ORIGINAL PAPER

COMPARATIVE EVALUATION OF ROOT DENTIN DEFECTS PRODUCED BY COMMERCIALLY AVAILABLE ROTARY ENDODONTIC SINGLE-FILE SYSTEMS USED IN TWO DIFFERENT MOTIONS: AN *IN-VITRO* STUDY

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ABSTRACT

Introduction: Optimal preparation of the root canal system allows establishment of the essential 'three-dimensional seal'. Overzealous preparation of root canals may cause dentinal cracks and fractures; leading to endodontic failure. Recent evidence iterates that vertical root fractures (VRFs) are probably caused by propagation of these smaller, less pronounced dentinal defects and not by force practiced during preparation.

Objectives: The aim of the study was to evaluate and compare the presence of dentinal defects after root canal preparation using two endodontic single file systems, One Curve and WaveOne Gold (WOG) with two different working motions, continuous rotary and reciprocating motion, respectively.

Material and methods: Twenty single-rooted teeth were selected and divided into three groups: Group 1, control (n = 4); group 2, continuous rotary One Curve single-file system (n = 8), and group 3, reciprocating WOG single-file system (n = 8). Root canal preparation was performed in groups 2 and 3, followed by root sectioning in all the three groups at 3, 6, and 9 mm from apical end, and observed under stereo-microscope (40× magnification) for the presence of any dentinal defects. Intra-group samples were compared for mean defect scores using analysis of variance (ANOVA), and Tukey's post-hoc test was applied for pairwise comparisons.

Results: All groups recorded the presence of dentinal defects. The recorded dentinal defects were 8.3%, 25%, and 12.5% in group 1, group 2, and group 3, respectively. Continuous rotary One Curve single-file system showed an increased number of dentinal defects compared with reciprocating WOG single-file system. Overall, craze line defects were more commonly observed when compared with incomplete and complete dentin cracks. Most of the defects were observed at the middle section, followed by the coronal and apical sections.

Conclusions: The current research show that dentinal defects can lead to vertical root fracture, compromising the prognosis. Detailed knowledge regarding instruments' kinematics and proper chemico-mechanical preparations are imperative in successful treatment.

Key words: One Curve, WaveOne Gold, stereo-microscope, rotary motion, reciprocating motion.

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INTRODUCTION

Introduced in 1958, nickel-titanium (Ni-Ti) technology created a revolution, and helped to establish the era of modern endodontics [1]. Increased flexibility, super elasticity of the alloy, and particularly, geometric design features are the main reasons behind its superior performance. Ni-Ti instruments display remarkable outcomes

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when compared with stainless-steel manual files regarding endodontic complications [2]. In general, Ni-Ti rotary instruments are classified into two groups, continuous rotating and reciprocating, based on their motions. Rotation motion is continuous rotary motion in 360 degrees, whereas reciprocation motion is an oscillating motion, when an instrument rotates clockwise and then in a counter-clockwise direction before completing a cycle [3]. In the past years, numerous Ni-Ti instruments have been manufactured and launched on commercial basis. The evolution of a novel single-file rotary system is believed to be feasible and time-saving when compared with multiple-file systems [4]. Despite the advantages of Ni-Ti systems, mechanics of instruments [2] and incorrect chemico-mechanical preparation [5] can lead to serious loss of radicular dentin that may promote an easy passage for dentin cracks and occurrence of miniature fractures [6]. In the long-term, due to continuous exposure to operative procedures, these defects can culminate into vertical root fracture (VRF), seriously affecting treatment prognosis [5].

This research focused on the comparison of dentinal defects produced by One Curve single-file system (Micromega™) and WaveOne Gold (WOG, Dentsply Mallifer™) single-file system in rotary and reciprocating motions, respectively.

OBJECTIVES

The aim of the study was to evaluate and compare the presence of dentinal defects after root canal preparation using two endodontic single file systems, One Curve and WaveOne Gold (WOG) with two different working motions, continuous rotary and reciprocating motion, respectively.

MATERIAL AND METHODS

The study protocol was approved by the Research and Recognition Committee at D.Y. Patil Dental College and Hospital, Pune (approval number, DPU/R & R (D)/32 (08)/19). The manuscript of this research study was written according to preferred reporting items for laboratory studies in endodontology (PRILE) 2021 guidelines. Sample size was estimated from a previous study [4] with values of alpha (90%), beta (80%), and variance (0.33). Sample size was determined according to OpenEpi software version 3.0.1. Inclusion criteria were patients aged 20-50 years, with teeth extracted due to periodontal reasons, teeth extracted due to orthodontic reasons, and single-rooted teeth with single-canal with closed apex. For this in-vitro study, twenty teeth were selected according to the criteria. To avoid dehydration, the extracted teeth were stored in a 0.5% thymol solution. Root surfaces were first examined under stereo-microscope (25× magnification) to rule out any external defects or cracks. To obtain a standardized 16 mm root length, teeth were decoronated using a slow-speed diamond disc along with water coolant to avoid any external cracks. The roots of the teeth were inserted into an acrylic block after covering them with aluminum foil. The roots were removed from the block after setting of the acrylic. To simulate periodontal ligament as present in natural teeth, aluminum foil was removed and replaced with light body silicone material. All samples were randomly divided into 3 groups: group 1, control; group 2, One Curve single-file system; and group 3, WOG single-file system. No root canal preparation was done in control group. No. #15 k file was applied to measure canal length in groups 2 and 3, and was confirmed radiographically. Glide path preparation was done with #15k and #20k hand files.

FIGURE 1. Specimen preparation in rotary motion with One Curve single-file system

ROOT CANAL PREPARATION

Two different single-file systems (One Curve and WOG) were used to perform root canal shaping procedures according to the manufacturers' instructions for each system in groups 2 and 3. To shape each canal, a new file was applied. Programmed rotary and reciprocating motions generated by XSmart motor (Dentsply Maillefer) and Gold Reciproc (VDW), respectively, were used to activate the instruments. In ROTARY mode, One Curve rotary file (tip size, 25; apical taper, 0.06) was used at speed 300 revolutions per minute (rpm) and torque 2.5 Newton-meters (Nm) (Figure 1). WAVE ONE All mode was used for WOG file (size, 25, .07; taper, d0-d3) at a speed of 350 rpm and torque 2.5 (Nm) (Figure 2). The files were used in a slow pecking motion and light apical pressure (amplitude less than 3 mm, 5 pecks). The teeth were irrigated with 5% sodium hypochlorite after insertion of each instrument with a 27-gauge endo irrigation needle (single-side vent) placed passively in the canal. Neutral saline was applied as a final irrigant. All the roots were kept moist in 0.5% thymol solution during experimental procedures to avoid any artifact

FIGURE 2. Specimen preparation in reciprocating motion with WaveOne Gold single-file system

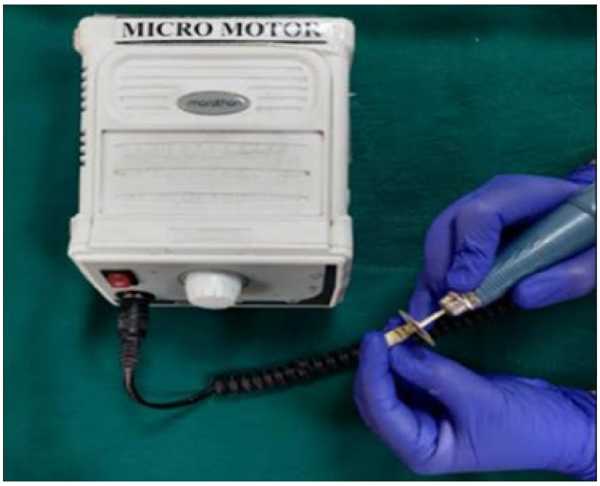

FIGURE 3. Specimen sectioning with diamond disks

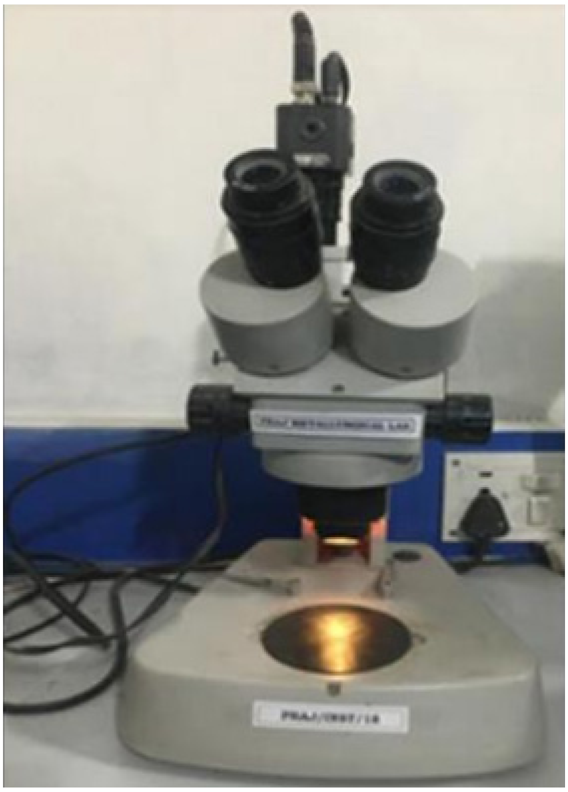

FIGURE 4. Stereo-microscope used for evaluation of defects

by dehydration. A digital stopwatch was used to record mean preparation time (in seconds) for each file [7].

MICROSCOPIC EXAMINATION

All the roots were sectioned horizontally at 3, 6, and 9 mm from the apical end using a disc impregnated with sharpened diamonds and water as a coolant (Figure 3). A 40× magnification stereo-microscope was applied to analyze the slices (Figure 4). To avoid any bias, two observers performed scoring criteria, and sections were evaluated according to scoring criteria described in Burklein *et al.* [8] (Table 1).

TABLE 1. Scoring criteria for evaluating dentinal defects

Score number	Score criteria
0	No crack Definition: Root dentin without any cracks on internal and external surfaces
1	Craze line Definition: Line extending from outer surface, but not reaching lumen of canal
2	Partial crack Definition: Line extending from root canal wall, but not reaching outer surface
3	Complete fracture Definition: Line extending from outer surface to root canal wall

STATISTICAL ANALYSIS

Data were entered in Microsoft Excel 2010. Descriptive statistics were expressed as mean ± standard deviation (SD) for each group for criteria of defect scores. Three groups were compared for mean defect scores with analysis of variance (ANOVA), followed by Tukey's post-hoc test for pairwise comparison. Similarly, intra-group comparison for the coronal, middle, and apical parts was done with analysis of variance (ANOVA), followed by Tukey's post-hoc test for pairwise comparison. Frequency distribution and percentage were applied to verify the distribution of criteria of defects among the three groups and three levels. In all the above-mentioned tests, p-value of 0.05 was considered statistically significant. Statistical Package for Social Sciences (SPSS) version 19 was used for all computations.

RESULTS

The roots were classified as non-defective (Figure 5), and defective if at least one of three sections showed either a craze line (Figure 6), partial crack (Figure 7), or a fracture (Figure 8). Results were expressed as the number and percentage of defective roots in each group. According to this *in-vitro* study, it was observed that groups 2 and 3 showed formations of dentinal defects at the apical, middle, and coronal levels. No formations were seen in the control group. Out of the total 60 sectioned samples, 50 (83.3%) recorded no cracks, 7 (11.7%) recorded craze line defects, 2 (3.3%) recorded partial cracks, and only 1 (1.7%) recorded a complete fracture. In the group 1 (control group), 11 (91.7%) samples showed no cracks, and 1 (8.3%) showed craze lines. In the group 2 (total, 24 readings), 18 (75%) samples showed no cracks, 3 (8.3%) had craze lines, 2 (8.3%) showed partial cracks, and only 1 (4.2%) presented fracture. In the group 3 (total, 24 readings), 21 (87.5%) samples recorded no cracks, and 3 (12.5%) recorded craze lines.

Craze line defects were more frequent when compared with incomplete cracks and complete fracture defects (Table 2 and Figure 9). There was a statistically insignificant difference among all the three groups for defect criteria scores with ANOVA and Tukey's post-hoc test ($p = 0.145$) (Tables 3 and 4). Even though there was no significant difference seen between the groups, most of the defects were observed in One Curve rotary single-file system group when compared with WOG reciprocating single-file system. In the individual groups, reciprocating single-file systems showed an increased number of defects at the apical level, and rotary single-file systems at the middle and coronal levels (Figures 10-12). Insignificant differences were observed with defects at each level of the root canal, but the defects were more at the middle level of the root when compared with the coronal and apical levels in all the groups (Figure 13).

DISCUSSION

The concept of rotary endodontics was established to save the time of procedure and to perform root canal preparation with increased accuracy and efficiency [8]. Endodontic instruments are believed to eliminate a sig-

FIGURE 5. Scoring criteria 0

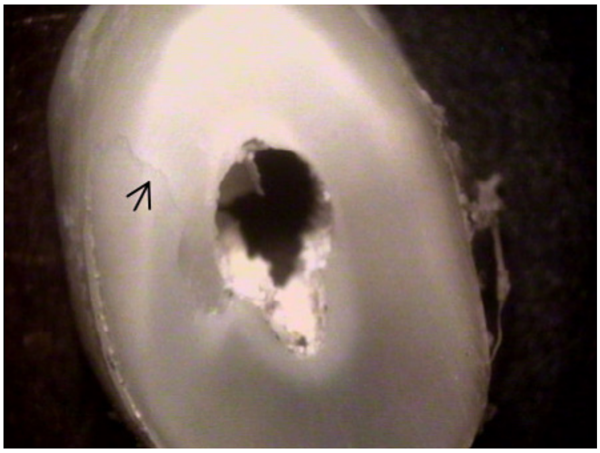

FIGURE 6. Scoring criteria 1

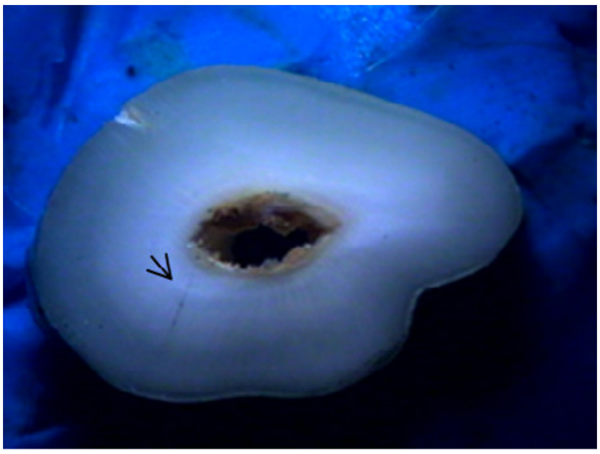

FIGURE 7. Scoring criteria 2

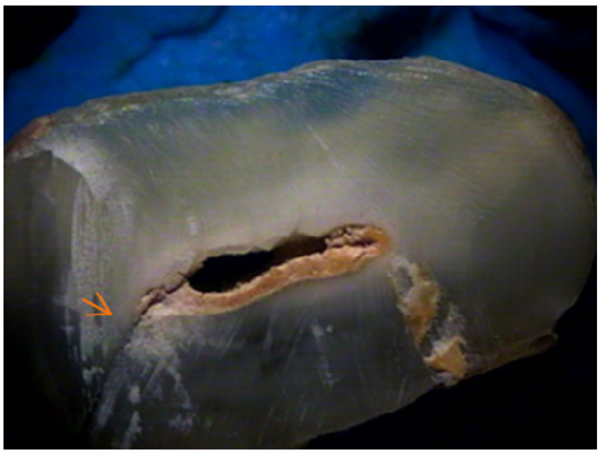

FIGURE 8. Scoring criteria 3

TABLE 2. Criteria of defects

Group	Frequency (*n*)	Cumulative percentage
Group 1, control group		
No crack	11	91.7
Craze line	1	8.3
Total	12	100.0
Group 2, rotary file system		
No crack	18	75.0
Craze line	3	12.5
Partial crack	2	8.33
Fracture	1	4.17
Total	24	100.0
Group 3, reciprocating file system		
No crack	21	87.5
Craze line	3	12.5
Total	24	100.0

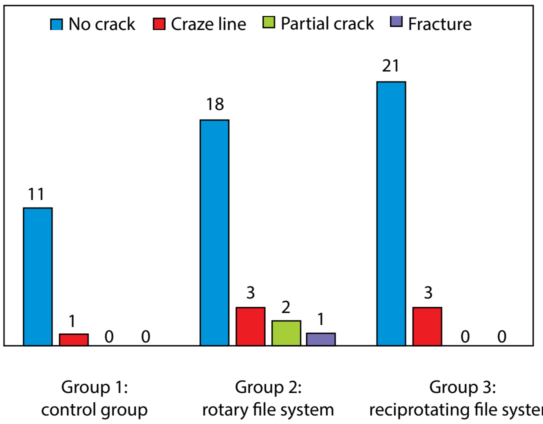

FIGURE 9. Frequency distribution for defects criteria among three groups

TABLE 3. Comparison of defects criteria scores among three groups using analysis of variance (ANOVA)

Criteria of defect	Sum of squares	Df	Mean square	F	Sig. *p*-value
Between groups	1.358	2	.679	1.998	.145
Within groups	19.375	57	.340		
Total	20.733	59			

TABLE 4. Pairwise (one-to-one) comparison of defects criteria scores among three groups using Tukey's post-hoc test

(I) Group	(J) Group	Mean difference (I-J)	Std. error	Sig. *p*-value	95% confidence interval	
					Lower bound	Upper bound
Group 1, control group	Group 2, rotary file system	–0.333	0.206	0.247	–0.83	0.16
Group 1, control group	Group 3, reciprocating file system	–0.042	0.206	0.978	–0.54	0.45
Group 2, rotary file system	Group 3, reciprocating file system	–0.292	0.168	0.202	–0.11	0.70

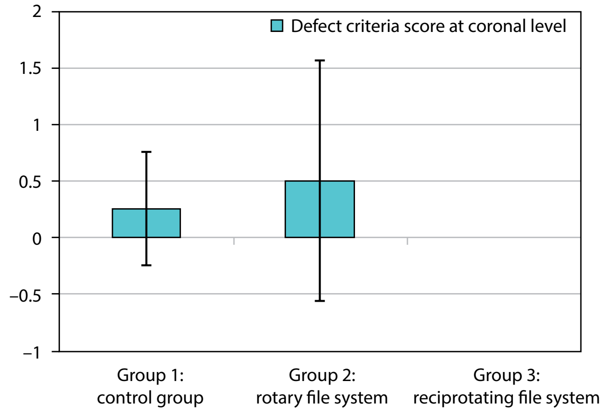

FIGURE 10. Defect criteria score at coronal level

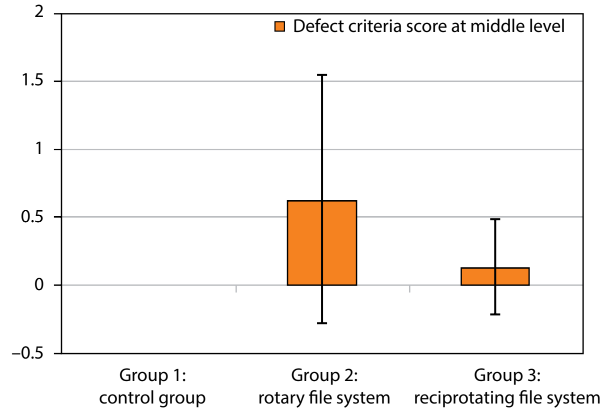

FIGURE 11. Defect criteria score at middle level

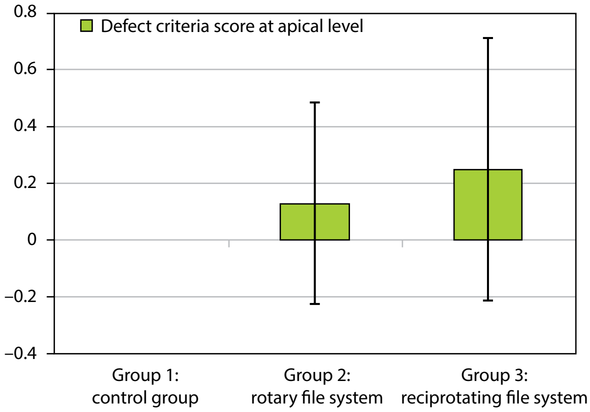

FIGURE 12. Defect criteria score at apical level

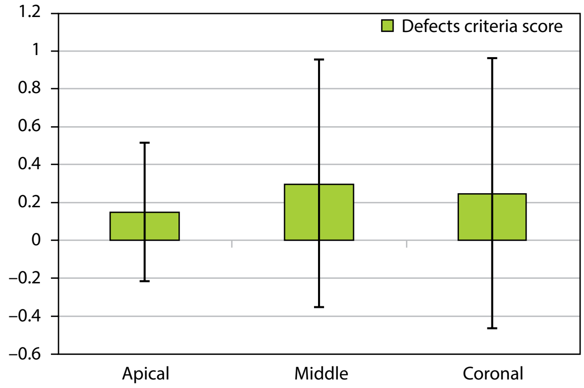

FIGURE 13. Comparison of defects criteria scores at all three root levels

nificant bulk of dentin at the canal aperture to create an easy passage for irrigating solutions and medicaments for bacteria eradication [9]. However, this results in the removal of an excessive amount of dentin on the inner curve of the canal and the root apex, while instrumenting with larger tapered files. This in turn exerts more stress on the canal wall, generating dentinal cracks [10]. On application of external influences, these defects act like stress concentration areas, which further disseminate in the root canal surface, causing vertical root fractures with poor endodontic prognosis.

In the study, the WOG reciprocating group showed a smaller number of defects when compared with the One Curve rotary group at the middle and coronal levels. However, in the apical group, the defects were observed more in the WOG reciprocating group when compared with the One Curve rotary group. A possible explanation could be the characteristic reciprocating motion. This motion may help to circumvent regular motion stress and the continual torque effect on the inner surface of root canal walls generated from traditional rotary-file systems. Reciprocating motion is found to be more centralized in the canal. In addition, the continuous and reverse motion used in reciprocating motion enables the file to release itself when blades are engaged in the inner circle of root during shaping procedure. This results in the interrupted application of flexural and torsional stresses, and could help prevent the formation of dentinal defects [11]. One Curve rotary files add continuous rotational stress and constant torque due to continuous rotation on the dentin wall. This causes an increased number of defects, which can further explain an increased number of defects in the middle and coronal levels of the root [12]. Also, instruments with varied cross-sections may exercise excessive pressure upon having contact with the dentin structure. This may result in the rapid development of a minute crack. In this study, the preparation of root canals was done with two files of different cross-sections. WOG file has an offset parallelogram transection and during a complete rotation, it alternatively contacts the dentin with two edges: one facing apical section and one facing coronal section. One Curve rotary file has a variable cross-section that is triangular at the apical part and an S-shaped cross-section that is directed more towards the coronal part of the file [12]. Another contributing factor to the occurrence of dentinal defects is file taper occurring mainly in tapered roots. The higher the taper, the greater the dentin structure removed by the files. This in turn makes the tooth structure vulnerable to fracture. The files used in the study had unequal apical circumferences (ISO, 25): 6% with One Curve, and 7% with WOG reciprocating single-file system. Even though the taper was more with the reciprocating file system, fewer defects were observed that may be due to the reciprocating motion [12]. To avoid the formation of defects, adequate preparation should be performed, possibly with small taper files as well as adjuvant irrigation techniques for better cleaning and shaping of the root canal.

Kim *et al.* [13] reported a relationship between Ni-Ti designs and the occurrence of VRF, showing that file pattern did influence strain concentration and apical stress during canal preparation. Liu *et al.* [14] established an important difference in dentinal defects occurring in rotary multiple-file systems and reciprocating single-file systems. They concluded that 50% of dentin cracks were detected in teeth prepared with ProTaper and only 5% in Reciproc files. Jalali *et al.* [15] conducted a study evaluating dentinal crack formation, and concluded that Mtwo and ProTaper rotary files caused significantly more dentinal cracks than reciprocating Reciproc file system. In a study conducted by Kfir *et al.* [16] it was reported that 30% of teeth presented with micro-cracks when treated with ProTaper and 20% in teeth treated with reciprocating WaveOne system. Pop *et al.* [17] in 2014 showed that post-shaping, an increase in incidences and dimensions of micro-cracks in sections was recorded. However, when compared with rotary and reciprocating file systems, the results were considered insignificant.

Dentinal defects are reported to be also caused by the forces exerted during tooth extraction and by the physical stress created during storage or slicing. This can justify the presence of defects in the non-preparation control group. In this study, defects were observed mainly in the coronal part of tooth sections, which may be due to stresses generated during teeth sectioning [13]. There are no confirmatory conclusions about the clinical correlation of dentinal defects in the long-term. However, it is not completely established that partial cracks or craze lines lead to complete cracks progressing to vertical fractures. In addition, the role of therapeutic processes, such as canal preparation, re-treatments, applied masticatory forces, and occlusal loading can be considered as secondary causes favoring cracks and fractures in dentin. However, to date, these factors have not been considered in research.

A few limitations observed during the research were mainly related to the file systems, since they were operated at different variables as recommended by the manufacturers. Therefore, files used at different speeds and torques could be a limitation in terms of standardization. It was difficult to regulate the downward force applied during each instrumentation. Force analyzer device, Endographe, can be a method used for standardization for future studies. This study included teeth with straight canals and without any anatomic complexities or irregularities, but they did not simulate clinical presentation [18]. Teeth with different dentin thicknesses were not involved in the study, which would certainly make a difference in the results due to their strength and response to stresses [19].

Greater taper instruments and specific motor mechanics can have a permanent impact on dentin structures, as mentioned in the paper. This can seriously compromise the prognosis of dental treatment and suggest that alterations in the instrument kinematics may lead to a decreased damage. Therefore, there is a high scope for research on the kinematics of endodontic instruments, and to understand their consequences on dentition [9].

CONCLUSIONS

Within the limitations of this study, all the groups produced dentinal defects. One Curve endodontic single-file rotary system used in rotary motion produced more dentinal defects compared with WOG single-file system in reciprocation motion. Thorough knowledge of the kinematics and mechanics of the instruments with correct chemico-mechanical means can help decreasing the incidences of dentinal defects, therefore assuring long-term treatment success.

CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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