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The Incidence of Dentinal Microcracks in Single-Rooted Teeth Using Reciproc, One Curve, and Vortex Blue Endodontic File Systems: An *In Vitro* Study

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ABSTRACT

Introduction: The occurrence of microcracks is rather frequent during the root canal preparation and increases with some endodontic file systems. We conducted this study because there have been few in vitro studies on the incidence of microcracks formation by using the stereomicroscope. This study aims to evaluate and compare the frequency and amount of microcracks formed after root canal preparation in non-surgical root canal treatment using three different types of endodontic file systems (Reciproc, One Curve, and Vortex Blue) using a stereomicroscope.

Material and Methods: Forty human extracted teeth were collected and randomly assigned to five groups (n=8) as per the instrumentation protocol: group I: non-instrumented teeth (control); group II: hand K-files; group III: Reciproc; group IV: One Curve; and group V: Vortex Blue. Each group was then instrumented using the assigned file system at the standardized working length. The samples were gathered to be scanned and evaluated after instrumented and sectioned to determine the microcracks under the stereomicroscope with a standardized magnification of 25X. The data were statistically analyzed using one-way ANOVA and chi-square tests.

Results: There is no statistically significant difference among the study groups in the number of micro crack formations (p=0.736) and at each section level (3mm, 6mm, and 9mm) (p=1.000).

Conclusions: No significant relationship between dentinal micro crack formation and canal preparation procedures with the control and hand k files groups were noticed. While the Reciproc, One Curve, and Vortex Blue systems had caused some microcracks.

Key words: Dentinal microcracks, Root canal instrumentation, Rotary file system, Reciprocating file system, Stereomicroscope

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INTRODUCTION

The dentinal crack is a defect initiating from the inner root canal space and reaches the outer surface of the root [1]. Cameron CE in 1964 was the first to establish the term "crack tooth syndrome", which is defined as "an incomplete fracture of a vital posterior tooth that occasionally extends into the pulp" [2]. Dentinal cracks can be either complete or incomplete and can also vary in extension, direction, and location. The American Association of Endodontists (AAE) introduced terms to give a detailed description of the variation of dentinal cracks to be recognized clinically [3]; five types of cracks, including craze lines, fractured cusp, cracked tooth, split tooth, and vertical root fracture (VRF) [3]. The crack patterns in cracked tooth and split tooth are mesiodistal and extend from coronal to apical direction, while in VRF, the course is buccolingual. Dentinal cracks, especially radicular cracks (extends beyond the orifices of the root canals), are the most difficult to diagnose and treat [4].

Cracks that are not detected early can cause vertical root fracture (VRF), which is one of the most common reasons for tooth extraction [5]. Walton et al. in 1984 defined VRF as the destructive clinical issue with poor prognosis in a long-term period that will ultimately result in extraction [6]. Another hypothesis for VRF was suggested, including placement of a post and related corrosion, an increased force of lateral condensation during root canal obturation and spreader size, and root size [7,8]. Holcomb et al. and Matheny et al. studies found a direct association between root canal obturation and dentinal cracks or VRF [8,9]. Over the years, there has been evidence that VRF is a result caused by the propagation of dentinal cracks such as craze lines or microcracks [10].

Recently, rotary and reciprocating NiTi files became the fundamental principle to mechanical preparation of the root canal with less inconvenience and disadvantages than conventional stainless-steel instruments such as canal transportation. A matter of concern in many studies was the formation of dentinal cracks after mechanical preparation with rotary and reciprocating NiTi files because it might carry the risk of unfavourable outcomes such as VRF, which is not taken lightly [10,11]. A lot of different factors can result in the initiation of dentin cracks during endodontic treatment such as mechanical preparation with instruments, methods of obturation of root canal systems such as vertical warm compaction, or lateral cold compaction of Gutta Percha with the use of spreaders and retreatment procedures [7]. Other factors such as worn teeth and storing media of extracted teeth used in experimental studies can be a reason for crack formation; however, it is beyond the scope of this study, and the aim is towards the cracks formed after the mechanical preparation of root canal systems [12]. The rationale beyond the formation of cracks claimed that larger taper instruments generated forces on walls of oval or curved canals. These forces lead to the creation of stress and crack propagation on the dentinal walls [4].

Dentinal crack formation comparison between using rotary and reciprocating instruments has been investigated in many studies [1,13-17]. Studies showed conflicting results regarding which system caused more cracks [18-21], and other studies showed no significant difference between the reciprocating and rotary instruments in the induction of the dentinal crack after root canal preparation [13-15,17].

This *in vitro* study seeks to help in the accomplishment of determining the type of endodontic systems that provoke the slightest amount of dentinal cracks to help in preserving the longevity of teeth. The null hypothesis was that there would be no significant difference in micro-cracks among the studied groups. Therefore, we aim for testing and comparing the incidence of microcracks in endodontically treated teeth instrumented with the use of Reciproc, One Curve, and Vortex Blue systems by using a stereomicroscopic.

MATERIAL AND METHODS

Experimental teeth selection

Approval from the research ethics committee (03-12-19) was obtained at the Faculty of Dentistry. Forty human extracted teeth with single canals, straight roots, and free of decay were enrolled in the study (n=40). The authors achieved a power of 0.80 with an alpha (α) level of 0.05 (Confidence level: 95%), and a sample size of 40 was considered for total samples. The inclusion criteria were permanent human teeth with a single canal and no evidence of pre-existing microcracks or decay and with mature straight roots, and the teeth free from open apices or fractures. Exclusion criteria of the study samples were teeth with anatomical variations, teeth with pre-existing microcracks, teeth with more than one canal, and teeth with decay. Preoperative radiographs (mesiodistal and buccolingual) were taken for all the enrolled teeth to confirm the number of canals and roll out the presence of any anatomical variations. The teeth were cleaned and stored in a 10% formalin solution at room temperature.

Teeth preparation

To standardize canal instrumentation, decoronation of all the specimens (N=40) were done at a standardized length of 16 mm measured from apex to crown using a diamond disc with water coolant (SMART CUT™, USA); the length was confirmed using a size #10 hand stainless-steel file (Dentsply Maillefer, Ballaigues, Switzerland) and an Endodontic ruler. The rubber stopper was also used with each file in a reliable and standardized reference point. All roots were inspected with a stereomicroscope (EMZ-13TRD, MEIJI Techno, Japan), under 10X magnification to detect any pre-existing craze lines or cracks before the root canal instrumentation.

Embedding of the specimens in acrylic resin blocks

A mounting device was fabricated to facilitate the positioning of the teeth. After rinsing every tooth with Normal saline and drying it with gauze, the roots were then covered with a single layer of aluminium foil and embedded in an acrylic resin block. The roots were then removed from the blocks and replaced with polyvinyl siloxane (PVS) impression material (Zhermack SPA, Italy) to simulate the periodontal ligament. This impression material was mixed according to the manufacturer's recommendation. The centre of the putty material was placed inside the plastic tube and the subsequently selected tooth is submerged in the putty before the setting of the impression material. The level of insertion is at the level or short of cement enamel junction (CEJ) approximately.

Grouping of the experimental specimens

The specimens were randomly distributed into 5 groups (n=8) according to the instrumentation files used for cleaning and shaping the root canals:

Group 1: Specimens without instrumentation (Control Group).

Group 2: Specimens were instrumented by hand stainless-steel K-files (Dentsply Maillefer, Ballaigues, Switzerland) were used in sequential order up to size (#25/.02), length 25 mm.

Group 3: Specimens were instrumented by Reciproc® single file system (VDW, Munich, Germany) (R40/.06), in a reciprocating movement at working length with gentle slow in-and-out pecking motion using reciprocating VDW GOLD® RECIPROC® endodontic micro-motor.

Group 4: Specimens were instrumented by One Curve (Mico-Mega, Besancon, France) (#25/.06), length 25mm, with gentle in-and-out rotation movement at working length using endodontic micro-motor (speed: 300 rpm, torque: 2.5 Ncm).

Group 5: Specimens were instrumented by Vortex Blue rotary file system (Dentsply Sirona, USA) was used in sequential order up to size (#25\.04), with gentle in-and-out rotation movement at working length using endodontic micro-motor (speed: 500 rpm, torque: 1.0 Ncm).

Standard irrigation protocol

Before instrumentation using hand endodontic files and rotary file systems, all teeth are floated with 3ml of(3% NaOCL) using a 27 Gauged side vented needle (Vista Dental Produces, Racine, WI, USA) to remove tissue debris and afterward 3 ml of saline solutions is used then suctioned using a high suction tube in the dental unit. Teeth were kept moist to prevent any alterations that might happen in dentin as a result of dehydration.

Root canal preparation

Each sample was selected from the labelled container, dried gently with gauze for root canal preparation. A glide path for every canal will be created using a size 10-15 K file (Dentsply Maillefer, Ballaigues, Switzerland) followed by irrigation with 3ml 3% NaOCL solution. After re-confirming the WL (16mm) and reaching a glide path, preparation of the groups using the assigned files will be done; Group 3: [Reciproc (VDW, Munich, Germany) (N=8)], Group 4: [One curve (N=8) (Mico-Mega, Besancon, France)], Group 5: (Vortex blue (N=8) (Dentsply Sirona, USA)). Regarding Group 2, the root canals were instrumented by hand K-files (Dentsply Maillefer, Ballaigues, Switzerland) and enlarged up to size #35. All teeth are to be prepared in a crown-down manner in a buccolingual or mesiodistal canal. During instrumentation, the previously stated irrigation protocol was applied to remove the debris after preparation. Each tooth was dried using an absorbent paper point (META BioMed, Seoul, Korea) before taking post-operative images using a stereomicroscope.

Sectioning and stereomicroscopic evaluation

All roots were sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex using a diamond disc with water coolant (SMART CUT™, USA). Sections were then investigated and viewed under a stereomicroscope (EMZ-13TRD, MEIJI Techno, and Tokyo, Japan). Digital images of sections were taken using a digital microscope camera (INFINITY 2, 2.0 Megapixel Sony ICX274 CCD sensors USB 2.0 Camera, Lumenera Corporation, USA) that was attached to the microscope. The presence of microcracks was registered by the images that were taken digitally and saved by intuitive image infinity capture software, v.6.3.2. (Infinity 2, Lumenera Corporation, USA) to compare the images of sections among the experimental groups. The entire periphery of the root slice was investigated for no cracks, complete cracks, and incomplete cracks. The identification of a crack was based on the following definition: "No Crack" was defined as root dentin without cracks or craze lines either at the internal surface of the root canal wall or the external surface of the root. "Crack" either incomplete or complete was defined by a line extending from the inner root canal space with/without reaching the outer surface. The teeth were examined under the magnification 25X of a stereomicroscope to investigate any dentinal microcracks. Each specimen was then checked for the presence of microcracks. Two examiners who were examined blindly the specimens to investigate the microcracks under the stereomicroscope and those examiners have checked the specimens independently. There was an agreement between the two examiners for micro crack findings by used the Pearson correlation coefficient and the value of the correlation coefficient was equal to 0.923. There was a strong positive correlation between the two examiners for the microcracks observation.

Statistical analysis

The agreement between the two examiners for micro crack observation was analyzed using the Pearson Correlation Coefficient (PCC) for the evaluation of the micro crack images. The Collected data were analyzed using IBM SPSS Statistics for Windows software (Version 25; IBM; Chicago; IL) and were expressed as means, standard deviations, and proportions. The one-way ANOVA test and chi-square test were used to determine the correlation between the study groups concerning the number, type, and location of microcracks. The level of significance was set at 0.05.

RESULTS

Incidence of microcracks after instrumentation

The general distribution of the status of cracks among all the experimental groups is shown in Table 1. There was no statistically significant difference between the 2 statuses regarding the incidence of microcracks formation (p=0.736), whereas the percentage of "No Cracks" was significantly higher than the "Cracks" as shown in Table 1.

The no instrumentation group (control group) and the hand K-files group presented no cracks. The cracks were found in the three file system groups included: reciproc®, one curve, and vortex blue endodontic file system groups.

There was no statistically significant difference between the experimental groups regarding the incidence of microcracks formation (p=0.726) as shown in Table 2. The stereomicroscopic images of no crack for different groups are present in Figure 1.

The stereomicroscopic images of complete crack (black arrows) among the rotary file system groups at different section levels are present in Figure 2.

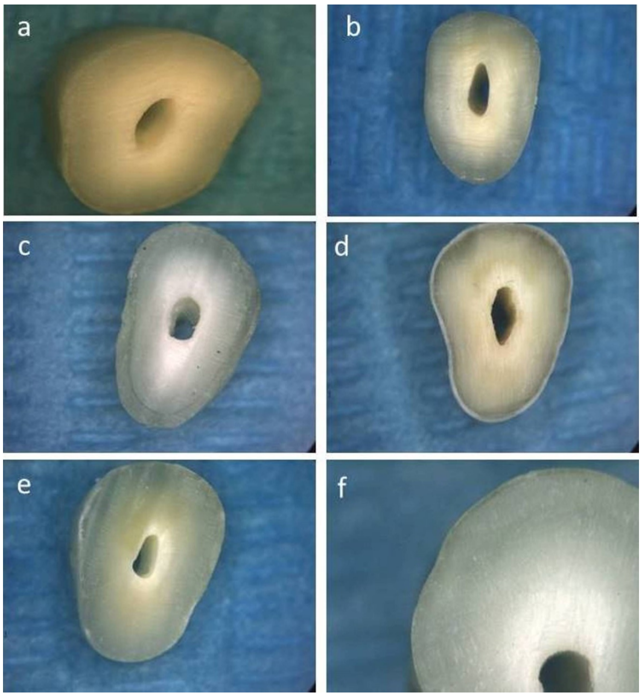

Figure 1: The stereomicroscope images of no crack (a-f): (a) Group 1, (b) Group 2, (c) Group 3, (d) Group 4, (e) Group 5, and (f) High magnification of no crack (from lumen of the canal to the outer surface).

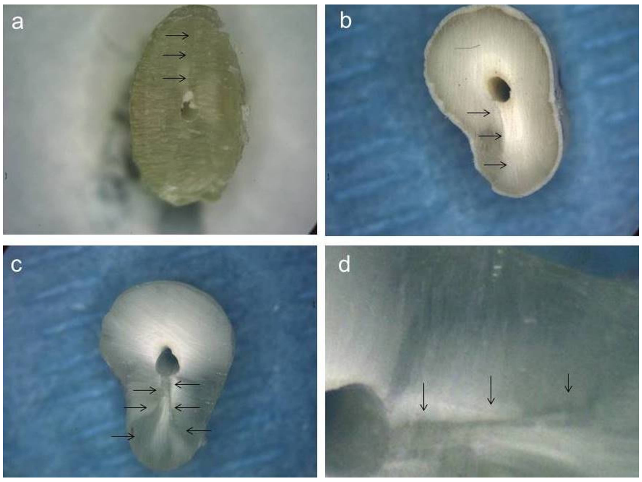

Figure 2: The stereomicroscope images of complete crack (black arrows) at different section levels (a-d): (a) At 3mm, (b) At 6mm, (c) At 9mm, and (d) High magnification of complete crack (from lumen of the canal to the outer surface).

Type and location of the microcracks

In reciproc® file system group at 9mm, one curve file group at 6mm, and vortex blue rotary file system group at 3mm presented with one crack only (n=3/120 sections, 2.5%), while the remaining 117 sections found in all the groups were classified as "No Cracks" at different levels (Table 3).

These microcracks were seen originating from the inner root canal space to the outer surface of the root and were classified as "Complete Crack". No incomplete cracks were found in all the experimental groups.

There was no significant difference between the study groups at each level (3 mm, 6 mm, and 9 mm) (p=1.000) as shown in Table 3.

There was no significant difference between the study groups in the incidence of micro crack formation at the apical level (3mm) (p=0.392) as shown in Table 4.

There were not any cracks in the four groups included: Group 1, Group 2, Group 3, and Group 4, whereas group 5 (vortex blue group) had only one micro crack at the apical level (3mm) (Table 4).

At the middle level (6mm) there is no significant difference in micro crack formation between all the experimental groups (p=0.392) as shown in Table 4.

There were not any cracks in the four groups included: Group 1, Group 2, Group 3, and Group 5, whereas group 4 (one curve group) had only one micro crack at the middle level (6mm) as shown in Table 4.

In Table 4 illustrated no significant difference between the study groups in the incidence of micro crack formation at the coronal level (9mm) (p=0.392).

There were not any cracks in the four groups included: Group 1, Group 2, Group 4, and Group 5, whereas group 3 (reciproc® file system group) had only one micro crack at the coronal level (9mm) as shown in Table 4.

Table 1: The general distribution of the status of cracks among all the experimental groups.

All the experimental groups	Status of Cracks	Numbers	%	Mean and Standard Deviation (Mean ± SD)	P-value
From Group 1 To Group 5	No Cracks	117	97.50%	3.00 ± 1.420	0.736>0.05 No Significant
	Cracks	3	2.50%		
	Total	120	100%		

Table 2: The number and percentage of the incidence of microcracks formation among the experimental groups.

Groups	Status of Cracks (No Cracks)	Status of Cracks (Cracks)	Mean and Standard Deviation (Mean ± SD)	Pearson Chi-Square	Degree of freedom	P-value
Group 1: No instrumentation (Control Group)	24(20.5%)	0(0.0%)	3.00 ± 1.432	2.051	4	0.726 >0.05 No Significant
Group 2: Hand K-files	24(20.5%)	0(0.0%)				
Group 3: Reciproc®	23(19.7%)	1(33.3%)				
Group 4: One Curve	23(19.7%)	1(33.3%)				
Group 5: Vortex Blue	23(19.7%)	1(33.3%)				

Table 3: The number and percentage of the incidence of microcracks formation among the experimental groups at each section level (3 mm, 6 mm, and 9 mm).

Groups	Status of Cracks	3 mm		6 mm	9 mm	Mean and Standard deviation (Mean ± SD)	Pearson Chi-Square	Degree of freedom	P-value		
		N	%	N	%					N	%
Group 1: No instrumentation (Control Group)	No Cracks	8	33.30%	8	33.30%	8	33.30%	6.00 ± 2.460	0	2	1.000>0.05 No Significant
	Cracks	0	0%	0	0%	0	0%				
Group 2: Hand K-files	No Cracks	8	33.30%	8	33.30%	8	33.30%				
	Cracks	0	0%	0	0%	0	0%				
Group 3: Reciproc®	No Cracks	8	34.80%	8	34.80%	7	30.40%				
	Cracks	0	0%	0	0%	1	100%				
Group 4: One Curve	No Cracks	8	34.80%	7	30.40%	8	34.80%				
	Cracks	0	0%	1	100%	0	0%				
Group 5: Vortex Blue	No Cracks	7	30.40%	8	34.80%	8	34.80%				
	Cracks	1	100%	0	0%	0	0%				

Table 4: Chi-square test for the incidence of microcracks among different groups at the apical, middle, and coronal levels (3mm, 6mm, and 9mm).

Levels	Groups	Status of Cracks (No Cracks)	Status of Cracks (Cracks)	Mean and Standard Deviation (Mean ± SD)	Pearson Chi-Square	Degree of freedom	P-value
Apical level (3mm)	Group 1: No instrumentation (Control Group)	8(20.5%)	0(0.0%)	3.00 ± 1.432	4.103	4	0.392>0.05 No Significant
	Group 2: Hand K-files	8(20.5%)	0(0.0%)				
	Group 3: Reciproc®	8(20.5%)	0(0.0%)				
	Group 4: One Curve	8(20.5%)	0(0.0%)				
	Group 5: Vortex Blue	7(17.9%)	1(100.0%)				
	Group 5: Vortex Blue	7(17.9%)	1(100.0%)				

Middle level (6mm)	Group 1: No instrumentation (Control Group)	8(20.5%)	0(0.0%)	3.00 ± 1.432	4.103	4	0.392>0.05 No Significant
	Group 2: Hand K-files	8(20.5%)	0(0.0%)				
	Group 3: Reciproc®	8(20.5%)	0(0.0%)				
	Group 4: One Curve	7(17.9%)	1(100.0%)				
	Group 5: Vortex Blue	8(20.5%)	0(0.0%)				
Coronal level (9mm)	Group 1: No instrumentation (Control Group)	8(20.5%)	0(0.0%)	3.00 ± 1.432	4.103	4	3.00 ± 1.432 No significant
	Group 2: Hand K-files	8(20.5%)	0(0.0%)				
	Group 3: Reciproc®	7(17.9%)	1(100.0%)				
	Group 4: One Curve	8(20.5%)	0(0.0%)				
	Group 5: Vortex Blue	8(20.5%)	0(0.0%)				

DISCUSSION

In the present study, five different groups with (n=8) teeth in each group and the roots were instrumented by different files in four out of five groups included: hand k files, reciproc® file system, one curve, and vortex blue systems were used for root canal preparation. The teeth were sectioned and investigated under a stereomicroscope for the absence/presence of microcracks. The sectioning method used in this study permitted the assessment of the impact of root canal preparation procedures on root dentine by direct inspection of the roots and is similar to the methodology depicted in different investigations [1,4,5].

In this study, as in the previous studies, teeth were sectioned at different levels, observing for microcracks with a stereomicroscope [13,16,22] which has a significant disadvantage related to the deleterious effect of the sectioning procedure [23]. Cracks after canal instrumentation were detected either in transverse sections at different levels along with the roots [24-27] or the apical root surface [1,24,28]. As in the studies of many other authors [25-27,29], we examined the micro crack formations by transverse cutting of the roots to evaluate the dentin root at different section levels. However, the possibility of micro crack formations during transverse cutting of the roots while preparing the teeth for examination was high in this type of studies but in this study, the samples were not affected by this sectioning and we found no microcracks formation in most of the tested groups especially the first two groups (control group and hand k file group).

Manual stainless-steel instruments have shown less dentinal cracks than any other mechanical preparation method [30, 31]. Crack incidence with manual instruments ranged from 0% to 60% [4]. In our study, we found no microcracks formation in the control group and hand k file group which are coming in line with several studies [29-33]. Also, both group's findings were similar to Bier et al. [27] and Ustun et al. [17] findings. Hand instrumentation did not cause damage to the root dentin due to its less aggressive movements in the canal compared with engine-operated files [34]. Only one study has shown that manual preparation with stainless-steel instruments produced more dentinal cracks than Pro-Taper Universal rotary instruments [35]. They compared the incidence of dentinal cracks after root canal preparation of mandibular incisor teeth between the Pro-Taper Universal rotary system and manual instruments with the step-back technique [35]. The teeth were sectioned at 3 and 6 mm from the apex and evaluated by the dental operating microscope (DOM) [35]. The rationale for the result of this study [35] was using a step-back technique that induced more cracks than a balanced force technique that was used in other studies with less dentinal cracks [30,31].

Versluis et al. [28] assured that during the instrumentation procedure, the stresses generated at the coronal, and middle levels were three times more prevalent than at the apical level. In our study, the occurrence of microcrack formations in the coronal level (9mm) was 33.3% and the same percentage in both the middle (6mm) and apical level (3mm). Our findings could be less prevalent compared with Versluis et al. study [28] in regards to stress related to microcrack formations.

The pioneers in discovering dentinal cracks after root canal preparation with rotary files were Bier et al. and Shemesh et al. in 2009 [26,27]. They reported that root canal preparation might cause dentinal defects such as craze lines, fracture, or incomplete cracks, and these defects observed on the dentin could be related to the kinematic of rotary NiTi instruments [26,27]. The studies on the dentinal cracks with either rotary or reciprocating NiTi instruments are varied, and that’s due to the difference in NiTi systems, preparation manner, observation methods to see the cracks, irrigation method, selection of samples, and definition of the cracks used in these studies [4]. Most dentinal crack studies used stereomicroscope as an evaluation method, Pro-Taper system in canal preparation, mandibular teeth, and sodium hypochlorite (NaOCl) as an irrigation solution [4].

Some studies [1,18-21] illustrated different results regarding which system caused more cracks, and if there are any significant differences between the instruments or no, for example, Bürklein et al. study [1] mentioned that a reciprocating system caused more cracks formation than the rotary system. In their study, they evaluated the incidence of dentinal cracks after root canal preparation of mandibular incisors with reciprocating instruments (Reciproc and Wave One) and rotary instruments (M-two and Pro-Taper). After sectioning of the root at 3, 6, and 9 mm from the apex and observation under microscope 25X magnification, they found reciprocating instruments induced more cracks than rotary instruments but not statistically significant [1].

Some studies found no difference between the reciprocating and rotary instruments in the induction of the dentinal crack after root canal preparation [13-15,17]. One study by Arias et al. [14] compared the dentinal cracks after root canal preparation between GT rotary files and Wave One reciprocating files using the cadaver model. They sectioned the roots at 3, 6, and 9 mm from the apex and evaluated them by taking color photographs at magnification (25X and 40X). The result of this study concluded that there is no difference between the GT rotary and Wave One reciprocating instruments in the creation of dentinal cracks [14].

A study done by Bayram et al. [36], found no new microcracks were induced by Vortex Blue rotary file during the instrumentation and they referred this outcome to the heat-treated structure of these instruments, which gives more flexibility to the files. This finding in accordance with our results regarding the vortex blue files which were no dentinal micro crack developed among the different section levels except one dentinal crack was formed at the apical level (3mm).

In our current study, there was no statistically significant difference seen in coronal, middle, and apical section levels among the tested groups. Although there was no statistically significant difference between Reciproc, One Curve, and Vortex Blue systems illustrated a few numbers of microcracks when compared with first and second groups in the three section levels. These outcomes showed agreement with previously published studies that found no significant difference between all the tested groups in dentinal micro crack formation [1,13-17].

Overall, the occurrence of microcracks is independent of the type of instrument used. The experimental groups varied in their manufactures. It can be concluded that different endodontic file systems tend to make different degrees of dentinal damage during root canal preparation. Different variables cause dentinal cracks, but the flexibility of the file due to heat treatment, kinematics of the file, and the basic architecture of the file are the most significant ones. In our study, single-rooted teeth were selected, and instrumentations were performed with full sequence Hand k file, Reciproc, One Curve, and Vortex Blue instruments, and also these instruments were used in different motions as mentioned in the sample groups. The differences in results might be related to different methodologies and teeth selections.

Within the limitations of this study, except for the two groups (control and hand k file), all test groups illustrated micro crack formation. Although Reciproc, One Curve, and Vortex Blue systems demonstrated few crack formations, there was no significant statistical difference, and all systems and motions did not affect the micro crack formations. Therefore, the null hypothesis of this study has been accepted.

CONCLUSIONS

It can be concluded that no significant relationship between dentinal micro crack formation and canal preparation procedures with the control and hand k files groups were noticed. While the Reciproc, One Curve, and Vortex Blue systems had caused some microcracks. In addition, there were microcracks formed at different section levels. Future studies may be needed to evaluate microcracks formation by different root canal instrumentation systems.

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