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Original Article

Fracture strength of roots instrumented with three different single file systems in curved root canals

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ABSTRACT

Objective: The aim of this study was to compare the fracture strength of roots instrumented with three different single file rotary systems in curved mesial root canals of maxillary molars. **Materials and Methods:** Curvatures of 25°–35° on mesial roots of 60 maxillary molar teeth were sectioned below the cementoenamel junction to obtain roots 11 mm in length. The roots were balanced with respect to buccolingual and mesiodistal diameter and weight. They were distributed into three experimental groups and one control group (no instrumentation) (n = 15): Reciproc rotary file (R25, VDW, Munich, Germany), WaveOne Primary rotary file (Dentsply Tulsa Dental Specialties, Tulsa, UK) and OneShape (Micro-Mega, Besancon, France) rotary file. Vertical load was applied until fracture occurred. Data were statistically analyzed using one-way analysis of variance test ($P < 0.05$). **Results:** The mean fracture load was 412 ± 72 Newton (N) for the control group, 395 ± 69 N for the Reciproc group, 373 ± 63 N for the WaveOne group and 332 ± 68 N for the OneShape group. The fracture load differences among three experimental groups were not statistically significant ($P > 0.05$.) Whereas, the fracture loads of control and OneShape groups were significantly different ($P = 0.012$). **Conclusions:** Fracture resistance of the roots instrumented with WaveOne and Reciproc file systems were similar to the control group whereas it was observed that OneShape rotary file systems enhance the fracture strength of standardized curved roots when compared with the control group.

Key words: Curved root, fracture resistance, root fracture, single file systems

INTRODUCTION

The strength of endodontically treated teeth are affected from several predisposing factors such as excessive loss of tooth structure due to caries or trauma, dehydration of dentin, access cavity preparation and instrumentation with rotary files, undesirable effects of irrigation solutions, excessive pressure during filling procedures and preparation of intraradicular postspace.[1-3] Experimental studies have shown that excessive removal of dentin during root canal preparation, postspace preparation, and obturation procedures increase susceptibility to root fracture.[4,5] Clinically, these fractures may decrease the long-term survival rate. Vertical root fracture (VRF) associated with endodontically treated teeth is one of the most difficult clinical complications that may occur due to instrument design, kinematics, and mechanical behavior or following root canal treatment procedures.[3,6] During shaping, geometric design of various rotary instruments also affects the root stresses.[7] Kim *et al.* reported a potential relationship between the design of nickel-titanium (Ni-Ti) instruments and the incidence of VRF.[8] The diameter of the prepared canal is another potential factor that could affect the tendency to VRF. Excessive taper may result in excessive removal of dentin and weakening of the root.[9]

Over the last decades, technological advances in endodontic treatment with rotary Ni-Ti instruments

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have led to new design concepts.[10] Various studies concluded that rotary Ni-Ti instruments exhibit higher performance than hand instruments such as easier, faster and better root canal shaping and less apical canal transportation.[11-13] Rotary Ni-Ti instruments facilitate root canal treatment, whereas they can weaken the tooth structure particularly in curved canals.[14] Especially the straightening of curved root canals with rotary Ni-Ti instruments are one of the major problems since they cause ledge formation, file fractures, and even perforation during root canal preparation.[15] Recently, manufacturers have introduced a new generation of Ni-Ti rotary instruments with a variable cross-sectional design and different working motion which completes canal preparation with only one instrument.[16]

The reciprocating single file systems such as Reciproc (VDW, Munich, Germany) and WaveOne (Maillefer, Ballaigues, Switzerland) provides more flexibility of the M-wire Ni-Ti alloy, greater resistance to cyclic fatigue and better handling of narrow and curved canals than the traditional Ni-Ti instruments and they are widely used in endodontic treatment.[17,18] These file systems use reciprocating movements in the preparation of root canals.[19] Another single file system is OneShape file (Micro-Mega, Besancon Cedex, France), which is used in a traditional continuous rotating motion.[20]

Several studies have compared the incidence of root cracks after root canal instrumentation with rotary systems[20-22]; however, the fracture strengths of roots instrumented with single file systems have not yet been compared. Our hypothesis was that instrument design, kinematics and mechanical behavior of single file rotary systems affect the extent of dentinal defects and consequently VRF susceptibility. The aim of this *in vitro* study was to assess the effect of single file systems on the fracture strength of curved mesiobuccal (MD) roots of maxillary first molars.

MATERIALS AND METHODS

This *in vitro* study was approved by the Medical Ethics Committee of Sifa University (Protocol No. 152-48). In total, 60 maxillary molar teeth with MD roots (curvatures of 25°–35° were included according to the method of Schneider[23]) recently extracted from patients were used and stored in 0.1% thymol until the beginning of the experiments but no longer than 30 days after extraction. The teeth were examined with a stereomicroscope under ×10 magnification (Zeiss, Oberkochen, Germany) to exclude any roots with open apices, root caries, cracks or fractures. Preoperative radiographs were obtained in the mesiodistal (MD) and buccolingual (BL) directions to confirm the presence of a canal without previous root canal treatment or calcifications. Teeth with such findings were excluded from the study and replaced by similar teeth. The coronal portions of all teeth were removed with a diamond-coated bur under water cooling, leaving roots approximately 11 ± 1 mm in length. The roots with standardized dimensions and weights were used to ensure homogeneity that BL and MD dimensions of the root canals were measured using a digital caliper (Teknikel, Istanbul, Turkey). Subsequently, the BL and MD diameters were multiplied. The weights of the roots were measured with a precision balance (Kern, Balingen, Germany) for the standardization of the samples. The roots were evenly distributed to three experimental groups and one control group (n = 15), based on their weights and the homogeneity of the groups [Figure 1]. This parameter was assessed using the analysis of variance (ANOVA) test (P = 0.322 for the weights and P = 0.837 for the products of the BLs and MDs).

Control group: No instrumentation

The root canals were not shaped or filled. These were used as a control.

Group 2: Instrumentation with Reciproc system

In the Reciproc group, R25 (25.08), (VDW, Munich, Germany) using Silver Reciproc reciprocating engine in a reciprocating motion in "Reciproc all" mode (VDW, Munich, Germany). The flutes of the instruments were cleaned after three pecking motions.

Group 3: Instrumentation with WaveOne system

In the WaveOne group, WaveOne primary

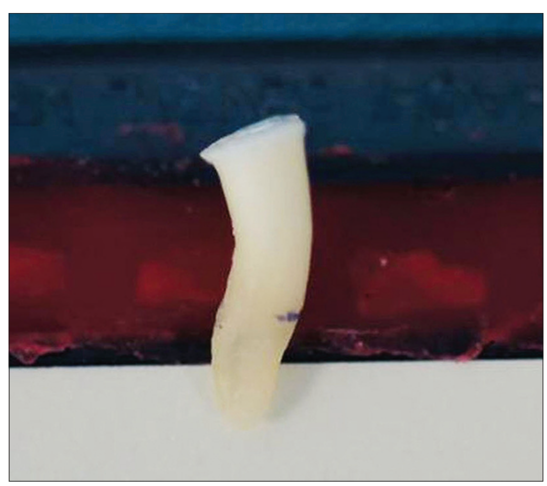

Figure 1: A specimen of curved mesiobuccal root

file (Dentsply Maillefer, Ballaigues, Switzerland) having a tip size 25.08 was applied using the same motor controller in "WaveOne all" mode.

Group 4: Instrumentation with OneShape system
In the OneShape group, root canal preparation was performed with OneShape rotary file No. 25.06 (Micro-Mega, Besancon, France) using a low-torque motor (VDW Silver, Munich, Germany) at a constant speed of 400 rpm and 400 gcm torque.

During the preparation, all root canals were irrigated with 2 mL 2.5% NaOCl solution after each instrument. After the instrumentation, a final flush was applied using 5 mL 17% ethylenediaminetetraacetic acid for 1-min and 5 mL 2.5% NaOCl for 1-min followed by the final rinse with 5 mL distilled water.

Placement of roots and fracture measurement
Acrylic resin blocks were prepared using cylindrical plastic molds (25 mm high and 10 mm in diameter). Self-cured acrylic resin (Imicryl, Konya, Turkey) was used to prepare the blocks. As described previously, the apical root ends were embedded vertically in 4 mm of the acrylic resin blocks before the setting.[3] The roots were kept wet with a wet towel to prevent dehydration until they were ready for strength testing. Instron testing machine (Shimadzu, Kyoto, Japan) running at a crosshead speed of 1 mm/min was used to fracture the roots. A steel conical tip (tip diameter = 0.5 mm, tapered at 60°) was attached and aligned with the center of the canal orifice parallel to the long axis of each specimen. The load necessary for fracture was recorded and expressed in Newton (N) [Figure 2].

Statistical analysis
The BL and MD dimensions, multiplication of the BL-MD diameter, and weights were subjected to a Kolmogorov–Smirnov statistical test to test the normality of these continuous variables. One-way ANOVA test of variance test was used to evaluate the difference among the BL and MD dimensions, multiplication of the BL-MD diameter, and the weight of the samples. After completing the fracture test, the data were subjected to statistical analysis using One-way ANOVA test of variance with Tukey *post-hoc* test for multiple comparisons.

Correlations between fracture data and BL and MD dimensions, multiplication of the BL-MD diameter, and weights were assessed using the Pearson correlation test. The testing was performed at the 95% level of confidence ($P < 0.05$).

RESULTS

The fracture loads of the roots and other variables in the four groups are shown in Table 1. Statistical analysis approved the standardization of roots among the groups according to weight, BL, and MD diameter, multiplication of the BL-MD diameter and fracture load. Failure load was applied until all of the roots fractured vertically in the labiolingual direction during testing. The mean fracture load was 412 ± 72 N for the control group, 395 ± 69 N for the Reciproc group, 373 ± 63 N for the WaveOne group and 332 ± 68 N for the OneShape group.

In this study, all of the roots were fractured vertically in the labiolingual direction during testing. The fracture load differences among Reciproc, WaveOne and OneShape were not statistically significant ($P > 0.05$).

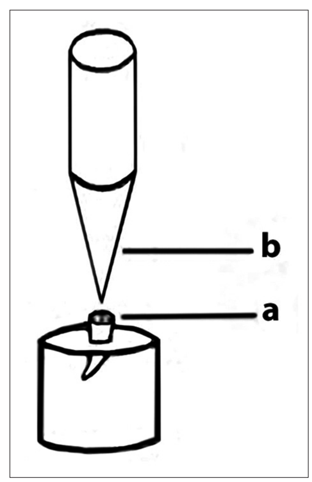

Figure 2: The experimental setup. (a) The apical root ends were embedded vertically in 4 mm of the acrylic resin, exposing 7 mm of the coronal portion of each root. (b) The blunt punch was attached to contact the root canal space until fracture occurred

Table 1: Cross-sectional diameters, multiplication of the BL-MD diameters, weights and fracture loads of the roots

Groups	*n*	BL	MD	Multiplication of BL and MB	Weight (g)	Fracture load (*n*)
Control	15	4.75±0.90	4.39±0.47	21.23±5.95	0.14±0.02	412.0±72*
Reciproc	15	4.50±0.71	4.41±0.25	16.71±2.75	0.15±0.02	395.0±69
WaveOne	15	4.91±0.48	4.19±0.09	20.62±2.24	0.16±0.05	373.5±63
OneShape	15	4.30±0.17	4.20±0.40	16.30±1.43	0.12±0.01	332.0±68*

*P<0.05. BL: Buccolingual, MD: Mesiodistal, MB: Mesiobuccal

Whereas, the difference between the fracture loads of control and OneShape groups was statistically significant ($P = 0.012$).

DISCUSSION

Anatomic variations of the roots, extraction time, age of teeth, storing conditions may affect the results of a study.[3,5] Standardization of the samples during mechanical tests is an important factor in the study in which fracture resistance is evaluated. In the present study, we selected as possible as similar teeth, and the roots were equalized with respect to the BL-MD diameter.[7,21] multiplication of the BL-MD diameter and the weight of the root among groups to eliminate variation factors.[3] If roots were not distributed among the groups equally, these parameters could have affected the results of *in vitro* studies.[24] Thus, In our study, we selected as possible as similar maxillary molar teeth with curvatures ranging in 25°–35° in order to stimulate the real clinical condition and investigated the fracture strength of roots instrumented with three single file systems that have different designs and kinematics (continuous rotation, reciprocating motion).

Resistance to fracture is an important factor both for subsequent restoration and function in endodontic treatment.[7] Over the last decades, Ni-Ti rotary instruments have been used in endodontic treatment and applied with rotational force on root canal walls, therefore they create microcracks, craze lines or VRF in root dentin.[21] The extent of such complications is related to the mechanical behavior of different preparation systems and geometric shape (the tip design, constant or progressive taper, constant or variable pitch) of Ni-Ti rotary instruments.[8] During root canal preparation, the contact between instrument and dentin walls provides the canal shaping. These contacts can cause many momentary stress concentrations in dentin, especially highest root stresses are actually located at the most curved midroot canal wall area.[25] Existence of such high stresses in these roots are expected to increase dentinal defects during instrumentation and thus VRF risk.[8]

Recently, some researchers have suggested that single file techniques used for root canal preparation are mostly based on practicability, simplicity and lower stress values on root canal walls than others.[7,26,27] To the best of our knowledge, there is no data in the literature about single file rotary systems regarding fracture strength. For this reason, the findings of the present study can only be compared with a study in which the resistance of the root micro cracks has been compared with other single file rotary systems. However, there are limited studies in which micro cracks were evaluated in single file systems.[20,21] An external force applied during the treatment, excessive removal of dentin or canal curvature, the craze lines and incomplete cracks in the dentin might become high-stress concentration areas. Previous studies showed that the influence of endodontic procedures on the root canals induces craze lines and incomplete cracks.[21,27] Thus, the crack may gradually spread to the root canal surface, and VRF occurs as a result of the propagation of a crack.[7,28]

It is considered that differences in rotational speed of rotary Ni-Ti instruments and cross-sectional designs are important factors in dentinal stresses. Recently, some researchers reported that OneShape single file system which works in a continuous rotation motion leads to weaker canals and stress on the dentinal walls compared with Reciproc single file system.[20,29] However, Reciproc instruments work in a reciprocating movement which is similar to the balanced force technique and also its cross-sectional design providing lower stress value on the dentinal walls than OneShape file.[26]

OneShape file has an asymmetric cross-sectional geometry, which has a tip size of 25 and constant taper of 0.06 and a rotational speed of 400 rpm, whereas WaveOne and Reciproc files have a taper of 0.08 over the first 3 mm from the tip which caused significantly less cracks than the OneShape file and a rotational speed of 300 and 350 rpm respectively.[26]

Liu *et al*.[20] compared three single file systems regarding the incidence of root cracks at the apical root surface and/or in the canal wall after canal instrumentation (OneShape, Reciproc and Self-Adjusting File) and they found that OneShape caused cracks in 35% whereas Reciproc files caused cracks in 5% of teeth only. This finding may be related with the differences in cross-sectional design of files or the reciprocating motion causing less dentinal damage than the continuous rotation motion.

Fracture resistance following endodontic treatment is vital both for the restoration and the functioning of the tooth. During root canal preparation, the dentin walls could be excessively thinned, and fracture risk could be increased.[3] According to the results of this study, it has been shown that fracture load differences among the root canal instrumentation with WaveOne and Reciproc file systems were not statistically significant compared with control groups, whereas the difference between OneShape and control groups were statistically significant ($P = 0.012$). Under the conditions of this study, it can be concluded that WaveOne and Reciproc file systems may decrease the risk of VRF than OneShape in the curved canals, and they might be recommended for clinical use.

While the results of this *in vitro* study did not reflect the clinical settings, we concluded that single file rotary systems tend to induce various degrees of dentinal damage, and they might cause VRF during root canal treatment. Further studies regarding speed, kinematics and torque of single file rotary instruments in curved canals and in other groups of teeth are required to assess the short and long-term impacts of instrumentation on the presence of cracks and VRFs.

CONCLUSION

Within the limitations and standardization conditions of this study, it can be concluded that fracture resistance of the roots instrumented with WaveOne and Reciproc file systems were similar to the control group whereas OneShape rotary file system enhance the fracture strength of standardized curved roots compared with the control group.

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