https://doi.org/10.5272/jimab.2018244.2245

Journal of IMAB - *Annual Proceeding (Scientific Papers)*. 2018 Oct-Dec;24(4)

Journal of IMAB
ISSN: 1312-773X
https://www.journal-imab-bg.org

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Original article

INCIDENCE OF DENTINAL MICROCRACKS AFTER ROOT CANAL PREPARATION WITH TWO RECIPROCATING SYSTEMS: A STEREOMICROSCOPIC STUDY

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SUMMARY

Purpose: The objective of the present study was to evaluate the incidence of microcracks after root canal preparation with two reciprocating systems.

Materials and methods: Thirty – six freshly extracted mandibular incisors were selected for this *in vitro* study. The samples were allocated in three groups (n=12): negative control, Reciproc, WaveOne Gold. Roots in the control group were left unprepared. Reciproc R25 and WaveOne Gold Primary files were used in the other groups. After shaping of the root canals teeth were horizontally sectioned at 3, 6, 9 mm from the apex and the presence of dentinal defects were registered. These data were analyzed statistically by Fisher's exact and chi-square tests ($p < 0.05$).

Results: No defects were observed in the control group. All instruments caused dentinal microcracks with no statistically significant differences between the two systems. Defects in the apical region in both experimental groups differed statistically from those in the coronal portion of the roots.

Conclusions: WaveOne Gold and Reciproc systems performed equally and resulted in dentinal defect formation regardless of their alloy type, taper and cross-section.

Keywords: NiTi instruments, WaveOne Gold, Reciproc, microcracks, instrumentation

INTRODUCTION

The main objective of the initial endodontic therapy is to eradicate the existing microbiota by cleaning and shaping of the root canal, and to ensure its tight-seal, three-dimensional filling. Various NiTi rotary systems are preferred over hand instrumentation for enlargement of the root canal system due to their increased cutting efficiency, exclusive superelasticity and flexibility, as well as minimized procedural errors [1, 2]. However, these files can exert different levels of stress onto the root wall, resulting in microcrack formation [1, 3, 4]. The degree of dentinal damage depends on the alloy, taper, tip design, cross-section and kinematic type of each system [5, 6]. In time, minor defects such as craze lines and partial cracks can further propagate into vertical root fracture (VRF). This complication is one of the most common reasons for tooth extraction) [3, 4, 7].

The constant demand for reduction of operators' fatigue and treatment time, has led to the appearance of the single-file techniques [8]. The newly introduced WaveOne Gold (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) and Reciproc (*VDW, Munich, Germany*) NiTi single-file systems are used in reciprocating motion. It is assumed that the alternating counterclockwise and clockwise movement decreases the stress on the instrument. Furthermore, this movement reduces the cyclic fatigue caused by tension and compression and lowers the risk of file separation [9, 10].

Conflicting data exists in the literature regarding the incidence of dentinal microcracks after preparation of the root canal space with various reciprocating files. Up to now, it is still not known whether the design of the files and the improvements in the alloy they are manufactured from favor safer instrumentation of the root canal. The present study aims to analyze the occurrence of dentinal defects after preparation with two reciprocating, single-file, engine-driven NiTi instruments manufactured from different alloys and geometries.

MATERIALS AND METHODS

Thirty-six mandibular incisors with straight roots were included in the study. Immediately after extraction teeth were stored in purified, filtered water until use. The external surfaces of all samples were cleaned from calculus and plaque and examined under a stereomicroscope (*Leica S6, Leica Microsystems, Wetzlar, Germany*) for detection of root defects, cracks or fractures. Teeth with more than one root canal, apical curvature, immature root apices, fractured root apex and any root or coronal defects, including cracks, were excluded from the study and replaced with new ones. To ensure standardization, teeth were sectioned under water cooling with a diamond disc at 16 mm from the apex.

The roots were covered with a single layer of aluminum foil and inserted in putty impression material set in an acrylic tube. After removal of the foil, a light body

silicon based material (*Oranwash; Zhermak SpA, Rovigo, Italy*) was used to fill the space created in order to simulate the periodontal ligament. Afterwards, the root was returned into the acrylic mould.

Apical patency was determined by inserting a size 10 stainless-steel K-file into the root canal until its tip was visible at the apical foramen, and the working length (WL) was set 1.0 mm shorter than this measurement. Then, a glide path was established with a size 15 K-file (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) up to the WL. The shaping of the root canal was conducted with Reciproc and WaveOne Gold NiTi rotary files by using preprogrammed unchangeable settings of X-Smart endo motor (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*).

During the shaping procedure, the root canals were irrigated with saline using 27G endodontic irrigation needle. Each instrument was used per three root canals. All samples were kept moist in purified, filtered water in order to prevent dehydration.

The roots were evenly distributed into 3 groups (n=12) as follows:

Group I (negative control): unprepared roots.

Group II (Reciproc): roots instrumented with R 25 (25/.08)

Group III: (WaveOne Gold): roots instrumented with WaveOne Gold Primary (25/.07).

Sectioning and Microscopic Observation

All roots were sectioned horizontally at 3, 6 and 9 mm from the apex with a low-speed saw under water cooling (*Leica SP1600, Leica Microsystems, Wetzlar, Germany*). A total number of 108 slices were obtained and viewed under a stereomicroscope by using a cold light source at x 40 magnification (*Leica S6, Leica Microsystems, Wetzlar, Germany*). Digital images of each section were captured with a camera attached to the microscope.

The dentin surface was inspected by a single observer, and dentinal defects 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.

STATISTICAL ANALYSIS

Fisher's exact and chi-square tests were used for statistical analysis of differences between groups at 95% confidence level ($p < 0.05$).

RESULTS

The distribution of microcracks per group and section level is shown in Figure 1. No cracks were observed in the control group. No complete fractures were present in any of the tested specimens. Comparison between Reciproc and WaveOne Gold instrumented group revealed insignificant difference concerning the number of defects registered at the three examined levels. In both tested groups defects at the apical portion of the root canal were significantly higher than those evaluated at the coronal portion ($p<0.05$) Table 1, Figure 2.

Fig. 1. Distribution of dentinal defects in 3, 6, 9 mm levels from the apex.

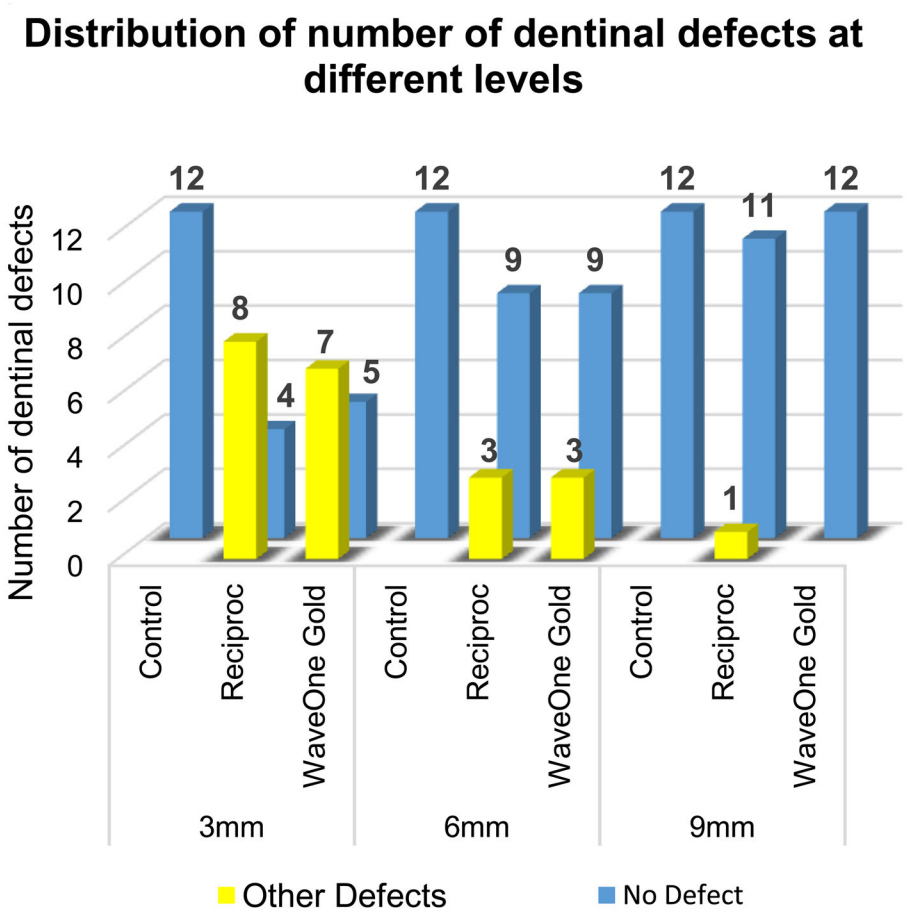
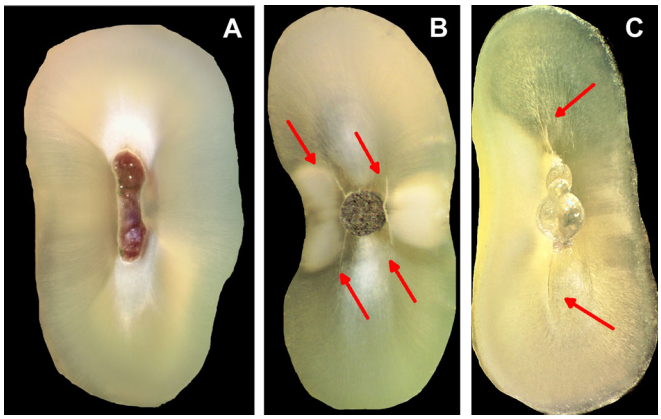


Table 1. Number and percentage of dentinal defects at different levels in the two experimental groups. Different letters in each tested group exhibit a statistically significant difference.

Level	Dentinal damage	Number and percentage of defects	Reciproc	WaveOne Gold	Total
3 mm	No defect	N	4	5	9
		%	33,3%	41,7%	37,5%
	Other defects	N	**8a**	**7a**	15
		%	66,7%	58,3%	62,5%
6 mm	No defect	N	9	9	18
		%	75,0%	75,0%	75,0%
	Other defect	N	3b	3a,b	6
		%	25,0%	25,0%	25,0%
9 mm	No defect	N	11	12	23
		%	91,7%	100,0%	95,8%
	Other defect	N	**1b**	**0b**	1
		%	8,3%	0,0%	4,2%

Fig. 2. Stereomicroscopic image at 3 mm level under x40 magnification: A) unprepared control group; B) Cracks produced by Reciproc R25; C) Cracks produced by WaveOne Gold Primary



DISCUSSION

The choice of the two single-file, reciprocating systems in the present study was made on the basis of previous reports claiming that this type of kinematics is safer than the full-sequence rotary instrumentation [4, 11]. *Jamleh et al.* stated that reciprocation provides the lowered magnitude of the forces accumulated on the root dentin and prevents the formation of microcracks and complete root fractures [12].

Based on the Gold technology files exhibit enhanced flexibility, fatique resistance and controlled memory effect compared to conventional and M-wire NiTi instruments [13]. It might be speculated that shaping with this novel, gold, heat-treated instruments would result in a lesser number of dentinal microcracks. Nevertheless, our results indicated that the type of alloy did not influence the defect formation as dentinal cracks in the three portions of the root canals instrumented with WaveOne Gold and Reciproc did not differ statistically. These findings are in contrast with the investigation of *Cassimiro et al.* In their study, the number of dentinal defects observed in the WaveOne Gold group was three times higher than that in the Reciproc group [14].

Conclusions on the relationship between the design of the NiTi instruments and their ability to cause dentinal defects are contradictory. *Kim et al.* assessed the link between NiTi files design with the generation of apical stress and strain concentrations during instrumentation [6]. The contact of files with different cross-sections with the dentinal surface may exert high pressure, causing an instant microcrack formation [6, 15]. In our experiment, the roots were prepared with two files with different cross-sections. Reciproc has an S-shaped cross-sectional design, with two cutting edges and a positive angle, which results in effective removal of dentin [2]. WaveOne Gold file has an offset parallelogram cross-section with alternating touches on the dentin with 2 edges apically and 1 coronally during a 360° rotation. [14]. Lack of statistically significant difference between the two tested systems by us might be due to the similar number of contacts of the instrument blades with the dentinal wall.

File taper is another contributing factor to the occurrence of dentinal defects, especially in narrow roots. The larger the taper, the greater amount of dentin is removed, thus, increasing fracture susceptibility of the tooth [16]. The two files used in the current *in vitro* study had equal apical diameters (ISO 25) and almost the same conicity at the tip of the instrument. This might explain the lack of statistically significant difference between the systems at the 3 mm level of the roots in terms of crack initiation ($p>0.05$). The taper of Reciproc (25/.08) and WaveOne Gold (25/.07) files is fixed in the first few millimeters of the tip

and then progressively decreases. This construction increases the file's flexibility and preserves the dentin in the coronal 2/3 of the root canal [8]. The findings in our experiment confirmed this statement. The higher number of defects at the apical level of the root in each of the tested files in comparison with the coronal 1/3 and the difference was statistically significant.

Recently, several methods for dentinal defect detection have been advocated. Sectioning of the specimens at apical, middle and coronal level followed by their stereomicroscopic evaluation is one of the most prevailing approaches [1]. This destructive methodology may also generate cracks and does not allow the assessment of pre-existing ones [17]. In order to guarantee an unbiased evaluation and exclude these limitations, we used a negative control group. No cracks appeared in the negative control group, confirming that the incidence of any dentinal damage occurred during the instrumentation procedures, which is in agreement with the findings obtained in previous studies [3, 14, 16, 17].

There are no unified criteria regarding sample selection in *in vitro* studies on dentinal crack initiation and propagation [1]. A finite-element analysis showed that stress concentrations were highest in oval roots, presenting greater buccal-lingual diameter [18]. It is suggested that the higher strain accumulation observed in buccal-lingual direction is due to the reduced proximal dentin thickness. Oval root canals present sharpened notch at the edge of the oval extension, which compared to round canals, is a site more susceptible to crack initiation when mesiodistal forces are applied from the inside out [8]. In an attempt to overcome the bias in the sample selection and to provide reproducible conditions for the conduction of the present in vitro experiment, we utilized mandibular incisors, which are more prone to fracture. Furthermore, to enable better stress distribution during the shaping procedures, we simulated PDL in our experimental design as suggested previously by other authors [4, 7]. Unlike most of the studies focused on the effects of different NiTi systems on the dentinal wall, we used saline as interim irrigation. This choice aimed to diminish the deleterious effect of various endodontic irrigants such as NaOCl, EDTA [19].

CONCLUSION

Within the limitations of the present study, it could be concluded that the single-file, reciprocating WaveOne Gold and Reciproc systems performed equally and resulted in dentinal defect formation regardless of their alloy type, taper and cross-section. Significantly greater number of microcracks was observed in the apical section of the root canal in both experimental groups compared to its coronal aspect.

ACKNOWLEDGMENTS

This article is sponsored by the Scientific Council of Medical University – Sofia, Bulgaria. Project No. 4847/25. 07. 2017; Contract No.239/15. 12. 2017.

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Please cite this article as: Tsenova I, Vassileva R, Karova E. Incidence of Dentinal Microcracks after Root Canal Preparation with Two Reciprocating Systems: A Stereomicroscopic Study. *J of IMAB*. 2018 Oct-Dec;24(4):2245-2249. DOI: https://doi.org/10.5272/jimab.2018244.2245

Received: 08/08/2018; Published online: 23/11/2018

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