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# Fracture resistance of teeth instrumented by the Self-Adjusting File, ProTaper NEXT and WaveOne



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ABSTRACT

*Aim:* The present in-vitro study aimed to compare the fracture resistance of mandibular premolars, obturated after instrumentation by Self-Adjusting File (SAF), ProTaper NEXT (PTN) and WaveOne (WO).

*Method:* Sixty extracted mandibular premolars were decoronated to obtain the root length of 15 mm. The samples were divided into 4 experimental groups: **Group 1** without instrumentation (control), **Group 2** instrumented with SAF, **Group 3** with PTN (X1 and X2) and **Group 4** with WO (primary). Following instrumentation, the samples were obturated by cold lateral compaction technique using gutta-percha and AH Plus sealer. A week later, after the sealer was completely set, a vertical load was applied to the specimen's canal until fracture. Statistical analysis was performed.

*Results:* The mean fracture load exhibited significant difference ($p < 0.01$) (One-way ANAOVA) between the groups. The Multiple Tukey post hoc tests revealed, the fracture resistance by group 1 showed no statistical difference when compared to group 2 and group 3 ($p > 0.05$), but a significant difference with group 4 ($p < 0.01$). Group 2 (SAF) presented a significantly higher fracture resistance when individually compared to group 3 and 4 (PTN and WO) ($p < 0.01$).

*Conclusion:* Teeth instrumented by SAF exhibited a better fracture resistance.

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## 1. Introduction

A challenging complication during an endodontic treatment or after completion of an endodontic treatment is a vertical root fracture (VRF) of the tooth treated.[1,2] It is a longitudinally oriented fracture extending to the periodontium that may begin in the crown, root apex, or any point in between. The prognosis of endodontically treated teeth to the presence of a VRF is sparingly poor with the treatment of choice being extraction.[3] Removal of caries, access-cavity preparations, canal instrumentation techniques, the effects of irrigation solutions, prolonged exposure to calcium hydroxide, pressure during obturation and tooth/crown preparation for the final restoration, can be included as the predisposing factors for

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VRFs.[4–6] The diameter of the prepared canal is another potential factor that could affect the tendency of VRF. Excessive taper can result in excessive removal of dentin and weakening of the root.[7–9]

In recent decades, advances in rotary nickel-titanium (NiTi) instruments have led to new design concepts for better root canal shaping and success. The latest generation of rotary shaping files is ProTaper NEXT (PTN; Dentsply Tulsa Dental, Tulsa, OK). These files are uniquely designed such that the center of mass and the center of rotation are offset. When in rotation, these files result in a mechanical wave of motion, along the active length of the file. These files are available as X1–X5. The PTN X1 and X2 files have an increasing and decreasing percentage of taper on a single file; whereas the PTN X3, X4, and X5 files present a fixed taper from the tip to 3 mm coronal (D1–D3), then a decreasing percentage tapered design over the rest of the file.[10]

Variable cross-sectional anatomy of the root canal is encountered as oval, flat, ribbon-shape and C-shape.[11] The rotary files prepare a circular bore when treating such canals without respecting the actual shape. The Self-Adjusting File (SAF; ReDent Nova, Ra'anana, Israel) is a specially designed hollow and flexible file that adapts itself to the shape of these canal anatomies and enlarges them maintaining their original canal shape. This file works in a transline in-out motion and its abrasive surface removes circumferential equal amount of radicular dentin thus preventing the chance of over preparation and thus resulting in preservation of the root canal wall.[12] Various studies have been reported on the formation of microcracks in the radicular dentin after instrumentation. When SAF was compared to the either rotary or reciprocating files, it proved to be more superior and also presented significantly less crack formation.[13,14]

Another single file instrument is the WaveOne (WO; Dentsply Maillefer, Baillagues, Switzerland) that works in a reciprocating manner. The WO reciprocating file depicts a reversed balanced force technique.[10] The CCW engaging angle is 5 times the CW disengaging angle. Strategically, after 3 CCW and CW cut cycles, the file will have rotated 360°, or one circle. This reciprocating movement allows a file to readily progress, efficiently cut, and effectively remove debris out of the canal with fewer chances for endodontic failure/complication.[10]

Most widely used technique for obturating an endodontically treated tooth is lateral compaction technique and is also reported in literature that it has an associated risk of VRF with this technique.[15] Various studies have been carried out and have been reported that the load generated by lateral condensation is less, than the load required fracturing the roots excluding the teeth with very weak roots. Hence it is unclear whether the various root canal-filling techniques, result in the VRFs of endodontically treated teeth or not.[16–18]

The fracture resistance of teeth instrumented by SAF has been rarely reported.[19] To the best of our knowledge there are no reports on fracture resistance of teeth instrumented by PTN rotary file or WO reciprocating file system. Hence, the purpose of this study was to assess and compare the fracture resistance of the teeth after the instrumentation by SAF, PTN and WO files; that were obturated using the cold lateral compaction technique.

## 2. Materials and method

A total of 60 intact human mandibular premolars with single straight root canals and completely formed apices, extracted for orthodontic treatment, were selected for the present study and the samples were stored in saliva substitute at 37 °C till their use. The coronal portions of all teeth were removed by using a diamond-coated bur under water-cooling; leaving roots approximately 15 mm in length. The teeth were examined with a stereomicroscope under 10× magnification to detect craze lines or cracks. Teeth with such findings were excluded from the study.

Because of limited availability of Micro-CT, Cone-beam computed tomography (CBCT) was used in the present study. The samples were scanned preoperatively using CBCT (Pro-Max 3D Mid; Planmeca OY, Helsinki, Finland) and the root length and mesiodistal and buccolingual diameter of the teeth were measured with a digital software (Romexis v3.20, Planmeca OY, Helsinki, Finland).

### 2.1. *Group 1: Control*

A total of 15 teeth were left un-instrumented.

The remaining 45 teeth facilitated the placement of # 25 k-files passively till the WL. These canals accommodated SAF 1.5 mm in group 2 ($n = 15$) and also allowed the use of PTN X1 and X2 in group 3 ($n = 15$) and the WO (primary) reciprocating file in group 4 ($n = 15$). All the files were used for shaping the canals according to manufacturers instructions.

### 2.2. *Group 2: Instrumentation with SAF*

A total of 15 specimens were instrumented by the 1.5 mm SAF with an in-and-out transline motion using a handpiece combined with an RDT3 head (ReDent Nova, Ra'nana, Israel) at a frequency of 5000 movements/min with an amplitude of 0.4 mm. Continuous irrigation with 2.5% NaOCl was applied through the file using a peristaltic pump (VATEA; ReDent Nova, Ra'anana, Israel) at a rate of 4 mL/min. The instrumentation was carried out for each sample for 4 min. After instrumentation, a final flush was applied using 5 mL 17% EDTA for 1 min and 5 mL 2.5% NaOCl for 1 min followed by the final rinse with 5 mL distilled water.

### 2.3. *Group 3: Instrumentation with PTN*

A total of 15 specimens were instrumented by PTN files (X1 and X2) using a gentle in-and-out motion with an electric and torque-controlled endodontic motor (X-Smart Plus, Dentsply Maillefer) at 300 rpm and a torque of 2.6 Ncm. The root canal orifices were flared using Sx file from the universal ProTaper (Dentsply Tulsa Dental, Tulsa, OK) set, in a brushing manner on the outstroke, eliminating triangles of dentin and relocating the coronal most aspect of a canal away from external root concavities. X1 and X2 files with an outward brushing motion followed this. On meeting obstruction the file was removed, the canal was irrigated, recapitulated by a # 15 k-file and the file was re introduced into the canal again. The instrumentation

was done in the above manner till the X1 and X2 both reached the working length.

### 2.4. *Group 4: Instrumentation with WO*

A total of 15 specimens were instrumented by WaveOne primary files (25/0.08, Dentsply Maillefer, Ballaigues, Switzerland), using X-Smart Plus endomotor (Dentsply Maillefer). The root canal orifices were flared using Sx as in Group 3. WO instrumentation with pecking motion followed this. On meeting obstruction the file was removed, the canal was irrigated, recapitulated by a # 15 k-file and the file was re introduced into the canal again. The instrumentation was continued in the above manner till the file reached working length.

### 2.5. *Irrigation for Group 2 and 3*

For these two groups a conventional needle and syringe irrigation was used with 2.5% NaOCl and EDTA gel (RC Help, Prime Dental Products, India), was used as a lubricant for the files. After the completion of cleaning and shaping procedure a final flush was applied using 5 mL 17% EDTA for 1 min and 5 mL 2.5% NaOCl for 1 min followed by the final rinse with 5 mL distilled water.

### 2.6. *Root canal obturation*

For all groups (except control) 4% gutta-percha that fit snuggly at the apex (tug back) was used as mastercone. For Group 2 (SAF) 30.04%, Group 3 (PTN) 25.04% and Group 4 (WO) 25.04% fitted the apex snuggly. This was followed by the use of accessory gutta-percha cones for lateral condensation using a # 25 finger spreader (Dentsply Tulsa Dental, Tulsa, OK).

AH Plus (Dentsply DeTrey, Konstanz, Germany) mixed according to the manufacturer's instructions was used as sealer. It was coated on to the radicular dentin using a lentulo spiral and mastercones were placed in the root canal followed by lateral condensation. After completing the obturation, the samples were kept at 37 °C with 100% humidity for 7 days to allow the sealer to set completely.

Acrylic resin blocks were prepared using cylindrical plastic molds (25 mm high and 10 mm in diameter) with the help of self-cured acrylic resin. The apical root ends were embedded vertically in 4 mm of the acrylic resin, exposing 9 mm of the coronal portion of each root. The roots were kept wet with a wet towel to prevent dehydration until the use for strength testing. An Instron testing machine (Instron, Canton, MA) 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 mounted and aligned with the center of the canal orifice parallel to the long axis of each specimen. The load necessary to fracture was recorded and expressed in Newton (N).

### 2.7. *Statistical analysis*

Mean (±SD) were calculated for each group, the groups compared using one-way analysis of variance (ANOVA) and to know the significant group a multiple comparison with the help of Tukey post hoc test was performed using SPSS software v16.

**Table 1 – Minimum, maximum, mean and standard deviation of the fracture loads required by the samples in all groups in Newton (N).**

| Group | Number of samples | Minimum | Maximum | Mean (±SD) |
|---|---|---|---|---|
| Control | 15 | 198 | 324 | 245.8 ± 33.4 |
| SAF | 15 | 224 | 352 | 276.7 ± 43.7 |
| PTN | 15 | 170 | 283 | 231.9 ± 35.7 |
| WO | 15 | 99 | 244 | 174.1 ± 36.7 |

## 3. Results

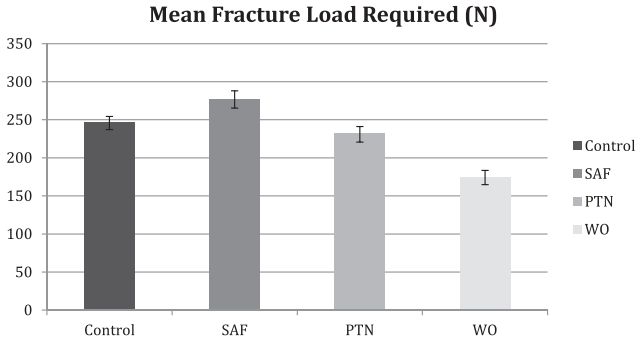
Statistical analysis revealed, the samples in all the four groups to be similar with respect to the mesiodistal and buccolingual dimensions. One-way analysis of variance (ANOVA) comparison among the samples of all the four groups revealed no statistical significant difference between them, buccolingual dimensions ($p = 0.432$) and mesiodistal ($p = 0.796$).

The mean fracture load required for group 1 (control) was 245.8 ± 33.4 N, group 2 (SAF) 276 ± 43.7 N, group 3 (PTN) 231 ± 35.7 N and group 4 (WO) 174.1 ± 36.7 N (Table 1). The meanwise presentation of the data has been plotted in Graph 1.

The fracture resistances exhibited a statistically significant difference between the groups (ANOVA, $p < 0.01$). The following multiple Tukey's post hoc tests revealed; group 1 (control) exhibiting no statistical significant difference when compared with group 2 and group 3 (SAF and PTN) ($p > 0.05$), but a significant difference with groups 4 (WO) ($p < 0.01$). Also Group 2 (SAF) presented a significantly difference when compared with group 3 and 4 (PTN and WO). Group 4 exhibited the least fracture resistance in all the groups tested. To summarize the fracture resistance was least in the teeth instrumented by WO < PTN < SAF.

## 4. Discussion

Root canal therapy invariably results in weakening of the tooth, after cleaning and shaping of its root canal and almost




**Graph 1 – Meanwise comparison of the fracture loads required by the samples in all groups in Newton (N).**

30% reduction in the vertical fracture resistance.[20] Walton et al proposed several causes for a vertical root fracture to occur and some of them stated were canal instrumentation and excessive force during lateral condensation.[21]

Standardization of the samples of studies undertaking mechanical tests in-vitro is an important factor defining the success of such studies. The dimensional variations of the root, extraction time, and storing conditions generally affect the results.[22] To eliminate differences of the samples tested, in the present study, at least statistical similar samples in their buccolingual and mesiodistal dimensions as well as working length maintained at 15 mm were used.

Nickel-titanium rotary/reciprocating files used for root canal instrumentation result in microcracks in the radicular dentine of the tooth instrumented. Cracks in the instrumented teeth have been observed and reported at various levels of horizontal cross sections or at the apical root surface.[23] These cracks or craze lines in the radicular dentine may become high-stress concentration areas from which the crack can gradually propagate to the root canal surface, a root cause for VRFs.[17,24]

The WO reciprocating files are characterized by a triangular or modified triangular cross section, resulting in a low cutting efficiency and less chip space. An increased cutting ability is usually associated with an improved cleaning efficacy and the reciprocal motion seems to enhance debris transportation toward the apex and may result in increased torsional forces.[25] Bürklein et al reported that this newer generation reciprocating instrument, WO caused significantly more microcracks than a full sequence of rotary files,[25] which may be the cause of less fracture resistance exhibited by the teeth in the group instrumented by WO files in the present study.

It has been reported in literature that the instrumentation of the root canals using the SAF system resulted in least dentinal microcrack formation.[13,14] According to the results of the present study, the root canal instrumentation with the SAF exhibited a higher resistance to fracture when compared to the reciprocating WO group. Capar et al[19] has recently reported the fracture resistance of teeth comparing teeth instrumented with SAF and ProTaper rotary files obturated with gutta-percha and AH Plus sealer. The results obtained from the present study are in accordance with their results obtained for the SAF group.

Excessive taper can result in excessive unnecessary removal of radicular dentin leading to weakening of the root. The new PTN files are designed with an uncommon design with the center of mass and the center of rotation are offset when in rotation. The file's offset design aids in more cross-sectional space for enhanced cutting, loading and auguring debris out of a canal compared to a file with a centered mass and axis of rotation. This unique design minimizes the engagement between the file and dentin. Also the PTN X1 and X2 files used in the present study present an increasing and decreasing alternating percentage tapered designs on these files. The alternate taper for X1 is 0.04 and X2 is 0.06.[10] As there is no study carried out using the PTN file, this unique design could be considered as a cause of better fracture resistance exhibited by the samples of this group.

The obturating materials are used to improve the fracture strength of an endodontically treated tooth.[26,27] The samples used in all the three groups were obturated using standard 0.02 tapered gutta-percha cones and epoxy-based resin AH Plus sealer. The root canal sealers when used, result in filling the gaps between gutta-percha cones and the walls of the radicular dentine.[28] It has been reported in previous studies that epoxy resin–based sealers have higher adhesion to root canal dentin and deeper penetration into dentinal tubules,[29,30] resulting in higher retention of the filling material by mechanical locking between the canal walls and the sealers. Hence a combination of gutta-percha and AH Plus sealer was used in the present study.

By far to the best of our knowledge the fracture resistance exhibited by the teeth instrumented using PTN and WO have not been reported in literature, with SAF scarcely reported. Hence, the study was designed and carried out to compare the fracture resistance exhibited by mandibular premolar teeth after instrumentation with SAF, PTN or WO. Further studies are required to assess the short and long-term impacts of instrumentation on the formation of cracks and vertical root fractures.

## 5. Conclusion

Under the limitations of the present in-vitro study, it can be concluded that the samples instrumented by the Self-Adjusting File exhibited a better fracture resistance when compared to rotary ProTaper NEXT and single reciprocating WaveOne file systems when filled with gutta-percha and epoxy-based sealer. Also the samples in the group instrumented reciprocating file WO; presented the least fracture resistance amongst the groups.

## Conflicts of interest

All authors have none to declare.

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