

Dentinal crack formation during root canal preparations by the twisted file adaptive, Reciproc and WaveOne instruments

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ABSTRACT

Objective: This study aimed to compare the frequency of dentinal microcracks after root canal shaping with 2 reciprocating (Reciproc and WaveOne) and 1 combined continuous reciprocating motion twisted files adaptive (TFA) rotary system. **Materials and Methods:** Ninety molars were chosen and divided into three groups of 30 each. Root canal preparation was achieved by using Reciproc R25, Primary WaveOne and TFA systems. All the roots were horizontally sectioned at 15, 9, and 3 mm from the apex. The slices were then viewed each under a microscope at $\times 25$ magnification to determine the presence of cracks. The absence/presence of cracks was recorded, and the data were analyzed with a Chi-square test. The significance level was set at $P < 0.05$. **Results:** Instrumentation with Reciproc produced significantly more complete cracks than WaveOne and TFA ($P = 0.032$). The TFA system produced significantly less cracks than the Reciproc and WaveOne systems apically ($P = 0.004$). **Conclusions:** Within the limits of this study, the TFA system caused less cracks than the full reciprocating system (Reciproc and WaveOne). Single-file reciprocating files produced significantly more incomplete dentinal cracks than full-sequence adaptive rotary motion.

Key words: Adaptive motion, dentinal defects, microcracks, reciprocation, single-file system

INTRODUCTION

Instrumentation with nickel-titanium (NiTi) instruments can result in some complications such as root canal transportation, perforations and vertical root fracture.^[1] Shaping procedures can damage the root dentin, resulting in dentinal cracks which can develop into vertical root fractures.^[2-4] The most susceptible teeth to fracture are those with a narrow distomesial dimension compared with the linguobuccal diameter as in mesial roots of lower molars.^[2]

With the newly introduced single-file NiTi systems Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) it is possible to shape canals with only 1 instrument, thereby requiring less time than rotary full-sequence systems.^[5] These files are produced with a special NiTi alloy (M-wire) subjected to a special thermal treatment process to increase the flexibility of the instrument.^[6] WaveOne and Reciproc files are used in a reciprocating

motion, in order to reduce stress on the instrument and to minimize fracture of cyclic fatigue.^[7,8]

Another new generation of NiTi instrumentation system has been introduced called the twisted files adaptive (TFA) (SybronEndo, Orange, CA). The TFA are produced by transforming the NiTi wire from the austenitic crystalline structure to the super-elastic crystalline R-phase structure by a method of heating and cooling.^[9,10] The TFA is used in a combination of both, reciprocating and continuous rotation. According to the

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load of pressure exerted on the file, the TFA instrument can change from continuous rotation to reciprocation mode with clockwise and counterclockwise angles varying from 0° to 600° up to 370–50°.

The quantity of dentine structure remnant is correlated to the strength of a root filled tooth.^[11] Dentine removal during root canal shaping was found to have an incidence on the formation of incomplete cracks.^[12-14] Moreover, it might be speculated that when using only one instrument, more stress will be generated during instrumentation, increasing the frequency of dentinal defects.^[15] Therefore, the aim of the present study was designed to evaluate the frequency of dentinal microcracks observed after root canal preparation with reciprocating (Reciproc and WaveOne) and “Adaptive Motion” (TFA) instruments. The null hypothesis was that there would be no significant differences in crack formation among groups.

MATERIALS AND METHODS

Ninety freshly extracted mandibular first and second molars with completely separated canals and mature apices were chosen. Only teeth with a curvature of the mesial root <25° were selected.^[16] Canals were controlled for apical patency with a size 15 K-file (VDW). The canal width near the apex was approximately compatible with size 15. This was checked with silver point sizes 15–25 (VDW). The coronal portions and distal roots of the teeth were removed by using an Isomet low speed saw (Isomet; Buhler Ltd., Lake Bluff, NY) under water cooling, leaving mesial roots with approximately 18 mm in length to prevent the introduction of confounding variables. All roots were observed with under a × 25 magnification stereomicroscope (Expert DN; Müller Optronic, Erfurt, Germany) to exclude cracks. As a result, 120 teeth were selected.

Samples were randomly assigned to each group ($n = 30$) according to the system used for root canal shaping.

Group 1: Reciproc group ($n = 30$)

All root canals were instrumented with the R25 (25/0.08) Reciproc single-file according to the instructions of the manufacturer. R25 was introduced with about amplitude of 3 mm with a slow in- and-out pecking motion and Reciproc VDW silver motor (VDW GmbH). After 3 pecking motions, the canal was irrigated with NaOCl (5.25%, 3 mL). Root canal patency was verified with a size K15 file to the working length (WL). This procedure was repeated until R25 reached WL.

Group 2: WaveOne group ($n = 30$)

WaveOne taper 0.08 and size 25 reciprocating file was introduced into the root canals in a slow in- and-out pecking motion with about amplitude of 3 mm according to the manufacturer's instructions. The WaveOne instrument was mounted on the VDW silver reciprocating motor using the manufacturer configuration setup. Root canals were irrigated with NaOCl (5.25%, 3 mL) after 3 pecking motions.

Group 3: Twisted files adaptive group ($n = 30$)

TFA instruments were used with the Elements Adaptive Motion Technology. Instrument sequence was TFA 25 taper 8 followed by TFA 25 taper 6 and 25 taper 4 to the WL. After reaching WL with 25 taper 4, TFA 25 taper 6 followed by TFA 25 taper 8 were taken to WL.

Between instruments, canals were irrigated with NaOCl (5.25%, 3 mL).

All groups

After instrumentation, all root canals were irrigated with NaOCl (5.25%, 3 mL). Irrigation was performed using an Endo-Eze (Ultradent, South Jordan, USA) irrigator tip mounted on a disposable 3 mL syringe. When preparation was achieved ethylenediaminetetraacetic acid (15%, 1 mL) (Wizard, Rehber Kimya San., Istanbul, Turkey) was applied for 1-min and canals were irrigated again with NaOCl (3 mL). Each instrument was changed after 3 canals. The final apical preparation resulting was standardized to size 25, taper 8% for all groups.

One operator performed all root canal preparations, and the assessments of the cross sections were performed by 2 examiners who were blinded in respect to all experimental groups.

After preparation, all the roots were sectioned horizontally at 3 (apical third), 9 (middle third) and 15 (cervical third) mm from the apex with a 0.1 mm low-speed saw (Leitz, Wetzlar, Germany) under water-cooling. To avoid any artifact by dehydration, the teeth were stored in purified filtered water throughout the experiment.^[17,18]

Dentinal microcrack evaluation

All slices were observed under a digital stereomicroscope (Expert DN) at × 25 magnification by using a cold light source and pictures were taken. In cases of discrepancy in the observations of the 2 examiners, the slices were inspected again and discussed until a consensus was reached. Fracture,

incomplete cracks, and craze lines, as well as the relative and absolute length of the defects, were recorded by using the ImageJ software (National Institutes of Health, public domain). The incidences of the different defects were analyzed by using the Chi-square test and the Fisher exact test at a significance level of $P < 0.05$.^[18,19]

Definitions of the defects

No defect is root dentin without any lines or cracks on the external or the internal surface of root [Figure 1].

An incomplete crack is a line extending from the canal wall into the dentin without reaching the outer surface.

A complete crack is a line extending from the root canal wall to the outer surface of the root [Figure 2].

Craze lines are all other lines that did not reach any root surface or extend from the external surface into the dentin but did not attain canal wall.

RESULTS

The distribution of the different defects is summarized in Tables 1 and 2.

Overall, Reciproc produced significantly more complete cracks compared with WaveOne and TFA ($P = 0.032$). There was no significant difference between TFA and WaveOne ($P > 0.05$). Regarding the middle and coronal third sections (15 and 18 mm), no significant difference was found between the 3 file systems ($P > 0.05$).

Only in the apical third section (3 mm) Reciproc and WaveOne produced significantly more incomplete cracks than TFA ($P = 0.004$). In the middle third section (9 mm), only the Reciproc system produced significantly more incomplete cracks ($P = 0.032$). In the coronal third sections, no significant difference was found between the 3 file systems ($P > 0.05$).

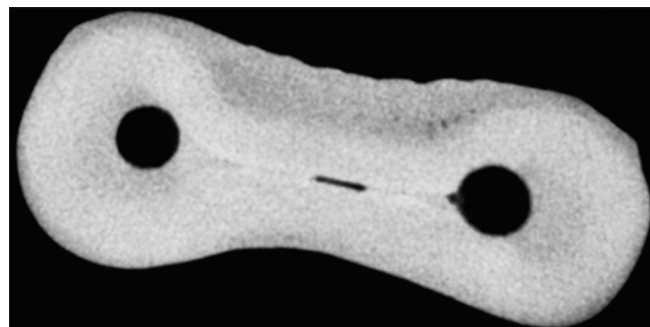


Figure 1: Cross section at the 3-mm without any dentinal defects

Craze lines were detected in the Reciproc group in the middle third with a significant difference ($P = 0.003$) [Table 3].

DISCUSSION

Vertical root fracture is not an instant phenomenon but rather a result of crack propagation.^[20] The main goal of the present investigation was to study the effect of two different kinematics using single-file and multiple file systems. This study revealed the incidence of dentinal defects was higher with single-file reciprocating instruments.

In the apical part of the canals, reciprocating files produced significantly more incomplete cracks compared with the rotary reciprocating adaptive motion ($P < 0.05$). The differences between the instruments tested regarding the incidence of dentinal defects may be due to the preparation technique and the cross-sectional design of instruments. The reciprocal motion seems to enhance debris transportation towards the apex and may increase torsional forces.^[11,20] It should be evaluated in further studies whether these increased torsional forces are associated with an increased risk of creating dentinal defects.

Reciproc instruments caused more complete cracks than WaveOne. The higher frequency may be correlated to the cross-sectional design of the instrument. In fact, the Reciproc R25 has an S-shaped geometry with a double cutting edge while WaveOne has a modified triangular cross section with radial lands at the tip and a convex triangular cross section in the middle and coronal portion of the instrument. The WaveOne cross section results in lower cutting efficiency and less chip space.^[5,21]

In the apical third and in the whole root canal, TFA produced the least dentin defects. The lowest incidence may be due to the new adaptive reciprocating motion.

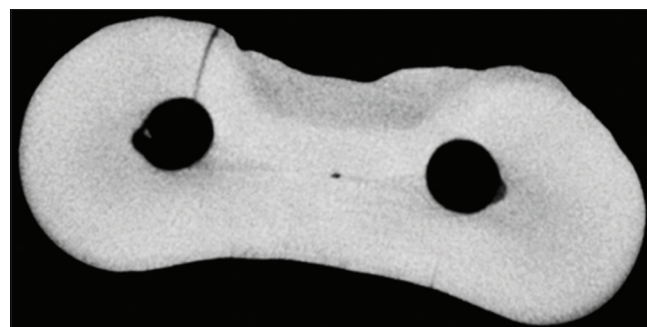


Figure 2: Cross section at the 3-mm level showing a complete crack

Table 1: Number of complete cracks in the different cross-section slices ($n=30$ in each group) and percentage of sections in which defects were present

	Absolute number of complete cracks/ percentage of specimens with complete cracks			
	Apical third	Middle third	Coronal third	Total
Reciproc ($n=30$)	4 (13.3) ^a	0 (0.0)	0 (0.0)	4 (4.4) ^a
WaveOne ($n=30$)	0 (0.0) ^b	0 (0.0)	0 (0.0)	0 (0.0) ^b
TFA ($n=30$)	0 (0.0) ^b	0 (0.0)	0 (0.0)	0 (0.0) ^b
<i>P</i>	0.032	1.000	1.000	0.035

Values with the same superscript letter were not statistically different, TFA: Twisted File Adaptive

Table 2: Number of incomplete cracks in the different cross-section slices ($n=30$ in each group) and percentage of sections in which defects were present

	Absolute number of incomplete cracks/ percentage of specimens with incomplete cracks			
	Apical third	Middle third	Coronal third	Total
Reciproc ($n=30$)	12 (40.0) ^a	4 (13.3) ^a	0 (0.0)	16 (17.8) ^a
WaveOne ($n=30$)	12 (40.0) ^a	0 (0.0) ^b	0 (0.0)	12 (13.3) ^a
TFA ($n=30$)	2 (6.7) ^b	0 (0.0) ^b	0 (0.0)	2 (2.2) ^b
<i>P</i>	0.004	0.032	1.000	0.003

Values with the same superscript letter were not statistically different, TFA: Twisted File Adaptive

Table 3: Number of craze lines in the different cross-section slices ($n=30$ in each group) and percentage of sections in which defects were present

	Absolute number of craze lines/ percentage of specimens with craze lines (%)			
	Apical third	Middle third	Coronal third	Total
Reciproc ($n=30$)	0 (0.0)	6 (20.0) ^a	0 (0.0)	6 (6.7) ^a
WaveOne ($n=30$)	0 (0.0)	0 (0.0) ^b	0 (0.0)	0 (0.0) ^b
TFA ($n=30$)	0 (0.0)	0 (0.0) ^b	0 (0.0)	0 (0.0) ^b
<i>P</i>	1.000	0.003	1.000	0.004

Values with the same superscript letter were not statistically different, TFA: Twisted File Adaptive

The file uses continuous rotation when it is exposed to a minimal or no applied load and uses reciprocal motion when it engages dentin and load is applied.^[22] The adaptive motion combined with the high flexibility and the multi-file system seems to decrease torsional forces resulting in less dentine defects.

No definitive conclusion can be made regarding the clinical implication of these dentinal defects on long-term follow-up. The presence of microcracks and dentinal defects after instrumentation has been

reported.^[2,23] These dentinal defects can become high-stress concentration areas which may propagate to the root canal surface when an external force is applied.^[24] Currently, there is an evident lack of correlation between the results obtained in this type of studies and the clinical situation. Despite efforts to reproduce the clinical conditions, it is impossible to eliminate possible influence of external factors such as storage of the specimens.

The sectioning method used in the study allowed evaluation of the impact of root canal treatment procedures on dentin root by direct inspection of the root. This method is in agreement with a methodology described in a previous study.^[17,25] However, other methods have been described such as stress distribution measures, observations of the presence of cracks in tooth sections, and resistance of the root canal treated tooth to fracture.^[24,26-28] The latter method applies an external force until root fractures.^[28] The method in the present study differed from that approach because no external forces were applied, and the influence of root canal preparation on the root canal walls and the adjacent dentin was observed directly. In addition, resistance to fracture does only provide information on vertical root fracture, but the occurrence of dentinal defects cannot be detected.

CONCLUSIONS

Under the study limitations, there was a significant difference between the groups in the formation of dentinal microcracks. Therefore, the null hypothesis is rejected. The TFA system caused less root microcracks than the Reciproc and WaveOne files. Overall, Reciproc produced the most complete microcracks. Further studies are required to assess the advantage of single-file reciprocating root canal instrumentation concerning its impact on the incidence of root microcracks.

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Conflicts of interest
There are no conflicts of interest.

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