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# Fracture resistance of endodontically treated teeth using ProTaper NEXT rotary and R-Motion reciprocating file systems

Tashmeem Mohammad[1]*, Praveen Dalavai[1], Venkata Karteek Varma Penmetsa [1], Madhu Varma Kanumuri[1], Durga Bhavani Panithini[1], Sahithya Gunda[1]

## Abstract

**Objective:** This study compared the fracture resistance of mandibular premolars instrumented using the ProTaper NEXT rotary and R-Motion reciprocating nickel-titanium file systems.

**Methods:** In this in vitro study, 45 extracted single-rooted mandibular premolars were decoronated to obtain standardized root lengths of 13 mm. The teeth were randomly allocated to three groups (n = 15). Group I served as the uninstrumented control group. Groups II and III were instrumented using the ProTaper NEXT rotary and R-Motion reciprocating file systems, respectively. The canals were then obturated using the lateral compaction technique. A vertical load was applied to each specimen until fracture occurred. Data were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test, with significance set at $P < 0.05$.

**Results:** A statistically significant difference in fracture resistance was found among the groups ($P = 0.006$). The uninstrumented control group showed the highest mean fracture resistance (758.0 ± 149.6 N), followed by the R-Motion reciprocating group (731.9 ± 123.6 N) and the ProTaper NEXT rotary group (595.65 ± 146.06 N). No statistically significant difference was found between the uninstrumented control and R-Motion groups ($P = 0.086$). The ProTaper NEXT group exhibited significantly lower fracture resistance than both the uninstrumented control group ($P = 0.008$) and the R-Motion group ($P = 0.029$).

**Conclusions:** Within the limitations of this in vitro study, the R-Motion reciprocating file system maintained fracture resistance comparable to that of the uninstrumented control group and significantly higher than that of the ProTaper NEXT rotary file system.

**Keywords:** Dental instruments, Endodontically treated teeth, Fracture resistance, Root canal therapy, Shape memory alloys, Tooth fractures

## Introduction

The primary biological objective of root canal treatment is to prevent apical periodontitis through effective cleaning, shaping, and disinfection of the root canal system (1, 2). Although endodontically treated teeth demonstrate favorable long-term survival, structural failure remains an important clinical concern. A recent study reported cumulative survival rates of 97% at 10 years and 68% at 37 years for endodontically treated teeth (3). Tooth extraction was predominantly associated with untreatable caries, crown fractures, vertical root fractures (VRFs), periodontal disease, and persistent endodontic inflammation, with VRFs accounting for 33.3% of cases (3).

[1] Department of Conservative Dentistry and Endodontics, Vishnu Dental College and Hospital, Bhimavaram, Andhra Pradesh, India

*Corresponding Author: Dr.Tashmeem Mohammad
Email: tashmeem.mohammed@vdc.edu.in

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Several factors may increase the susceptibility of endodontically treated teeth to fracture. Structural loss may result from caries, trauma, or access cavity preparation. Root canal instrumentation may further weaken the root through dentin removal and procedural stresses. Obturation and post-space preparation may also affect root integrity (4-6). Therefore, biomechanical preparation must achieve adequate canal debridement and shaping while preserving as much radicular dentin as possible.

Nickel-titanium (NiTi) files are widely used in root canal preparation because of their superior flexibility compared with stainless-steel instruments of similar design. This greater flexibility may help maintain the original canal curvature during instrumentation (7). However, NiTi preparation still involves dentin removal and generates stresses within the root, and the magnitude of these effects may differ among NiTi file systems (8). One of the main characteristics that distinguishes these systems is their kinematics, which refers to the pattern of instrument movement inside the root canal, including the direction, angle, and speed of rotation. Engine-driven NiTi systems, including those evaluated in the present study, mainly use continuous rotary, reciprocating, or adaptive kinematics.

Continuous rotary files rotate in one direction, whereas reciprocating files alternate between clockwise and counterclockwise rotation. Adaptive systems modify their motion according to the load applied to the instrument (9).

NiTi File systems also differ in tip design, cross-sectional geometry, taper, core dimensions, flute configuration, number of instruments, and NiTi alloy treatment (10). These variations may influence the amount and pattern of dentin removal and the stresses generated within radicular dentin. Therefore, the effects of different file systems on remaining dentin thickness, dentinal defects, and root fracture resistance may be system-specific rather than determined by kinematics alone (11-13).

ProTaper NEXT (Dentsply Maillefer, Ballaigues, Switzerland) is a nickel-titanium rotary instrumentation system manufactured using M-Wire technology. The files have a variable taper and an off-centred rectangular cross-section. The off-centred design causes the file to move asymmetrically, producing a snake-like "swaggering" motion during rotation. This feature allows intermittent contact between the file and canal walls during rotation. The system is designed for efficient canal shaping using continuous rotational motion (8, 14).

R-Motion (FKG Dentaire Sàrl, Le Crêt-du-Locle, Switzerland) is a reciprocating Ni-Ti instrumentation system that incorporates a reduced central-core cross-sectional area to enhance flexibility. The files feature a rounded triangular cross-section with sharp cutting edges and a specially designed tip. Root canal preparation is performed using alternating clockwise and counterclockwise movements. This reciprocating motion may reduce continuous engagement between the file and canal walls and influence the distribution of flexural and torsional stresses during instrumentation (15). The combination of reduced core dimensions, cross-sectional geometry, heat-treated Ni-Ti alloy, and reciprocating motion may facilitate efficient canal preparation while minimizing unnecessary mechanical stress on radicular dentin (16).

Previous investigations have compared different rotary and reciprocating instrumentation systems with respect to fracture resistance, dentinal defects, shaping ability, and mechanical behaviour (17-19). However, the file systems, tooth types, final preparation sizes, and testing methods differed among these studies. Several investigations focused on instrument performance or dentinal defects rather than the fracture resistance of prepared roots (10, 13).

Although ProTaper NEXT and R-Motion have been compared in terms of apical debris extrusion and dentinal crack formation (18), evidence regarding the fracture resistance of roots instrumented with these two systems remains limited. Therefore, this in vitro study aimed to evaluate and compare the fracture resistance of mandibular premolars instrumented using ProTaper NEXT rotary and R-Motion reciprocating Ni-Ti file systems.

## Materials and methods

The study protocol was approved by the ethics committee of Vishnu Dental College and Hospital, Bhimavaram, Andhra Pradesh, India (approval no. IECVDC/2022/PG01/CE/IVT/19).

A total of 45 extracted human mandibular premolars were selected. All specimens had been extracted within the previous three months for orthodontic reasons. The teeth were cleaned with an ultrasonic scaler, stored in a 0.5% chloramine-T (sodium N-chloro-p-toluenesulfonamide) solution for one week, and then stored in distilled water for up to three months.

The specimens were examined under a stereomicroscope (Labomed, Labo America, Inc., Fremont, CA, USA) at 10 × magnification. The inclusion criteria were the presence of a single root canal and a fully formed apex, with no evidence of caries, restorations, cracks, fractures, resorption, or calcification. Periapical radiographs were obtained in mesiodistal and buccolingual views to confirm the presence of a single root and a mature apex.

### *Sample size calculation*

The G*Power software (Version 3.1.9.2; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Deutschland) was used for sample size estimation. The effect size (Cohen's f = 0.488) was obtained from a pilot study performed with the same fracture resistance testing protocol described in this study. With a significance level of 5% and statistical power of 80%, the required total sample size was calculated as 45 specimens, with 15 specimens allocated to each group.

### *Sample standardization*

The samples were kept at room temperature in a saline solution. All specimens underwent transverse decoronation using a diamond-coated disc (NMD; Nexus


**Figure 1**. The rotary and reciprocating endodontic instruments used in this study; (A) ProTaper NEXT instruments, including X1 and X2 files. (B) R-Motion instruments, including R-Motion Glider (15/.03) and R-Motion 25 (25/.06) files.

Medodent, Mumbai, India) under water cooling, leaving a root length of 13 mm measured from the root apex.

To ensure that the study groups were comparable in specimen dimensions and weight, the buccolingual and mesiodistal root dimensions at the decoronation level were measured using a digital caliper (Mitutoyo Corp., Kawasaki, Japan). The product of the two diameters was calculated for each specimen as an index of its cross-sectional size. The weight of each specimen was also measured using a precision balance. One-way ANOVA confirmed no significant differences among the groups in specimen weight ($P = 0.915$) or dimensional product ($P = 0.998$). The specimens were then randomly allocated to the groups using Research Randomizer (www.randomizer.org).

## *Endodontic procedure*

A size 15 K-file (Mani Inc., Tachigiken, Japan) was used to establish canal patency. The file was advanced through the canal until its tip was visible at the apical foramen to determine the working length (WL).

The specimens were randomly assigned to one control and two experimental groups (n = 15 each) as follows:

- Group I (control): The specimens were neither instrumented nor obturated with gutta-percha.
- Group II (ProTaper NEXT): The root canals were instrumented using ProTaper NEXT rotary files (Figure 1A). The ProTaper NEXT SX orifice modifier was used first, followed by the X1 (17/0.04) and X2 (25/0.06) files in sequence. The files were used with continuous rotation until the X2 file reached the full working length. The endodontic motor (E-Connect S; Eighteeth, Changzhou, Jiangsu, China) was set to a rotational speed of 300 rpm and a torque of 4 N·cm.
- Group III (R-Motion): The root canals were instrumented using the R-Motion (Figure 1B) Glider (15/0.03), followed by the R-Motion 25 (25/0.06). The same endodontic motor was operated in reciprocating mode at 300 rpm and a torque of 4 N.cm. In this group, the R-Motion files were used with a brushing motion, defined as lateral strokes against the canal walls during file withdrawal. According to the manufacturer, this motion is used to remove coronal interferences and to ensure uniform shaping of irregular canals.

The characteristics of the two file systems are presented in Table 1.

## *Irrigation protocol*

During instrumentation, the canals were irrigated with 2 mL of 3% sodium hypochlorite (NaOCl; Parcan, Septodont Healthcare India Pvt. Ltd., Raigad, India) using a 27-gauge needle after each instrument cycle. Final irrigation was performed with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA; Dent Wash, Prime Dental Products Pvt. Ltd., Thane, India), followed by 5 mL of 3% NaOCl and a final rinse with 5 mL of 0.9% saline. The canals were then dried with absorbent paper points.

## *Obturation procedure*

AH Plus sealer (Dentsply DeTrey GmbH, Konstanz, Germany) was used in Groups II and III. The canals were obturated with appropriately sized master gutta-percha cones using the lateral compaction technique. The coronal orifices were then sealed with Orafil-G temporary filling material (Prevest DenPro Limited, Jammu, India). Finally, all specimens, including those in the uninstrumented control group, were stored in an incubator at 37°C and 100% humidity for seven days.

## *PDL simulation*

A 0.3-mm-thick layer of aluminium foil (Alufoil Products Pvt. Ltd., Kolkata, India) was wrapped around the root surfaces to simulate the periodontal ligament. Each specimen was placed vertically in a mold filled with self-curing acrylic resin to a level 2 mm below the cementoenamel junction (Figure 2A). After initial

**Table 1.** Design features and operating settings of the ProTaper NEXT and R-Motion file systems used in the present study

| Specification | ProTaper Next | R-Motion |
|---|---|---|
| Metallurgy | M-Wire nickel-titanium | Heat-treated nickel-titanium |
| Cross-sectional design | Off-centred rectangular | Rounded triangular, with sharp cutting edges |
| Motion | Continuous rotation | Reciprocating, counterclockwise cutting action |
| Rotational speed | 300 rpm in the present study | 300 rpm in the present study |
| Torque | 4 N·cm in the present study | 4 N·cm in the present study |
| Final shaping file (tip size/taper) | ProTaper NEXT X2 (25/0.06, variable taper) | R-Motion 25 (25/0.06) |

polymerization, the foil was removed, and light-body silicone impression material (Neopure, Orikam Healthcare India Pvt. Ltd., Gurgaon, India) was injected into the resulting space.

### *Mechanical testing*

Fracture testing was performed using a universal testing machine (Instron 3400, Norwood, MA, USA). Each acrylic resin block was placed on the lower plate of the universal testing machine, with the long axis of the specimen aligned vertically.

A 0.5-mm-diameter stainless-steel conical tip was attached to the upper arm of the machine and positioned over the centre of the canal orifice to apply a vertical load along the long axis of the tooth (Figure 2B). The load was applied at a crosshead speed of 1 mm/min until fracture occurred. The maximum fracture force for each specimen was recorded in Newtons.

### *Statistical analysis*

All statistical analyses were conducted using IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA). Data normality was assessed using the Shapiro–Wilk test, which showed no significant deviation from normality in any group ($P > 0.05$). Fracture load was compared among the groups using one-way analysis of variance (ANOVA), followed by Tukey's honestly significant difference (HSD) post hoc test. Statistical significance was set at $P < 0.05$ for all analyses.

## Results

Table 2 presents the mean and standard deviation (SD) of the fracture loads recorded for the study groups. ANOVA revealed a statistically significant difference in

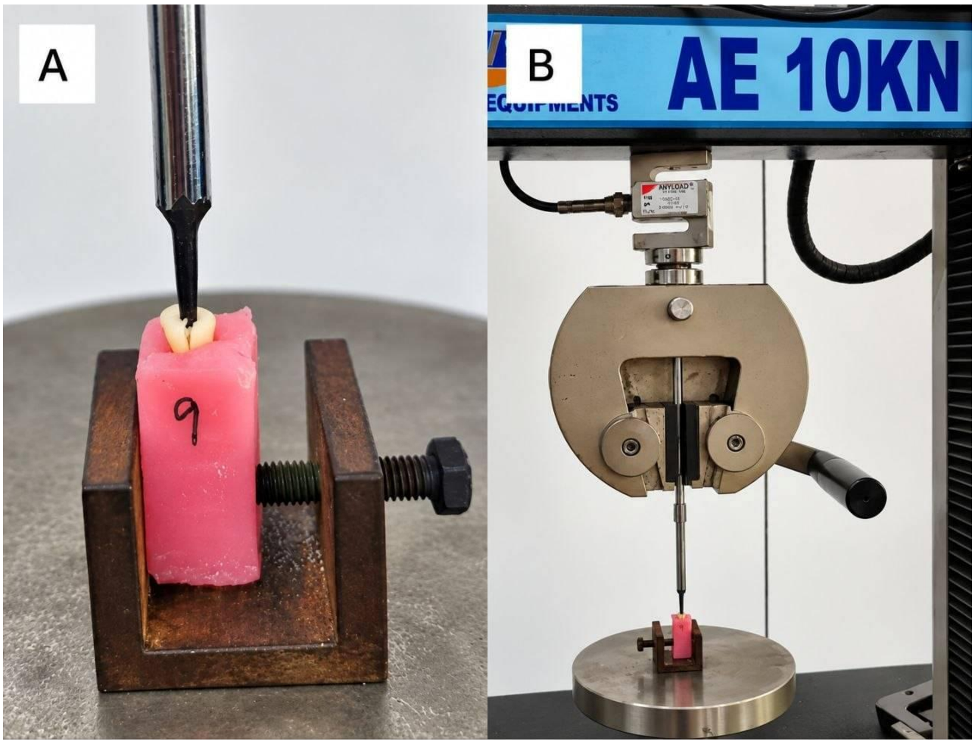


**Figure 2**. Fracture resistance testing: (A) A representative specimen embedded in acrylic resin; (B) A specimen positioned in the universal testing machine.

**Table 2.** Mean and standard deviation (SD) of fracture resistance (N) in the study groups

| Groups | Definition | Mean ± SD (N)* |
|---|---|---|
| Group I | Control (Uninstrumented) | 758.0 ± 149.6[a] |
| Group II | ProTaper NEXT | 595.6 ± 146.0[b] |
| Group III | R-Motion | 731.9 ± 123.6[a] |
| P-value | | 0.006 |

* Different superscript letters indicate a statistically significant difference according to Tukey's honestly significant difference (HSD) post hoc test (P < 0.05). The overall P-value was obtained using one-way analysis of variance (ANOVA).

fracture resistance among the groups (P = 0.006). Tukey's post hoc test revealed no statistically significant difference between the R-Motion reciprocating group (Group III) and the uninstrumented control group (P = 0.086). In contrast, the ProTaper NEXT rotary group (Group II) exhibited significantly lower fracture resistance than the control group (P = 0.008) and the R-Motion group (P = 0.029).

## Discussion

The present study evaluated the fracture resistance of endodontically treated mandibular premolars instrumented with the ProTaper NEXT rotary and R-Motion reciprocating systems and compared them with an uninstrumented control group. ProTaper NEXT was used as the conventional rotary Ni-Ti system for comparison with the reciprocating R-Motion system. The control group showed the highest mean fracture resistance (758.0 ± 149.6 N), followed by R-Motion (731.9 ± 123.6 N) and ProTaper NEXT (595.6 ± 146.0 N). R-Motion did not differ significantly from the control group, whereas ProTaper NEXT showed significantly lower fracture resistance than both the control group and the R-Motion group. These findings suggest that under the conditions of this study, canal preparation with R-Motion preserved fracture resistance of premolars more effectively than ProTaper NEXT.

Specimen standardization is important in mechanical testing because variations in root morphology and dimensions can influence fracture load. In the present study, the specimens were standardized for root length, buccolingual and mesiodistal canal dimensions at the decoronation level, and weight, with no significant intergroup differences observed before instrumentation. These measures reduced anatomical variability and improved the comparability of the study groups.

The uninstrumented control group exhibited the highest mean fracture resistance among all groups. This finding may be explained by the preservation of radicular dentin and the absence of instrumentation-related changes. Because no canal preparation was performed in this group, dentin removal and mechanical stresses associated with instrumentation were avoided. In contrast, canal preparation in the experimental groups may have reduced the remaining dentin thickness and altered stress distribution within the roots, potentially contributing to the lower fracture resistance observed.

Specimens instrumented with the R-Motion system exhibited significantly higher mean fracture resistance than those instrumented with ProTaper NEXT. This difference may be related to several design and operational characteristics of the two systems, including kinematics, core design, cross-sectional geometry, tip design, and Ni-Ti metallurgy. In the R-Motion group, the R-Motion Glider was first used to establish the glide path, followed by the R-Motion 25 file for canal shaping using reciprocating motion. In contrast, the ProTaper NEXT group was instrumented sequentially with the SX, X1, and X2 files using continuous rotary motion. Thus, the two systems differed not only in kinematics but also in the number of shaping instruments. These differences may influence the amount and distribution of dentin removal and the resulting stress distribution within the root, potentially affecting fracture resistance. However, because these variables were not isolated experimentally, they should be considered possible explanations rather than direct causal determinants of the observed difference.

Recent studies have shown that fracture resistance may vary according to file taper, preparation design, obturation technique, and restorative method (20-22). A recent study comparing the JIZAI nickel–titanium (NiTi) rotary file system, ProTaper Ultimate, and XP-endo Rise reported differences in fracture resistance among the systems, with XP-endo Rise producing the highest value among the experimental groups (21). These variations may be related to differences in file geometry, taper, metallurgy, instrumentation protocols, specimen standardization, and obturation or restorative procedures.

ProTaper NEXT demonstrated the lowest mean fracture resistance among the study groups, showing fracture resistance values that were significantly lower than both the control and R-Motion groups. Canal preparation in this group was completed with the X2 file (25/0.06). ProTaper NEXT is manufactured from M-Wire and features a variable taper and an off-centred rectangular cross-section. This design shifts the mass of the file away from its central rotational axis, producing an asymmetric motion during rotation. Previous experimental studies have likewise reported lower fracture resistance following ProTaper NEXT instrumentation than in uninstrumented controls (17, 23).

The possible influence of instrumentation kinematics on root fracture resistance is supported by previous evidence. Reciprocating motion may reduce torsional and overall stresses compared with continuous rotary motion because of differences in movement dynamics. Using finite element analysis and computer-aided design models, Sasidhar et al. (24) compared the stresses generated by rotary and reciprocating files in straight and curved canals. In curved canals subjected to a vertical load of 12.5 N, the maximum von Mises stress was 40.28 MPa with rotary motion and 27.524 MPa with reciprocating motion. These findings suggest that instrumentation kinematics can influence stress generation; however, the extent to which this contributes to root fracture resistance requires further investigation.

With respect to the ProTaper NEXT group, the present findings are consistent with those of previous studies. Pawar et al. (23) and Aidasani et al. (17) both reported significantly lower fracture resistance in mandibular premolars instrumented with ProTaper NEXT than in uninstrumented teeth. Similarly, Yashas et al. (25) compared uninstrumented teeth with teeth instrumented with the Self-Adjusting File (SAF), ProTaper NEXT, and HyFlex EDM systems, and reported the highest mean fracture resistance in the control group and the lowest in the ProTaper NEXT group, with a statistically significant difference among the groups. In contrast, the R-Motion group in the present study did not differ significantly from the uninstrumented control group, indicating that instrumentation with R-Motion did not significantly reduce fracture resistance under the conditions of this study.

On the other hand, an advantage of reciprocating over continuous rotary kinematics in preserving root fracture resistance has not been consistently demonstrated. Jaggi et al. (11) reported significantly higher fracture resistance and greater remaining dentin thickness in the coronal and middle thirds of teeth prepared with the TruNatomy rotary system than in those prepared with the WaveOne Gold reciprocating system. Similarly, Singh et al. (26) compared mandibular premolars prepared with stainless-steel hand K-files using a manual step-back technique, ProTaper NEXT in continuous rotation, WaveOne Gold in reciprocation, and a hybrid technique combining rotary ProTaper Universal files in the coronal and middle thirds with hand K-files in the apical third. The WaveOne Gold group showed the lowest mean fracture resistance among the instrumented groups; however, its difference from the ProTaper NEXT group was not statistically significant.

The authors attributed the lower value of the WaveOne Gold group to single-file preparation, in which both the instrument and the canal walls are subjected to considerable stress, and to the large taper of the instrument, which may promote the formation of dentinal defects. Moreover, unlike the present study, in which the final instruments of both systems had the same tip size and taper (25/0.06), the final instruments in that study differed in size and taper (ProTaper NEXT X3, 30/0.07; WaveOne Gold, 35/0.06). Moreover, contrary to their findings, R-Motion showed significantly higher fracture resistance than ProTaper NEXT in the present study. This discrepancy may reflect differences in the reciprocating systems evaluated (WaveOne Gold versus R-Motion), instrument taper, specimen preparation, and loading protocols. Therefore, it appears that the reciprocating motion alone may not determine root fracture resistance, and that other file and procedural characteristics may also contribute.

Evidence regarding the effect of instrumentation kinematics on dentinal microcrack formation is inconsistent. In a micro-CT study of maxillary molars, Soltaninejad et al. (27) found that preparation with two rotary systems (One Curve and VDW.ROTATE) and one reciprocating system (EdgeOne Fire), all manufactured from heat-treated NiTi alloys, significantly increased the number of sections with dentinal microcracks, with no significant difference among the systems. Likewise, Ibrahim et al. (18) reported similar dentinal crack formation after preparation with ProTaper NEXT and ProTaper Ultimate, both used in continuous rotation, and R-Motion, used in reciprocation. In a systematic review of ex vivo micro-CT studies, Călin et al. (28) concluded that reciprocating kinematics tended to produce fewer dentinal microcracks than continuous rotation in moderately curved canals. Furthermore, although reciprocating motion is often considered to improve instrument fatigue resistance, a recent meta-analysis found no statistically significant difference in time to fracture between rotary and reciprocating files (29).

Taken together, the findings indicate that the effect of root canal instrumentation on fracture resistance may depend on the file system used. This variation may be associated with differences in file geometry, taper, core dimensions, alloy characteristics, kinematics, and instrumentation sequence, which may influence dentin removal and stress distribution within the root. The R-Motion group showed significantly higher fracture resistance than the ProTaper NEXT group. This difference may be related, at least in part, to differences in kinematics and file design, including the reciprocating kinematics and smaller central core of the R-Motion instruments. These characteristics may influence instrumentation-related stresses and the preservation of radicular dentin. Nevertheless, the individual contribution of each design or operating variable cannot be determined from the present study because these factors were not independently evaluated.

This study has several limitations. Only single straight-rooted mandibular premolars were evaluated, which does not reflect the anatomical complexity of curved or multirooted teeth. In addition, static vertical loading does not reproduce the dynamic, multidirectional, and cyclic forces encountered in the oral environment, and dentinal crack formation was not assessed before or after instrumentation. Future studies should evaluate the fracture resistance of teeth with curved canals and multiple roots prepared with these systems, apply cyclic loading protocols that better simulate masticatory forces, use finite element analysis to determine the stress distribution within the root after instrumentation, and assess dentinal crack formation before and after instrumentation using micro-computed tomography. In addition, clinical studies are needed to determine whether the differences observed in vitro translate into differences in the incidence of vertical root fracture.

## Conclusions

Within the limitations of this in vitro study, it can be concluded that:

1- Teeth instrumented with R-Motion showed fracture resistance comparable to that of uninstrumented teeth; thus, instrumentation with this system did not significantly reduce fracture resistance.
2- Instrumentation with ProTaper NEXT significantly reduced fracture resistance compared with both uninstrumented teeth and teeth instrumented with R-Motion.


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Not applicable.

## Conflict of interest

The authors declare no conflict of interest.


## Author contributions

T.M. and D.P. contributed to conceptualization, study design, investigation, data acquisition, and manuscript preparation. T.M. also performed the literature search and formal analysis. K.V. contributed to study design and investigation; K.M.V. to study design, literature search, and formal analysis; and D.B.P. and G.S. to literature search, investigation, and data acquisition. All authors critically reviewed and approved the final manuscript.

## Ethical considerations

The study protocol was approved by the ethics committee of Vishnu Dental College and Hospital, Bhimavaram, Andhra Pradesh, India, affiliated with Dr. NTR University of Health Sciences (approval no. IECVDC/2022/PG01/CE/IVT/19).


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