



## **Influence of Different Endodontic File Systems on Vertical Fracture Resistance of Mandibular Bicuspid: An In-Vitro Study**

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**ABSTRACT**

**Background:** Endodontic treatment's success largely hinges on the techniques and instruments employed. Different endodontic file systems can variably impact the structural integrity of mandibular bicuspid. This in-vitro study aims to assess the influence of various file systems on vertical fracture resistance, providing insights into how these systems affect tooth resilience. Understanding this relationship will enhance clinical decision-making, ultimately leading to improved patient care and outcomes in endodontic procedures while minimizing the risk of fracture during and after treatment. **Aim:** To assess the impact of Hand K-files, ProTaper Next, Mani JIZAI rotary files and Self-adjusting File (SAF) systems on the vertical fracture resistance of teeth instrumented with them. **Materials and Methods:** Fifty newly extracted mandibular bicuspid were chosen, and the samples were sliced at or below the cemento-enamel junction to get 14 millimetres of uniform length of root. The specimens were then unintentionally assigned to five groups, with group 1 acting as the reference group, groups 2, 3, 4, and 5 being instrumented with Hand K-files, ProTaper Next (PTN), Mani JIZAI rotary files, and Self-adjusting File systems, respectively. Subsequently biomechanical preparation, the specimens were embedded in auto-polymerizing acrylic blocks, and the specimens were loaded vertically in a universal testing machine at a cross-head speediness of one millimetre/minutes until vertical root fractured. The forces necessary to cause the fractures were then documented. Analysis of data was made by One-way ANOVA. A p-value of <0.05 was deemed statistically significant. **Results:** There was a statistically significant variation in the fracture resistances across the categories. The control and SAF groups have comparable fracture resistance ( $p > 0.05$ ). **Conclusion:** The SAF-instrumented samples showed enhanced resistance to fracture, indicating its superior performance in preserving tooth integrity during endodontic procedures. This study suggests that selecting appropriate file systems is essential for minimizing the risk of vertical fractures in mandibular bicuspid.

**Key words:** Fracture resistance, ProTaper Next, Mani JIZAI rotary files, Self-adjusting File.

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## Introduction

Endodontic therapy's main objective is to use a variety of equipment and supplies to sterilize the entire root canal chamber and remove the affected tooth tissue. A vertical root fracture (VRF) is when a crack originates at the root of a tooth and extends upward towards the crown along the tooth's length. However, these cracks can also start in the crown region and then expand downward to root based on the cause. VRF has been linked more often to teeth that have had endodontic treatment, with a prevalence that ranges from 4% to 32%. Furthermore, loss of pulp tissue, dentin dehydration, impacts of irrigated solution, and high pressure used during root-filling treatments are the risk variables that contribute to VRFs. Rotating endodontic files during instrumentation remove additional root dentin and may decrease the structural strength of the dentin, which reduces the restored tooth's resistance to fracture.<sup>1</sup>

While rotating files offer numerous advantages over manual files, they exert additional strain on root canal walls and increase the risk of microcracks forming in the dentin. Furthermore, it is established that Ni-Ti rotary tools focus pressure on the dentinal walls, heightening the risk of root fractures.<sup>2</sup> Consequently, our research's goal to investigate and contrast the fracture resistance of teeth during instrumentation using unprepared canals, Hand K-files (MANI, Japan), ProTaper Next files (Dentsply Sirona, Ballaigues, Switzerland), JIZAI (Mani, Tochigi, Japan), and SAF (Redent Nova, Israel).

## Materials and Methods

The local Ethical Committee examined and authorized the investigation's design. Fifty human mandibular bicuspid, each with a single root canal and a fully matured apex, were collected and stored at a constant 37°C in a synthetic saliva solution until they were required. A buccolingual and mesio-distal radiograph was taken to verify the existence of one root and canal as well as a developed apex. Teeth that displayed an blunderbuss canals, various canals, canal calcification, cracks or fractures, senile caries, angulated roots, previous endodontic treatments, or internal or exterior resorption were not included in the investigation.

To ensure consistent sampling characteristics, the mesio-distal and bucco-lingual diameters of the specimens were measured at the CEJ level using a Vernier caliper; the average measurements were 6.5-7.0 mm for the bucco-lingual dimension and 4.5-5.0 mm for the mesio-distal dimension. Any specimens outside these size ranges were not included. The teeth were cut at or near the cervical line using a bur with diamond coated with constant water cooling to achieve a uniform root length of 14 millimetres. To do this, a #15 K-file (Mani, Japan) was placed till it was accessible at the end of the foramen and then withdrawn by 0.5 mm.

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Following that, the samples were split into five groups at randomization as:

Group 1 (n=10): Reference group- This specimen receives no preparation of canals and endure untreated.

Group 2 (n=10): Hand K-files- ISO 2% NiTi K-files hand files was used to prepare the specimens. Using the sequence of #10, #15, #20, and #25. Apical enlargement was carried out gradually from ISO #10 to #25. Step-back preparation was then carried out till #40.

Group 3 (n=10): PTN rotary files- PTN files (X1 and X2) utilizing preprogrammed endomotor (Waldent EndoPro LED) at 300 rpm speeds and 2 Ncm torque implementing a mild in-and-out motion. The X1 and X2 PTN files were utilized with a lateral scrubbing motion until the WL was achieved, following the use of Sx file to flare the root canal orifices.

Group 4 (n=10): JIZAI rotary file system- The specimens were first equipped with a JIZAI orifice opener (025 14) to widen the one third of the root channels using an X Smart Plus endomotor at 500 rpm and 3Ncm torque in a clockwise direction, followed by a D-finder #10 (Mani, Japan) till working length; a JIZAI GLIDER (013 04) that moved delicately in transline (in and out) motion up to it reached the desired working length at 300 rpm and 1Ncm torque in a clockwise direction; and then JIZAI I (025 04), II (025 06), and III (035 04) respectively for preparation of the canals using transline motion at 500 rpm and 3Ncm torque till working length.

Group 5 (n=10): SAF files- To instrument the samples, a two-millimetre SAF with transline motion (in-and-out) was used. The EndoStation endodontic system (ReDentNova) was used to push the file in transline motion until the working length at 5000 vibrations per minute. Constant hydration with 5.25% sodium hypochlorite at an average rate of four millilitre/minute was applied to the file for 4 minutes, as advised by the manufacturer. A peristaltic pump that was integrated inside the void file was used to apply the irrigation fluid. The files were recapitulated, and the root tip preparation was uniformed to ISO size 25. Following the use of each equipment in all groups, 2 mL of 3% sodium hypochlorite (NaOCl) was used to irrigate the chamber. After washing the root canals with five millilitre of seventeen percent EDTA solution for one minute to eliminate smear layer. Regular saline approximately five millilitre was utilized for final irrigation. Paper points that were absorbent were used to dry the canals. Up to 8 mm from the apex, all the specimens were implanted in autopolymerizing acrylic blocks, keeping coronal 6 mm uncovered. Until they were prepared for strength testing, the roots were kept moist with a damp cloth.

In a universal testing machine, the samples underwent a vertical load applied at a rate of one millimetre/minute until a vertical root fracture happened. The force needed to break each sample was measured in Newtons, with a steel conical tip (0.5 mm in diameter and tapered at 60°) aligned parallel to the canal orifice's long axis. To

finalize the findings, the data was rigorously analyzed statistically. A one-way ANOVA test was employed for inference-based statistics, comparing fracture loads across groups. For detailed pairwise comparison, a post hoc Tukey's test was conducted. A significant difference was identified when "p" was less than 0.05.

## Results

Table 1 demonstrates comparison of mean vertical fracture resistance between the control group and various file systems. This table suggests that the least fracture resistance was shown in group 4 followed by group 3, 2 and 5 respectively compared to group 1.

Table 2 demonstrates comparison of mean differences in vertical fracture resistance between the control group and various file systems. Apart from groups 1 and 5, the between-group examination revealed a statistically significant variance between the categories.

**Table 1: Comparison of mean vertical fracture resistance between the control group and various file systems.**

Groups (n=50)	Mean fracture resistance (in Newton) $\pm$ Standard deviation	p-value
Group 1	566.78 $\pm$ 128.36	< 0.05*
Group 2	423.5 $\pm$ 114.56	
Group 3	287.36 $\pm$ 78.23	
Group 4	143.58 $\pm$ 26.78	
Group 5	545.23 $\pm$ 214.4	

\*- Statistically significant difference

**Table 2: Comparison of mean differences in vertical fracture resistance between the control group and various file systems.**

Groups	Mean difference	p-value
Group 1 vs Group 2	143.28	< 0.05*
Group 1 vs Group 3	288.42	< 0.05*
Group 1 vs Group 4	423.2	< 0.05*
Group 1 vs Group 5	21.55	> 0.05*

Group 2 vs Group 3	136.14	< 0.05*
Group 2 vs Group 4	279.92	< 0.05*
Group 2 vs Group 5	121.73	< 0.05*
Group 3 vs Group 4	143.78	< 0.05*
Group 3 vs Group 5	257.87	< 0.05*
Group 4 vs Group 5	401.65	< 0.05*

\*- Statistically significant difference

## Discussion

Dentinal cracks occur during cleaning of root canals using NiTi instruments, however they are less common than with stainless steel instruments. Additionally, Bier CA et al. (2009)<sup>3</sup> noted that improvements in root canal shape and instrument designs have been made possible by technological advancements in rotary NiTi devices. When compared to hand files, root canal shaping techniques and rotational instrumentation using NiTi equipment can significantly increase the production of cracks. Clinically, microcrack propagation results in root fracture. This increases the risk of subsequent infections due to bacterial growth in crack lines.<sup>4</sup>

Increased amounts of stress caused by stiffer file designs might result in root dentin flaws and eventual root fracture. The cross-section, dimensions, taper off, process of production, and materials used to make the files all affect its stiffness.<sup>5</sup> More tapered rotary files are said to put more strain on the walls of the root canals and may contribute to the development of dentinal cracks as cited by Bapna P et al. (2023).<sup>6</sup>

In this study, the teeth were decoronated to eliminate the effect of root canal opening and coronal dentin preservation on the samples' fracture tendencies. This approach allowed for a focused comparison of how different files influence the force needed to fracture the teeth, as opposed to the unprepared control group. Notably, no root canal filling procedures were considered to keep the results pure. The Mani JIZAI system, with its 6% taper, stands out as a relatively new option with features like a variable flute pitch to prevent a screw-in effect, radial lands for minimizing canal wall engagement, and an off-centered file axis for enhanced debris clearance. In contrast, ProTaper Gold files offer a customizable taper for preparation.<sup>7</sup>

The NiTi mesh used to make the SAF is hollow. In addition to lacking flutes, blades, and a metal core, it cannot remove dentin. Instead, its rough texture of files scratches the dentin, reducing the probability of dentinal microcracks forming and the quantity of intact dentin that can be removed.<sup>7</sup>

A research investigation conducted by Yoldas O and co-authors (2012)<sup>8</sup> and Liu R and colleagues (2013)<sup>9</sup> provided assistance to this present research. They found that the radicular dentin of the specimens filled with

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SAF and hand files was found to be free of microcracks.

Kim HC and colleagues (2013) reported that the SAF produced stress of about 10 MPa. This may be explained by the fact that SAF boosts the treated teeth's resistance to fracture by producing very few or no microcracks. It was observed that most of the teeth fractured along the buccolingual axis. According to Nassar S et al. (2022), this lends credence to the theory that teeth might be softer buccolingually than mesio-distally. This study confirms that teeth that have undergone endodontic treatment become weaker and are known to be more brittle. Therefore, care should be made to prevent removing unnecessary dentin during endodontic treatment in order to maintain the teeth's strength.

## Conclusion

The study's findings indicate that the Self-adjusting File (SAF) system provided markedly superior fracture resistance when compared to traditional file systems, such as Hand K-files, ProTaper Next (PTN), and Mani JIZAI rotary files. This enhanced performance of SAF-instrumented samples highlights its potential advantages in maintaining the structural integrity of mandibular bicuspid during endodontic procedures. Notably, the fracture resistance exhibited by the SAF group was nearly equal to that of the untreated control group, suggesting that the SAF system effectively preserves tooth structure similar to that of a non-instrumented tooth.

However, the study also acknowledged certain limitations that warrant consideration. The in-vitro nature of the research may not entirely replicate the complexities of real clinical situations, including variations in tooth anatomy, canal morphology, and the presence of pre-existing dental conditions. Furthermore, the scope of the study was limited to a specific sample size and type of teeth, which could affect the generalizability of the results.

To validate these findings, further research is needed, particularly long-term experiments that incorporate diverse characteristics mimicking clinical scenarios. These future studies should encompass a wider variety of tooth types and conditions, as well as factors such as different endodontic procedures and variations in operator techniques. Such comprehensive research will enhance our understanding of the performance of various file systems in real-world settings, ultimately leading to improved clinical outcomes and greater knowledge of fracture resistance in endodontically treated teeth.

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## References

1. Patel S, Bhuvra B, Bose R. Present status and future directions: vertical root fractures in root filled teeth. *Int Endod J*. 2022; Suppl 3(Suppl 3):804-826.
2. Pawar AM, Thakur B, Kfir A, Kim HC. Dentinal defects induced by 6 different endodontic files when used for oval root canals: an in vitro comparative study. *Restor Dent Endod*. 2019;44(3): e31.
3. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. *J Endod*. 2009; 35:236–8.
4. Pawar AM, Pawar MG, Thakur B, Banga KS, Luke AM. Resistance to fracture of teeth instrumented using novel EndoStar E5 rotary versus ProTaper NEXT and WaveOne file systems. *J Conserv Dent*. 2018;21(1):52-56.
5. Lertchirakarn V, Palamara JE, Messer HH. Patterns of vertical root fracture: factors affecting stress distribution in the root canal. *J Endod*. 2003;29(8):523-8.
6. Bapna P, Ali A, Makandar SD, Ghani NR, Metgud S. Comparative Evaluation of Fracture Resistance of Endodontically Treated Teeth Instrumented with K3XF Rotary Files Using Different Tapers. *Cureus*, 2023, 15(1).
7. Bürklein S, Donnermeyer D, Hentschel TJ, Schäfer E. Shaping Ability and Debris Extrusion of New Rotary Nickel-Titanium Root Canal Instruments. *Materials (Basel)*. 2021;14(5):1063.
8. Yoldas O, Yilmaz S, Atakan G, Kuden C, Kasan Z. Dentinal microcrack formation during root canal preparations by different NiTi rotary instruments and the self-adjusting file. *J Endod* 2012; 38:232-5.
9. Liu R, Hou BX, Wesselink PR, Wu MK, Shemesh H. The incidence of root microcracks caused by 3 different single-file systems versus the ProTaper system. *J Endod* 2013; 39:1054-6.
10. Kim HC, Sung SY, Ha JH, Solomonov M, Lee JM, Lee CJ, et al. Stress generation during self-adjusting file movement: Minimally invasive instrumentation. *J Endod* 2013; 39:1572-5.
11. Nassar S, Shetty HK, Nair PM, Gowri S, Jayaprakash K. Comparative evaluation of fracture resistance of endodontically treated bicuspid instrumented with hand files, trunatomy, protaper next, protaper gold, and waveone – An In vitro study. *J Pharm Bioall Sci*,2022;14: S600-4.



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