Resistance to fracture of teeth instrumented using novel EndoStar E5 rotary versus ProTaper NEXT and WaveOne file systems

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Abstract

Aim: The current study compared the fracture resistance of samples instrumented by two rotary files and a reciprocating file, obturated with gutta-percha and AH Plus.

Materials and Methods: A total of 60 freshly extracted mandibular premolar teeth with single roots and single canals were acquired and decoronated at or below the cementoenamel junction. The samples were randomly divided into four groups (n = 15). Group 1 control (noninstrumented/obturated), and for Groups 2–4 root canal instrumentation was done by EndoStar E5 (EE5), ProTaper NEXT (PTN), and WaveOne, respectively. Following instrumentation, the samples were obturated using gutta-percha cones and AH Plus sealer using lateral compaction. A week later, vertical load was applied to the specimen’s canal in each group until fracture. The loads required for fracture were recorded and statistically analyzed.

Results: The mean loads required to fracture (Newton; N) for the four groups were; 388.54 (±29.93), 310.35 (±26.05), 328.40 (±20.67), and 278.54 (±34.16). The loads exhibited highly significant difference (P < 0.0001; analysis variance). The following Tukey’s post hoc test confirmed, both samples in Groups 2 and 3 required similar loads for fracture (P > 0.05) and significantly higher than Group 4 (P < 0.01).

Conclusion: The samples instrumented by EE5 and PTN exhibit similar fracture resistance.

Keywords: EndoStar E5; fracture strength, instrumentation; ProTaper NEXT; WaveOne

INTRODUCTION

Root canal instrumentation with motorized endodontic files results in weakening the dentin integrity, leading to a reduction in the fracture resistance of treated tooth.¹⁻³ This may also lead to a vertical root fracture (VRF) with extraction being the only treatment option left.⁴⁻⁵ Instruments used for root canal shaping have evolved from conventional 2% taper hand instruments to recently used rotary and reciprocating instruments with a greater taper (4%–9% taper).⁶⁻⁸ As these files have a design, which incorporates increasing tapers, it results in the aggressive removal of the radicular dentin reducing the fracture strength.⁴⁻⁵,⁷

Another important factor is the stress generated on the radicular dentin when using endodontic instruments for shaping. The dentin’s tensile strength is 106 MPa, but the currently used rotary files generate 311–368 MPa of stress on the radicular dentin, thus leading to the formation of micro-cracks.⁶ The rotary files are associated with 18%–60% and the reciprocating files are associated with around three times more formation of micro-cracks in the radicular dentin when used for instrumentation.⁶

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Lateral compaction with nickel-titanium spreader using gutta-percha cones and a sealer is the most commonly used technique for obturation as it results in less amount of force generated during the procedure.[4]

The current study aimed to compare the fracture resistance of teeth instrumented by a novel rotary file EndoStar E5 (EE5; Poldent Co. LTD., Warsaw, Poland), ProTaper NEXT (PTN; Dentsply Tulsa Dental, Tulsa, OK) and reciprocating WaveOne (WO; Dentsply Maillefer, Ballaigues, Switzerland) file systems after obturation.

MATERIALS AND METHODS

Freshly extracted mandibular premolar teeth with single straight root canals and completely formed apices were acquired and stored in saliva substitute at 37°C. The samples were sectioned at/below the cementoenamel junction using a diamond-coated bur under water cooling; leaving roots segments of 16 mm in length and examined with a stereomicroscope under ×10 magnification to detect any defects. Teeth with such findings were excluded and 75 teeth were selected for the current study.

The selected samples were scanned using cone beam computed tomography (CBCT; ProMax 3D Mid; Planmeca OY, Helsinki, Finland) to standardize the root canal shape (mesiodistal and buccolingual dimensions). For all the samples except the control group, a glide path was prepared till working length with a #20 k-file.

Instrumentation

Group 1 (Control)
The samples in this group remained untreated with no instrumentation and no filling.

Group 2 (EndoStar E5)
The samples were instrumented using EE5 rotary file system. File sizes: E5 1:size 30/0.08 taper; E5 2:size 30/0.06 taper; E5 3:size 30/0.04% taper; E5 4:size 25/0.04 taper and E5 5:size 20/0.04 taper [Figure 1a]. The files were operated at 300 rpm with torque a setting of 2.5 Ncm using Xsmart Plus (Dentsply Maillefer) at 300 rpm and a torque of 2.6 Ncm. The root canal orifices were flared using Sx (Dentsply Tulsa Dental). The PTN X1 and X2 files were used in an outward brushing motion following coronal flaring. On meeting obstruction in the canal, the file was withdrawn, the canal was irrigated, recapitulated by #15 k-file and the file was reintroduced into the canal.

Instrumentation was carried out in the above manner till the X1 and X2 both reached the working length. The irrigation protocol during instrumentation using this file was similar to Group 2.

Group 3 (ProTaper NEXT)
Samples were instrumented by PTN rotary files (X1: 20/0.04 taper and X2: 25/0.06 taper), using a gentle in-and-out motion with Xsmart Plus (Dentsply Maillefer) at 300 rpm and a torque of 2.6 Ncm. The root canal orifices were flared using Sx (Dentsply Tulsa Dental). The PTN X1 and X2 files were used in an outward brushing motion following coronal flaring. On meeting obstruction in the canal, the file was withdrawn, the canal was irrigated, recapitulated by #15 k-file and the file was reintroduced into the canal.

The instrumentation was carried out in the above manner till the X1 and X2 both reached the working length. The irrigation protocol during instrumentation using this file was similar to Group 2.

Group 4 (WaveOne)
The WO (primary; 25, 0.08% taper; Dentsply Maillefer) reciprocating single file system was used to instrument the samples in this group. The root canal orifices were flared using Sx as done in Group 3. Following flaring, the WO files were used in pecking motion with Xsmart Plus (Dentsply Maillefer). On meeting obstruction in the canal, the file was removed, the canal was irrigated, recapitulated by #15 k-file and the file was reintroduced into the canal.

The instrumentation was continued in the above manner till the file reached working length.

Final irrigation protocol for Groups 2–4
After completion of instrumentation, a final flush was performed using 5 mL of 17% aqueous EDTA (Dent Wash, Prime Dental Products) for 1 min and 5 mL of 5.25% NaOCl for 1 min followed by the final rinse with 5 mL of distilled water.

Obturation

After instrumentation (Groups 2–4), the canals were dried with sterile paper points and master gutta-percha cones confirmed radiographically, were selected. The dentinal wall was then coated with AH plus sealer (Dentsply DeTrey, Konstanz, Germany) using a lentulo spiral, followed by placing the master-cone, and adding accessory cones.
using a #25 Ni-Ti finger spreader. Excess gutta-percha was sheared off using a hot hand plugger, access cavities were filled with composite resin and sealer was allowed to set for 7 days at 37°C and 100% humidity.

**Fracture testing**

The samples were covered with wax obtaining 0.2–0.3 mm thickness of layer (apical 5 mm). Further, samples were mounted in copper rings with height of 25 mm and a diameter of 15 mm and filled with self-cure acrylic resin, exposing 9 mm of the coronal part. Once the polymerization started, the roots were removed and the wax was cleaned off, followed by coating them with a thin layer of polyvinyl siloxane impression material and embedding again into acrylic resin.

The acrylic blocks were then placed on the universal testing machine (Instron Corp, Canton, MA, USA). The tip with a diameter of 3 mm was used. The tip was centered over the canal orifice, and a gradually increasing vertical force was exerted (1 mm/min) until fracture. The maximum force required to fracture each sample was recorded in Newton (N).

**Statistical analysis**

The fracture loads required for Groups 1–4 were analyzed using one-way analysis variance (ANOVA) followed by Tukey’s *post hoc* test for multiple. The abovementioned tests were performed using Statistical Package for the Social Sciences (SPSS) software version 20 (SPSS Inc., Chicago, IL, USA).

**RESULTS**

The mesiodistal and buccolingual dimensions for the samples in four groups were similar ($P = 0.579$ and $P = 0.762$; one-way ANOVA), respectively. The mean load required to fracture in 4 groups were 388.54 (±29.93), 310.35 (±26.05), 328.40 (±20.67), and 278.54 (±34.16) for Groups 1–4, respectively. The loads acquired exhibited a significant difference ($P < 0.01$; one-way ANOVA). Intergroup analysis (Tukey’s *post hoc* test) revealed that samples in Groups 2 (EE5) and 3 (PTN) to be similar ($P > 0.05$) in fracture resistance. Furthermore, samples in Group 5 (WO) exhibited significantly less fracture resistance ($P < 0.01$) [Tables 1 and 2].

**DISCUSSION**

Root canal therapy results in weakening of the tooth, after shaping and cleaning of its root canal and almost 30% reduction in the vertical fracture resistance. Various causes of VRFs have been proposed in literature and root canal instrumentation is one of them. The results of the current study indicate that the fracture resistance of endodontically treated tooth was reduced as compared to the control group. It has been reported that root canal instrumentation using rotary files or reciprocating files reduces the fracture resistance of tooth, with the reciprocating files reducing it to a higher extent. In the current study, the samples instrumented with reciprocating WO file exhibited the least fracture resistance in groups tested.

In such in vitro studies, which undertake mechanical tests, the standardization of the samples being tested is the most important factor of such studies. The extraction time and storing conditions, variation in the length of the roots, shape of the root canals and volume of the root canal space generally affect the results of such studies. To eliminate these discrepancies in the current study, the samples tested were scanned preoperatively using CBCT to measure and use samples with similar mesiodistal and buccolingual dimensions. Furthermore, the working lengths of the root segments were maintained at 16 mm for all the samples.

The rotary/reciprocating files result in formation of dentinal micro-cracks. These files possess varying percentages of taper (0.06%–0.09%), which may contribute to the dentinal micro-crack formation. These micro-cracks have been reported to form at levels ranging from the coronal third to the apical third of the roots instrumented and also become high-stress concentration areas and the crack can gradually propagate to the root canal surface, a root cause for VRFs.

The presence of excessive taper results in unnecessary removal of root dentin. The PTN rotary files are designed with an unusual design where the center of mass and the center of rotation are offset when this file is in the rotation. This unique pattern aids in an increased

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**Table 1:** Mean and standard deviation for the loads required for the fracture of the samples in Newton (N) for control and the instrumented groups

| Instrumentation | Mean ± SD  |
|-----------------|------------|
| Control         | 388.54 ±29.93 |
| EE5             | 310.35 ±26.05 |
| PTN             | 328.40 ±20.67 |
| WO              | 278.54 ±34.16 |

*P value (ANOVA)*: 0.579 and 0.762; one-way ANOVA. Also the $P < 0.0001$ (one-way analysis of variance) concludes that all the groups exhibit a significant difference. SD: Standard deviation, ANOVA: Analysis of variance, PTN: ProTaper NEXT, WO: WaveOne, EE5: EndoStar E5

**Table 2:** *Post hoc* test results for inter group comparison for the groups tested

| Groups | Instrumentation | Post hoc test |
|--------|-----------------|---------------|
| 1      | Control         | >2, 3, 4      |
| 2      | EE5             | <1; >4; ≈3    |
| 3      | PTN             | <1; >4; ≈2    |
| 4      | WO              | <1, 2, 3      |

*: Almost similar, PTN: ProTaper NEXT, WO: WaveOne, EE5: EndoStar E5
cross-sectional space for better cutting, loading, and auguring debris coronally. This pattern also helps in minimizing the dentin engagement, thus producing less stress on the radicular dentin. These files exhibit an alternating (increasing and decreasing) percentage tapers (X1; 0.04 and X2; 0.06). Less micro-cracks are associated with these files is reported, which was attributed to swaggering motion (alternating taper), decreasing the screwing effect, by minimizing the contact between the file and the dentin. \[11\] In addition, these files are manufactured using M-wire alloy, which exhibits more flexibility than nickel-titanium (NiTi). \[15-17\] Pawar et al., in a recent study reported better fracture resistance of samples instrumented with PTN compared to WO. \[14\]

The WO files are characterized by a convex triangular or modified triangular cross-section resulting in a low cutting efficiency and less chip space. The reciprocal motion also enhances debris transportation towards the apical third and result in increased torsional forces. WO files cause significantly more micro-cracks than a full sequence of rotary files, also these cracks are more at the apical level, which may result in less fracture resistance exhibited by the teeth in the group instrumented by WO files in the present study. \[4,18\] Bürklein et al. in their study reported that this newer generation reciprocating instrument, WO caused significantly more micro-cracks than a full sequence of rotary files. \[18\] The WO primary files have a taper of 0.08 and a tip diameter of 0.25. However, the PTN X2 file has a taper of 0.06 and E5 has 0.004 taper for the apical size of 0.25. Thus, we believe that the larger taper sizes of the WO primary instruments could result in more cracks thus reducing the fracture resistance of the teeth instrumented. \[19\] Although with the reciprocating movement, flexural and torsional stresses acting on the dentin are reduced, using a single file to enlarge the canal, regardless of the preexisting conditions of the canal and large taper of the WO file could still result in the formation of more dentinal defects. \[20-22\] Furthermore, stiffer file designs generate higher stress during shaping, which raises the risk of dentinal defects that may lead to apical root cracking. \[8\]

To the best of the authors’ knowledge, till date fracture resistance exhibited by the teeth instrumented using novel EE5 rotary file is yet to be reported in the literature. The Endostar E5 rotary files [Figure 1a] have a cross section similar to the Mtwo files. \[23\] These files are manufactured using NiTi alloy, having a cross-sectional design of the modified shape of the letter “S” with a two-point contact at 90’s [Figure 1b], making the file more aggressive. Hin et al., confirmed that the rotary files have an active rotary movement of and can cause high-stress concentration resulting in crack formation, which results in a reduction of fracture resistance of the instrumented teeth. \[24,25\] In the current study, there was no significant difference between the samples instrumented using rotary files.

**CONCLUSION**

Within the limitations of the current study, it can be concluded that the teeth instrumented by the novel EE5 rotary file system exhibit better fracture resistance than those instrumented using WO reciprocating file system. Furthermore, the teeth group instrumented with EE5 did not differ when compared to those instrumented using PTN. Further investigation is required addressing the issue of micro-crack formation in teeth instrumented using EE5.

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**Conflicts of interest**

There are no conflicts of interest.

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