done by Eugenia Pedulla et al.[15]

CONCLUSION

Within the limitations of the present study, it could be concluded that multiple factors of single file systems are responsible for inducing dentinal damage but the flexibility of NiTi instruments because of heat treatment seems to influence the incidence of microcracks more than other factors such as kinematics and geometric features. But the results of the present study are in no way conclusive, further more studies need to be done with these single file systems with a large sample size to validate the research.

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How to cite this article: Jehan SS, Farooq R, Pura A, Ahmad F, Masoodi A. In Vitro Comparative Evaluation of Dentinal Microcrack Formation during Root Canal Preparation Using Reciprocating and Continuous Motion Single File Systems. Ann. Int. Med. Den. Res. 2020; 6(6):DE71-DE75.

Source of Support: Nil, **Conflict of Interest:** None declared