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A Comparative Evaluation of two engine driven Nickel-Titanium files used in different kinematics

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Abstract

Introduction: this study aims to compare two engine driven Nickel-Titanium files used in different kinematics, regarding Root surface strain (RSS), fracture resistance of roots and preparation time.

Material and methods: Mesial root canals of twenty five mandibular first molar were collected, embedded in resin moulds and strain gauge connected to the exposed apical part of the root. The specimens were divided into two study groups (n=10); the Reciproc R25 group and the TFA ML1 Group, and one control group (n=5) according to the file used in the preparation. RSS was recorded for each root and overall RSS calculated. Preparation time was recorded. After the root canal preparations the roots were loaded in the Universal testing machine until fracture and the force used was recorded.

Results: Reciproc caused significantly higher RSS than TFA and took significantly longer preparation time. Roots prepared with reciproc showed significantly lower fracture resistance than those prepared with TFA.

Conclusion: TFA File causes less Root strain and could help to lower the risk of root fracture after root canal treatment.

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Introduction

One of the main steps in achieving successful endodontic treatment is mechanical preparation of the root canal. This has to be done to achieve proper debridement of the root canal without changing the original shape of the root canal. Aberrant root canal anatomies makes proper debridement difficult and might lead to unwanted adverse events such as generation of excessive root surface strain, canal transportation, dentine microcracks with subsequent root fractures. The incidence of such unfortunate events is high with using stainless steel files and hence the development of Nickel-Titanium (NiTi) files for a safer root canal preparation. Despite the use of highly flexible NiTi files in both rotary and reciprocating motions, dentinal defects after the instrumentation were inevitable indicating the deleterious root surface strain caused during instrumentation.

Recent advances made in these NiTi instruments with modifications in the file design, alloy or kinematics. This led to the development of files such as the Twisted File-Adaptive (TFA; SybronEndo, Orange, CA). The unique R-phase heat treatment and twisting of the metal in the TFA instruments improved their flexibility, strength and cyclic fatigue resistance. Furthermore the development of the innovative kinematics provided by the specialized motor (Elements Adaptive motor, SybronEndo) which switches between rotation and reciprocation motions depending on the intracanal stresses on the file during instrumentation to minimize dentinal defects. Also, the Reciproc (VDW, Munich, Germany) instruments have been specifically designed for use in reciprocation. Its non-cutting tip and M-Wire nickel-titanium alloy with the innovative thermal-treatment process offers increased cyclic fatigue resistance and greater flexibility than traditional nickel-titanium. The aforementioned files are being compared regarding how the innovative file design, alloy and kinematics affect the amount of root strain during instrumentation, and in turn the correlation of the strain with the fracture resistance of the roots after root canal preparation, in simulated oral conditions.

Material and methods

Sample Selection:

Twenty-Five recently extracted, fully erupted, defect-free human mandibular first molar teeth were obtained from patients scheduled for extraction as a part of their dental treatment for either orthodontic or periodontal reasons, from the Department of Oral and Maxillofacial Surgery, AinShams University. All superficial tissues were mechanically removed using a hand scaler, and the teeth were stored in distilled water immediately after extraction. The criteria of selection of these molars were as follows:

Inclusion criteria: Mature lower first permanent molars – Intact mesial roots with moderate curvature (20-35 degrees) - Type III Weine's canal configuration.

Exclusion criteria: Mesial roots showing caries, resorption, cracks, fracture lines or open apices - Mesial roots showing anatomic irregularities - Extremely short roots - Type II canal configuration.

Angled digital radiographs of the molars were taken to confirm the presence of two separate mesial canals and apical foramina (type III weine's canal classification), then all molars were observed under a digital microscope to exclude teeth with external fracture lines, open apices or anatomic irregularities. All molars were selected to have an angle of curvature of the mesial root ranging from (20^{o}-35^{o}). This was measured on a digital radiograph taken using Vatech EzSensor Classic Digital Intraoral Sensor. The angle was determined using ImageMeter Software. Furthermore, for more accurate measurements, the selected molars were then scanned using a CBCT scanner to precisely measure the angle and the radius of curvature of each canal separately. Measuring Pre-operative canal curvature was done using Schneider's method using Invivo imaging software.

Sample preparation:

Crowns and distal roots were sectioned away from the teeth using a diamond disc whilst maintaining a 12-mm length of the mesial root with a flattened, cut surface in order to standardize the canal length (CL), provide a reference plane and facilitate access. Lengths were measured using a digital caliper. The distance between the coronal end and AF of each root was determined by inserting a K file #10 into the canal until the tip of the file was just visible at the AF, with a mean length of 12 mm.

Mounting of the roots:

Each root was wrapped with a single layer of aluminium foil and embedded in auto-polymerizing resin set in an acrylic tube (9 mm height and 20 mm in diameter), ensuring that each root was centrally positioned with the long axis of the root aligned parallel to the sides of the acrylic tube with the apical end (4mm) exposed and emerging from the resin. The roots were then removed from the tube and the aluminum foil peeled off. The root surface and the root space were coated with a hydrophilic vinyl polysiloxane impression material, and the root was immediately repositioned in the acrylic resin socket. Thus, the polysiloxane filled in the space created by the foil representing a simulated periodontal ligament and all the excess material were removed. The polysiloxane was applied to each root individually. The apical end (4 mm) of the root apex is exposed to allow placement of the strain gauge and the intraoperative image recordings. The samples were then maintained immersed in distilled water until the root canal instrumentation.

Sample classification:

All the 25 roots were coded. The roots were then randomly distributed into two experimental groups: TF Adaptive ML1 (n = 10), Reciproc R25 (n = 10), and one control group (n = 5). In the experimental groups, the working length was determined by inserting a size 10 K-file into the root canal until the tip of the instrument was flush with the major apical foramen as observed under the dental operating microscope. The distance from the reference plane in the occlusal direction to this flush level minus 1 mm was defined as the working length of the root canal.

The roots were then placed in a custom-made specimen holder in which each root could be positioned in the same place before and after instrumentation.

Mounting of the Strain Gauge

An electrical strain was fixed on the proximal root surface 1 mm from the apex, which had been polished with a bur and cleaned with acetone to bond the strain gauge with cyanoacrylate adhesive. Once the strain output stabilized, it was zeroed and canal shaping was performed. The strain gauge was connected to a strain amplifier via a bridge box to measure the root surface strain (RSS) values that were induced by the canal instrumentation. (Fig. 1) The instantaneous RSS induced by each instrument, and the maximum RSSs were recorded.

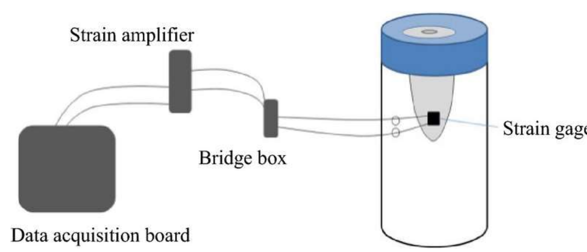

Figure 1: A schematic drawing showing the entire setting mounted to the root.

Root canal instrumentation

The working length for all root canals was standardized. Each instrument had a rubber stopper, fixed with cyanoacrylate adhesive at this length to limit preparation to the working length and was used to prepare not more than 4 canals.

Before shaping, the canal was irrigated with distilled water and agitated with (K-file # 10) and a glide path was established using (K-file # 15) in watch-winding motion until stable RSS readings appeared, and then amplifier was adjusted to zero to start the procedure. During canal shaping, the sample was fixed. Both canals were prepared in each root. All instruments were used to the full length of the canals. Instrumentation was performed by a single operator in strict accordance with the manufacturers' recommendations. Apical patency was maintained using a size 15 K-file. Saline was used for irrigation. The flutes of the instruments were cleaned after three in-and-out-movements (pecks). The instrument was removed once the working length was reached.

In group 1, TF Adaptive Elements motor was used with the individual torque limit and rotational speed programmed in the file library of the motor. In Group 2, VDW Silver Reciproc Endomotor was used with the recommended settings. The preparation time, which included the total active instrumentation only was recorded.

Evaluation of root surface strain

During canal shaping, the strain output of the amplifier was digitally recorded and saved as data files, which were contain the strain values that were induced by the canal shaping on the external surface of the root and converted to Excel files. The instantaneous RSS was induced by each instrument, and the maximum RSSs were determined.

Fracture load measurement

Each root was placed in a gypsum mold where the apical 2 mm of the root embedded in gypsum and mounted vertically, such that apex of the root was sitting on hard surface. The stone was allowed to set for 30 min before testing. Roots were kept wet via damp cotton to prevent dehydration. Universal testing machine running at a cross head speed of 1 mm/min was used to fracture the roots. Mounted roots were placed on universal testing machine and a thin metal tip attached to testing machine was inserted into the mesiobuccal root canal as far as it can go and force was applied gradually within the canal until fracture was detected. The load at fracture was recorded in Newton force.

Results

Reciproc R25 caused a significantly higher RSS in both canals than TFA. No significant difference between RSS in MB and ML canals with both files. (Table 1) Reciproc R25 caused a significantly higher overall RSS than TFA ML1 file in mesial roots of first permanent molars. (Table 2) The use of both files significantly decreased the fracture resistance of the roots after preparation. The use of Reciproc R25 files in root canal preparation caused a significantly higher drop in the fracture resistance of the roots than the TFA. There is a correlation between the RSS and the fracture resistance, where roots with higher RSS values showed a lower fracture resistance. (Table 3) Reciproc R25 took significantly longer time to reach the working length than TFA did. There is no significant difference between the time taken to prepare the MB and ML canals in both groups. (Table 4)

Table 1: Mean and Standard deviation (SD) values of maximum RSS in MB and ML canals in both groups.

RSS max		
	MB^{a}	**ML^{a}**
TF^{b}	44 ±8.096639	36 ±8.43274
R25^{c}	256 ±57.96551	270.5 ± 60.66529

Different superscript letters indicate statistically significant difference between groups ($P < .05$)

Table 2: Mean and Standard deviation (SD) values of maximum overall RSS

RSS max	
TF [a]	R25 [b]
40 ±9.032106	263.25 ± 58.2254

Different superscript letters indicate statistically significant difference between groups (P < .05)

Table 3: Mean and Standard deviation (SD) values of fracture resistance in all 3 groups.

Fracture Resistance	
Control[a]	216.94 ±28.18089581
TF[b]	159.661 ±24.19913105
R25[c]	90.628 ± 18.89666684

Different superscript letters indicate statistically significant difference between groups (P < .05)

Table 4: Mean and Standard Deviation values of preparation time in both groups

Time		
	MB[a]	ML[a]
TF[b]	16.545 ±3.498886331	15.053 ±2.548285
R25[c]	54.592 ±8.607738	50.803 ±10.99446

Different superscript letters indicate statistically significant difference between groups (P < .05)

Discussion

Mechanical preparation and chemical disinfection cannot be considered separately and are commonly referred to as chemomechanical or biomechanical preparation. Biomechanical preparation of root canals is the most essential step in achieving endodontic success due to enabling bacterial elimination, removal of debris, and facilitating obturation. The use of nickel–titanium (NiTi) engine-driven endodontic instruments in the preparation of the root canal space reduces operator fatigue, the time required for shaping, and the risk of procedural preparation errors. The microorganisms can proliferate in crack lines leading to secondary bacterial infections. These dentinal microcracks may also have the potential to propagate into root fractures, which usually lead to tooth loss. These complications necessitate a better understanding of the factors that initiate microcracks.

The first used instrument was the Reciproc R25 which is a 25/8% Single-file system where the file is prefabricated with M-Wire® nickel-titanium. Increased cyclic fatigue resistance is achieved through the use of this alloy produced in an innovative thermal-treatment process. M-Wire® has both greater resistance to cyclic fatigue and greater flexibility than traditional nickel-titanium. The file operates in a reciprocating motion which is provided by a special motor that utilizes the balanced force concept of canal preparation to minimize the stresses. The second instrument used was the TF Adaptive ML1 which is also a 25/8% file, the first of a 3-file-system designed to prepare medium and large canals. TF™ instruments are created by taking a raw NiTi wire in the austenite crystalline structure phase and transforming it into a different phase of crystalline structure (R-phase) by a process of heating and cooling. In the R-phase, NiTi cannot be ground but it can be twisted. Once twisted, the file is heated and cooled again to maintain its new shape and convert it back into the austenite crystalline structure, which is super elastic once stressed. The file operates in an Adaptive motion through a special motor which allows the file to adapt to the intracanal stresses by switching between rotary and reciprocation motions.

Mesial roots of lower first molars were selected, to test the strain caused by the files in each canal individually and the overall strain on the root. To the best of our knowledge, all previous studies were carried on simulated canals in resin blocks or roots with single canals. Distilled water was used as irrigant in this study instead of Sodium hypochlorite irrigating solution NaOCl, in order to avoid the irrigant effect on RSS. For this reason, this medium was previously recommended for investigations of human dentine because it causes the least amount of changes in dentine over time. Root canal irrigation with Sodium hypochlorite irrigating solution NaOCl could significantly affect strain, elastic modulus and flexural strength of the dentin, potentially predisposing teeth to fracture. However, a study showed that irrigating the root canals with 0.9% NaOCl presented greater resistance to root fracture than other irrigants used.

External reinforcement was avoided using a thin uniform layer of silicone (A hydrophilic vinyl polysiloxane impression material) as a simulated periodontal ligament, surrounded by auto-polymerizing acrylic resin to simulate the surrounding bone. Periodontal ligament simulation is important because it acts as a major stress absorber and should influence the outcome of such studies. Because an ''exposed'' apex is common in teeth with chronic apical periodontitis or periapical cysts, the apical 4mm portion of the root was exposed to allow for intraoperative strain recordings. Conservation of the dentin adjacent to the apical root canal is crucial to maintain strength and fracture resistance of the tooth structure. The file tips reaching RCL_1mm might have had a sufficient amount of dentin around the file tip to resist the formation of cracks. Moreover, it has been shown that stresses resulting from canal preparation 1 mm short of the apical foramen were one-third of the stress at more coronal levels. The stresses were more on the external aspect of the root curvature than on the internal aspect. Therefore, the strain gauge was fixed to the apical third of the proximal root surface 1mm from the apex, to measure the circumferential RSS during canal shaping. All samples were mounted on a bench and all canals were done with a single experienced operator. The apical force used during instrumentation could affect the strain recordings. Tapered canals preparation leaves the roots prone to fracture due to stresses which are high during masticatory loadings. The fracture resistance of the roots were measured using a special tip applied to the root surface to simulate masticatory loading.

When comparing the root surface strain, the Reciproc R25 caused significantly higher strain values than the TFA. This might be attributed to the manufacturing modifications on the metallurgical properties of the TFA. The R-phase alloy used and the twisting of these files gave them superior flexibility and surface characteristics which might have caused less RSS during instrumentation. This might also be attributed to the kinematics used in the TFA which allows the files to switch to reciprocation if stressed and hence reduce the overall strain on the root.

All prepared roots showed a significantly lower fracture resistance when compared to control group, which proves the weakening effect that occurs after the root canal preparation. The samples that showed higher RSS values had a significantly lower fracture resistance in all groups indicating a direct correlation between the maximum strain and the fracture resistance and this could be explained by the development of more microcracks at higher strain.

Conclusion

TFA File causes less Root strain and could help to lower the risk of root fracture after root canal treatment.

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