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# THE IMPACT OF VARIOUS TAPER DESIGNS OF NITI INSTRUMENTS ON THE FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MANDIBULAR MOLAR TEETH

Mohammad Osama* *and* Ghada Moustafa Abd Elrazik*

## *ABSTRACT*

**Aim:** The current study was intended to compare the impact of various taper designs of different NiTi rotary instruments on the fracture resistance of endodontically treated mandibular molar teeth.

**Materials and methods:** 90 mature mesial roots with 13 mm length were collected from permanent mandibular molars after removal of its crowns and distal roots. All mesial roots were then embedded in self-cure acrylic resin blocks. Samples were randomly divided into control group and five groups (n = 16) at which the roots were prepared as follows: RaCe EVO #25/0.04, RaCe EVO 25/0.06, RaCe EVO 30/0.04, ProTaper Gold F2, and WaveOne Gold Primary file. Samples were obturated using single cone obturation technique. All specimens were subjected to an increasing compressive force applied perpendicularly to the roots. The forces required to induce vertical root fracture in the root samples were recorded and analyzed.

**Results:** One way ANOVA test revealed significant difference between the tested group regarding required force to fracture. Paire wise comparison with Tukey's postHOC test revealed that there were significant differences between control group and the tested groups except with 25/0.04 group (p=0.89). However, ProTaper Gold group demonstrated the least resistance in comparison with the test groups. there were no significant differences between 25/0.04, 25/0.06 30/0.04 groups, and WaveOne Gold.

**Conclusion:** Preparation of root canal using greater taper NiTi rotary files would affect root resistance toward fracture. However, it safer to consider constant taper instruments over progressive taper instruments during preparation of root canals.

**KEYWORDS:** Taper, RaCe EVO, ProTaper Gold, WaveOne Gold, root fracture

* Assistant Professor, Department of Endodontics, Faculty of Dentistry, Mansoura University, Egypt

## INTRODUCTION

Appropriate root canal instrumentation is an essential practice for the success of root canal treatment. However, root canal instrumentation has been linked to dentinal cracks that have a higher potential for vertical root fracture (VRF), either by exerting forces at the root surfaces or by compromising the dentin strength of the tooth[1,2]. This can lead to the extraction of the tooth. In previous research[3], authors have conducted that 31.7% of tooth extraction was due to VRF where 93.6% of these cases were endodonticaly treated.

The use of nickel-titanium (NiTi) instruments for mechanical preparation during root canal treatment has become increasingly prevalent due to their superior flexibility and ability to maintain the original canal anatomy. Since the introduction of rotary NiTi instruments, new systems with a variety of tapering designs have been developed [4]. The impact of these different taper designs on the fracture resistance of endodontically treated teeth vary according to the type of the rotary file used for preparation [5]. It has been cited that the design and taper of NiTi instruments have been considered as significant factors influencing root dentin removal and impacting the fracture resistance of endodontically treated teeth [6,7].

Multiple new file systems have been marketed with claims of causing fewer dentinal cracks during mechanical canal instrumentation, and consequently reducing the incidence of VRF[8,9]. RaCe EVO (RE) NiTi rotary system (FKG Dentaire, La Chaux-de-Fonds, Switzerland) is a 4% and 6% constantly tapered instrument with tip diameter of #15 to #50. It is manufactured from heat treated alloy with symmetrical triangular cross section [10]. ProTaper Gold (PTG) NiTi rotary file system (Dentsply-Maillefer; Ballaigues, Switzerland) features a variable taper design. It is developed with a convex triangular cross-section and manufactured from a proprietary heat-treated alloy that enhances its flexibility and resistance to fracture [11]. WaveOne Gold (WOG) NiTi system (Dentsply-Maillefer; Ballaigues, Switzerland) is a single-file reciprocating system in which the file has an increasing taper from the tip to the coronal portion. Also, it is manufactured with heat treated alloy that claimed to be more resistant toward cyclic fatigue [12].

As of present, the current study was intended to compare the impact of various taper designs of PTG, WOG and RE NiTi instruments on the fracture resistance of endodontically treated permanent mandibular molars.

## MATERIALS AND METHODS:

### Sample size calculation:

The sample size was calculated using G*Power 3.1.9 for Windows with an effect size f of 0.5 along with $\alpha = 0.05$ at power of 95%. The anticipated sample size was not less than a total of 90 specimens.

### Sample preparation

The present in-vitro study included 90 mature mandibular molars that were recently extracted for reasons unrelated to the research aims, following the acquisition of ethical approval (Ethical Approval No. M0309023RC) from Research Ethics Committee at Faculty of Dentistry, Mansoura University. All collected teeth were cleaned and disinfected by immersing in 2.6% NaOCl solution for 10 minutes. after that, all teeth were radiographed two dimensionally using CMOS sensor (CDR Elite, Fona Dental Inc., Bratislava, Slovakia) and inspected under a high magnification using dental operating microscope (Zumax OMS2380, Zumax medical ltd, Suzhou, China) by two blinded examiners to exclude teeth that did not belong to inclusion criteria. Only mandibular molars with fully formed apices, root length more than 13 mm, with type IV Vertucci's classification [13] in mesial root were included in the present study. Teeth

exhibiting root caries, visible cracks or fractures, extensive coronal restorations, cervical restorations, internal resorption, calcification, or excessively bent roots were eliminated from the study. All teeth were stored in thymol solution until use.

Coronal portions and distal roots of all teeth were removed, standardizing the root length to 13 mm, using a low-speed saw with water cooling (Isomet; Buehler Ltd., Lake Bluff, IL). the roots were covered with single layer of tin foil and then embedded in self-cure acrylic resin (Acrostone Acrylic, Acrostone Inc, Cairo, Egypt) in 20 mm diameter cylindrical mold with 3 mm of the sample exposed. following the setting of acrylic resin material, the roots were removed from the acrylic block and covered with a thin layer of a layer of vinylpolysiloxane (Elite HD+, Zhermack, Rovigo, Italy) and repositioned in its place in the resin block.

**Sample grouping and root canal preparation:**

All roots in resin blocks were randomly allocated into six groups ($n = 16$) in accordance with type and final apical diameter related to the rotary system used for preparation:

Control group: root canal was not prepared.

RE 25/0.04 group: canals were prepared using RE files up to size of #25/4% taper.

RE 25/0.06 group: canals were prepared using RE files up to size of #25/6% taper.

RE 30/0.04 group: canals were prepared using RE files up to size of #30/4% taper.

PTG: canals were prepared using PTG files up to size of 25/8% taper (F2 file).

WOG: canals were prepared using WOG file up to size of #25/.07 taper (WaveOne Primary).

A single experienced operator performed instrumentation procedures according to the manufacturer's instructions. The patency of the root canals was confirmed by inserting a size 10K-file from the root canal orifice until its tip was observable at the apical foramen. The definitive working length (WL) was subsequently determined as the distance from the occlusal reference point to 1 mm less than the length of the #10 K-file.

As a standard preparation protocol for the three rotary systems, each rotary file was mounted to a torque-controlled electric motor (FKG Rooter S, FKG Dentaire, La Chaux-de-Fonds, Switzerland) with a contra angled head (16:1 reduction speed). All files were repeatedly withdrawn from the canal using long, gentle picking motions, three times to the WL before removal while still rotating. Between the use of each file, or if the rotary file failed to reach the apex, the canal was recapitulated with a #10 K-type file and irrigated with 2 mL of 2.5% sodium hypochlorite solution using a 30-gauge needle syringe (Fanta Dental Corp, Shanghai, China). Each rotary file was discarded after preparing only three roots. For WOG system, the files were attached to electric endodontic motor with dedicated reciprocating program for WO files (Woodpecker Endomatic Endomotor, Guilin Woodpecker Medical Instrument CO. LTD., Guangxi, China).

For the 25/0.04 taper group, the root canals were instrumented using a sequence of 15/0.04 and 25/0.04 taper files to the WL. Similarly, the 25/0.06 taper group followed the same protocol as the former group, with the addition of 25/0.06 taper files for continued preparation to full WL. In the case of the 30/0.04 taper group, the root canals were prepared using a sequential approach involving 15/0.04, 25/0.04, and finally 30/0.04 taper files at the full WL. For the PTG group, the canals were first pre-flared with the SX file to 4 mm, followed using S1, S2, F1, and finally the F2 file at the full WL. Lastly, the WOG group utilized a single file to prepare the canals using reciprocating mode to the full WL.

**Root canal obturation:**

Following instrumentation, the root canals were dried with sterile paper points and obturated utilizing the single cone technique with gutta-percha points; matching each apical diameter; and ADSeal resin-based sealer (Meta Biomed, Chungcheongbuk-do, Korea). Then, the roots were stored in incubator at 37°C and 100% humidity for 7 days.

**Fracture resistance test:**

The obturated root specimens were subjected to a progressively increasing compressive force applied perpendicularly to the root's occlusal surface using a 1.5 mm diameter steel tip mounted to a universal testing machine (Instron, Ma, USA) at a constant rate of 1 mm/min, until the root fractured (figure 1). The forces required to induce vertical root fracture in the root samples were recorded and analyzed.

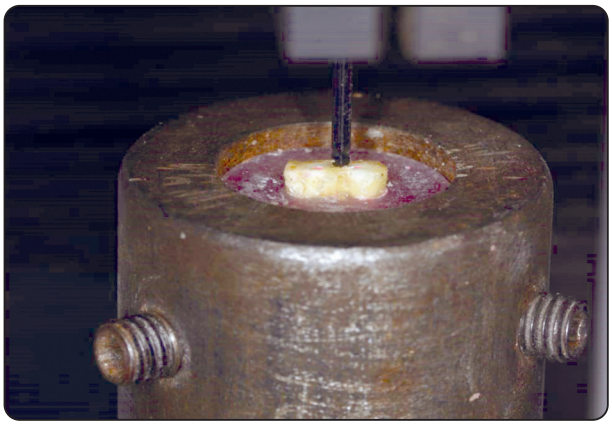

Fig. (1) Representative root sample held in resin block and being assessed for fracture resistance using universal testing machine.

**Statistical analysis:**

Statistical analysis was conducted using SPSS Statistics for Windows software (SPSS v20, IBM Corp, NY, USA). Kolmogorov-Smirnov Normality revealed that the data followed a normal distribution. Accordingly, the mean and standard deviation of the NCF and instrument length were calculated for each group and compared at 0.05 level of significance using ANOVA and Tukey's multiple comparison postHOC tests.

**RESULTS**

Data regarding forces required to induce vertical root fracture is tubulated in table (1) and presented in figure (2). One way ANOVA test revealed significant difference between the tested group regarding required force to root fracture. Paire wise comparison revealed that there were significant differences between control group and the tested groups except with 25/0.04 group (p=0.89). However, PTG group demonstrated the least resistance in comparison with all test groups. It also revealed that there were no significant differences between 25/0.04, 25/0.06 30/0.04 groups, and WOG.

TABLE (1) showing mean and standard deviation of load values before fracture of mesiobuccal roots of permanent mandibular molars:

| Group | **Loud** |
|---|---|
| | Mean± SD |
| Control | 236.39 ± 50.73 [(a)] |
| 25/4 | 224.42± 32.74 [(ab)] |
| 25/6 | 201.05 ± 33.23 [(b)] |
| 30/4 | 198.13 ± 28 [(b)] |
| PTG | 155.69 ± 17.7 [(b)] |
| WOG | 192.93 ± 15.22 [(c)] |
| P-value | 0.000 |

***Values with different superscripts are significantly different at p<0.05.***

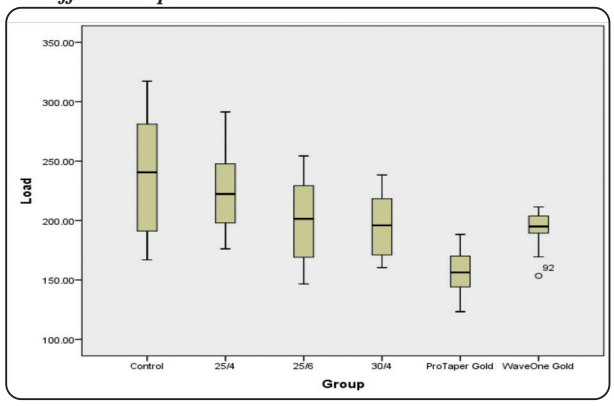


Fig. (2) showing mean and standard deviation of load values before fracture of mesiobuccal roots of permanent mandibular molars.

## DISCUSSION

The present study compared the root fracture resistance of roots instrumented with different taper designs related to different NiTi rotary file systems. The results demonstrated that root canals treated with PTG NiTi files exhibited reduced resistance to root fracture compared to those treated with RE NiTi files. Consequently, the null hypothesis was dismissed.

During root canal mechanical preparation several variables such as shape of the canal, the force that is given to the instrument, instrument's taper, cross-sectional design and metal properties, can induce stress on the dentinal walls which can then lead to the growth of vertical root fractures [14]. The rotary file systems chosen for the present study were selected with the intention of varying solely the instrument tapering design, thus, different constant taper files by RE system in addition to progressive taper designs by PTG and WOG systems were selected. Additionally, heat-treated instruments were specifically utilized to minimize the potential impact of divergent metallurgical properties on the integrity of the dentine [5].

Although evaluation of root fracture is commonly performed in roots with single canal [15–17], present study utilized mesial roots of mandibular molars following results reported by previous investigations [3,18]. Von Arx et al [18] reported that mesial roots of mandibular molars have higher tendency of VRF and Yoshino et al [3] found that more than 50% of extracted teeth because of VRF were assigned to first mandibular molar.

To minimize the introduction of potential variables that may affect the outcomes, the coronal sections of teeth were trimmed to a standardized length of 13 mm [19]. Additionally, roots were then coated with light-body silicon impression material to simulate periodontal ligament space and mounted on acrylic blocks, mimicking a patient's oral condition. This silicon material serves to imitate the periodontal ligament that partially absorbs vertical forces [20].

The current study employed the single cone obturation approach to fill the root canals before conducting root fracture tests, consistent with previous research [16]. This rational has been considered to avoid wedging forces that may result from cold lateral compaction or dentinal matrix collapse by inappropriate temperature regulation during warm vertical condensation [21].

All experimental groups, with the exception of 25/0.04, had a significant decrease in fracture resistance values compared to the control group, aligning with earlier comparable findings [22]. Among the experimental groups, root samples treated with F2 PTG file (25/0.08 taper) exhibited reduced fracture resistance compared to those prepared with alternative files. This may be attributed to the convex triangular cross-section, the progressive taper design, and the substantial tapering ratio of the PTG file. Progressively tapered file with a convex triangular cross-section has been associated with an increased risk of root fracture during root canal instrumentation, as it induces high stress concentration in the root dentin at the external root surface, approaching the strength properties of dentin [23]. Additionally, rotary files with a larger taper typically excise more peri-cervical dentin compared to those with a smaller taper, so weakening the tooth's structural integrity [15]. Current results come in agreement with Hamid et al [24] who reported that mesial roots of mandibular molar prepared with RE files with different tapers were more resistant toward fracture than that prepared with ProTaper Next files.

Despite the similarity between PTG and WOG files regarding the design of taper, the WOG was not significantly different from RE groups which is consistent with previous report [25]. An explanation could be related to different preparation kinetics as WOG was operated with reciprocating motion rather than continuous rotation. Reciprocating

motion during mechanical canal preparation may led to less dentinal stresses than that produced by rotational motion despite the progressive taper presented by WOG file. Wei et al [26] reported that reciprocating motion produced significantly fewer dentinal cracks than the conventional rotational motion. Considering the comparison between PTG and WOG, results indicated significant difference in force values needed to cause root fracture, as samples prepared with WOG were more resistant to fracture than PTG. This agrees with Nasr & Kader [27] who reported that WaveOne instruments induced less cracks and exhibited greatest resistance to fracture compared with ProTaper F2 files used in rotating motion.

Previous researches [22,28] reported that increased speed and rotational torque may be related to creation of dentinal defects and could increase the prevalence of root fracture. The present findings disagree with those reports. The RE files were rotated at higher speed and rotation torque than that was applied on the PTG files, however, groups prepared with RE demonstrated higher resistance toward fracture compared to PTG group. This finding suggests that factors other than speed and torque, may play a more significant role in altering the biomechanical strength of roots.

The limitation of the present study is that the controlled laboratory setting may not fully capture the complexities encountered in clinical practice. The use of extracted teeth, a common approach in endodontic research, does not account for the living oral environment, which could impact the findings. Additionally, the exclusion of specific root conditions and the use of standardized protocols may not reflect the diverse clinical scenarios in dental practice. Furthermore, the focus on a specific file system may not represent the wide variety of instrumentation options available, limiting the generalizability of the results.

## CONCLUSION

Within the limitation of the present study, it can be concluded that preparation of root canal using greater taper NiTi rotary files would affect root resistance toward fracture, however, it safer to consider constant taper instruments over progressive taper instruments during preparation of root canals.

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