

# Comparison of Four Rotary NiTi Files on Vertical Root Fracture Resistance of Endodontically Treated Teeth: An In-vitro Study

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## ABSTRACT

**Introduction:** There are several reasons associated with vertical root fracture, from which biomechanical preparation can be considered as one of the predisposing factors which can increase the susceptibility to vertical root fracture. It depends upon the amount of forces used during the preparation and taper of the file systems used for the preparation.

**Aim:** To compare vertical root fracture resistance of teeth prepared by four different rotary NiTi file systems.

**Materials and Methods:** This was an in-vitro study conducted on 150 extracted mandibular premolars from September 2022 to November 2022 in the Department of Conservative Dentistry and Endodontics, Karnavati School of Dentistry, Karnavati, Gandhinagar, Gujarat, India. All the teeth were decoronated keeping the remaining root length of 13 mm. The roots were divided into five groups of 30 each. Group-1: Vortex blue, Group-2: Edge File X7, Group-3: Hyflex EDM, Group-4: ProTaper Gold, Group-5: Control Group. The roots were placed in silicon impression material to resemble periodontal ligament. All the root canals were negotiated to their terminus with stainless

steel K Files except the control group. All teeth from each group were then prepared with their respective file systems and were obturated and sealed with composite. All the samples were then tested with a universal testing machine to evaluate the vertical root fracture. Compressive force was applied and the load necessary to fracture was recorded in Newton. Statistical analysis was done using one-way Analysis of Variance (ANOVA) followed by post-hoc Tukey test.

**Results:** Fracture resistance of Group-5 (Control group) was the highest (522.789±98.79215), followed by Group-1 (Vortex blue) (457.964±37.75982) whereas Group-4 (ProTaper Gold) showed least resistance (349.445±33.62643). The fracture resistance of Vortex blue file system showed significant difference when compared to Hyflex EDM and ProTaper Gold file systems ( $p < 0.001$ ).

**Conclusion:** The maximum amount of force needed to fracture the samples were prepared with Vortex blue file while ProTaper Gold file shows minimum amount of force needed to fracture the sample.

**Keywords:** Compressive force, Nickel-titanium rotary files, Universal testing machine

## INTRODUCTION

Clinical endodontics covers a variety of treatment approaches, but the root canal system is the most crucial one since it allows patients to keep their natural teeth in both forms and function as well as appearance [1]. There are multiple reasons for vertical root fracture but one of the factor considered can be the forces applied during biomechanical preparation and the amount of dentin left after the preparation [2].

Recently multiple file systems are marketed with claim of creating less cracks in dentin during canal preparation and hence, reduces incidence of vertical root fracture. They are of various wire technology as well as different body taper and tip designs. ProTaper Gold was first released with exclusive superior metallurgy. Having a gradually tapered form, the firm claimed it would increase cutting efficiency and safety. It has a convex triangular cross-section, a progressive variable taper, and is offered in eight sizes [3].

HyFlex EDM files are produced using manufacturing process called Electrical Discharge Machining with cross-section design. Almost triangular cross-section at top, trapezoidal cross-section in middle, quadratic cross-section at tip [4]. Vortex blue, a newly developed NiTi rotary instrument made from M Wire [5]. The distinctive blue colour of Vortex blue is due to an optical effect, created by light rays interacting with a titanium oxide layer on the surface of the file. It has a triangular cross-section, with constant taper and available into variable sizes [6].

Edge File X7 rotary file is made of an Annealed Heat Treated (AHT) nickel-titanium alloy brand named Fire-Wire™ with constant

taper and triangular cross-section [7]. Vertical root fracture can be assessed by different types of mechanical test stands and kits which works with digital pressure gauge. Many studies have been carried out on file systems inducing vertical root fracture using universal testing machine [8-12]. No studies have been carried out with Edge-X7 file and Vortex blue comparison with Protaper Gold and Hyflex EDM.

Hence, the aim of the present study is to compare the VRF resistance of teeth instrumented with, ProTaper Gold (Dentsply), Hyflex EDM (Coltene), Vortex blue (Dentsply), Edge file X7 (Edge Endo), which are amongst the newly introduced rotary instruments.

## MATERIALS AND METHODS

This in-vitro study was conducted on 150 extracted mandibular premolars in Department of Conservative and Endodontics at Karnavati School of Dentistry, Gandhinagar Gujarat, India from September 2022 to November 2022.

**Inclusion criteria:** The study included single rooted permanent human mandibular premolars having fully formed apices which were extracted for orthodontic purpose with age group of 15-30 years.

**Exclusion criteria:** Teeth with caries, visible cracks or fracture observed under dental operating microscope, restored teeth, internal resorption, calcification, curved root, bifurcation were excluded.

**Sample size calculation:** The study considered the data based on the previous study [13,14] on comparison of the resistance of teeth instrumented with different nickel-titanium files to evaluate vertical root fracture where difference between six groups were

calculated having statistical significance with samples 12 teeth/group. Accordingly, a higher sample size of 30 teeth/group was used in present study to analyse data with 80% power and 5% significance using statistical power analysis.

### Study Procedure

Total 150 samples of extracted premolars [Table/Fig-1] were selected and cleaned for removal of calculus and stains with ultrasonic scaler (Satelac) and stored in deionised water till usage. All the teeth were decoronated using diamond disk under water coolant in such a way that remaining root length is 13 mm. The samples were then examined under dental operating microscope at 10X magnification to detect any craze lines or micro cracks developed during decoronation. The samples where the cracks present were replaced with intact roots. Samples were then divided into five groups of 30 each.

- Group-1: Vortex blue, n=30;
- Group-2: Edge File X7, n=30;
- Group-3: Hyflex EDM, n=30;
- Group-4: ProTaper Gold, n=30;
- Group-5: Control group, n=30.



[Table/Fig-1]: Total 150 extracted premolar samples.

The roots were covered with a layer of aluminium foil and were placed in a self-cure acrylic block. After this the roots were removed and the aluminium foil was replaced with addition silicon impression material to resemble periodontal ligament and the roots were kept back in to mould. All the canals were negotiated to their terminus with stainless steel K Files (Mani) except the control group. The teeth from each group were then prepared with their respective file systems sequentially using Xsmart endomotor setting the torque and rounds per minute (rpm) as per their files manufacturer instructions, followed by irrigation with 3% sodium hypochlorite and normal saline sequentially. After biomechanical preparation, all the samples were obturated using single cone technique with AH plus sealer and sealed with nano-hybrid composite material (Ivoclarvivadent). All the samples were kept in an environment of 100% moisture. No instrumentation or obturation was done in control group. All the samples were tested with a universal testing machine. Compressive force was applied with the help of a tip made up of a stainless steel of 1 mm diameter. The load necessary to fracture was recorded in newtons.

### STATISTICAL ANALYSIS

The statistical analysis was done using Statistical Package for Social Sciences (SPSS) IBM version 23.0 software, with one-way ANOVA for analysis of significant difference between the groups.

Intergroup comparison was done by post-hoc Tukey test. This comparison was considered significant with p-value of <0.001.

### RESULTS

[Table/Fig-2] shows fracture resistance between the five groups. The mean value of fracture resistance was highest for the control group (522.789±98.79215), followed by Vortex blue (457.964±37.75982) and least resistance (349.445±33.62643) was in the ProTaper Gold. This comparison was statistically significant with p-value of <0.001.

Variable	Groups	n	Mean	Std. Deviation	Statistic/ F	p-value
Fracture resistance	Group-1 Vortex blue	30	457.964	37.75982	46.084	<0.001
	Group-2 Edge endo X7	30	423.9753	39.86994		
	Group-3 Hyflex EDM	30	402.4	37.18606		
	Group-4 ProTaper Gold	30	349.445	33.62643		
	Group-5 Control group	30	522.789	98.79215		
	Total	150	431.3147	79.57461		

[Table/Fig-2]: One-way analysis of variance (ANOVA) test analysis of fracture resistance in various groups. bold p-values are significant

[Table/Fig-3] shows post-hoc Tukey test done to compare the mean values of inter-group file systems. The comparison of Group-2 Edge endo X7 and Group-3 Hyflex EDM was not statistically significant with a p-value of 0.557 compared to other inter-group comparison.

Variable	Comparison of	Comparison with	Mean differenc E	Standard error	p-value
Fracture resistance	Group-1 Vortex blue	Group-2 Edge endo X7	33.98867	14.27765	0.1270
		Group-3 Hyflex EDM	55.56400*	14.27765	<0.001
		Group-4 ProTaper Gold	108.51900*	14.27765	<0.001
		Group-5 Control Group	-64.82500*	14.27765	<0.001
	Group-2 Edge endo X7	Group-3 Hyflex EDM	21.57533	14.27765	0.5570
		Group-4 ProTaper Gold	74.53033*	14.27765	<0.001
		Group-5 Control Group	-98.81367*	14.27765	<0.001
	Group-3 Hyflex EDM	Group-4 ProTaper Gold	52.95500*	14.27765	<0.001
		Group-5 Control Group	-120.38900*	14.27765	<0.001
	Group-4 ProTaper Gold	Group-5 Control Group	-173.34400*	14.27765	<0.001

[Table/Fig-3]: Intergroup comparison by Post-hoc Tukey test.

### DISCUSSION

The present study showed that canals prepared with Vortex blue file system needed maximum amount of force to fracture as compared to other file systems. During the stage of cleaning and shaping of the root canal space various factors induces stress on the dentinal wall. These factors like curvature of the canal, amount of force which has been given to instrument, taper of the file, cross-sectional design of the file metallurgical properties of the file, speed of the rotary instruments, torque of the instruments, these all can affect the dentinal crack formation. These kinds of cracks ultimately lead to the development of vertical root fracture. Vertical root fracture is a frustrating event because the fracture is usually diagnosed years

S. No.	Authors name and year	Place of study	Sample size	Files compared	Parameter assessed	Conclusion
1.	Present study	India	150	Vortex blue, Edge File X7, Hyflex EDM, ProTaper Gold.	Vertical root fracture resistance of teeth prepared by four different NiTi rotary instruments were observed.	Vortex Blue file showed the best result. Maximum amount of force needed to fracture the samples were prepared with Vortex blue file. ProTaper Gold file showed minimum amount of force needed to fracture the sample.
2	Lin GSS et al., [20] Year 2022	Japan	80	T-Pro, HyFlex CM, TG6, 5-ZenFlex.	Vertical root fracture resistance.	The highest (VRF) resistance was noted in the control group (453.15±92.23 N), followed by T-Pro (387.43±76.81 N), HyFlex CM (381.88±52.73 N), ZenFlex (369.15±89.41 N) and finally TG6 (346.05±72.08 N), but there was no significant difference between T-Pro and HyFlex (p=0.438).
3.	Abou El Nasr HM and Abd El Kader KG; [21] 2014	Egypt	65	Control group (n=5) and 3 experimental groups of 20 roots each. Group WO was instrumented with the WaveOne primary file (Dentsply Maillefer, Baillagues, Switzerland), group PT-Rec was prepared with F2 ProTaper files (Dentsply Maillefer, Baillagues, Switzerland) used in a reciprocating motion, and group PT-Rot was prepared with F2 ProTaper files used in a rotation motion.	Instrument construction of single-file systems on dentin walls and fracture resistance of oval roots.	WaveOne instruments induced the least amount of cracks and exhibited greatest resistance to fracture compared with ProTaper F2 files whether used in reciprocating or rotating motions.
4.	Nassar S et al., [22] Year 2022	India	45	(NiTi) Hand Files (control group), instrumentation with TruNatomy files, instrumentation with ProTaper Next files, instrumentation with ProTaper Gold files, and instrumentation with Wave One gold files.	Vertical root fracture resistance.	The study reported that teeth instrumented with NiTi hand files exhibited the highest fracture resistance when compared to all the rotary and reciprocating file systems. Among rotary and reciprocating instruments, root prepared with TruNatomy files showed the most significant resistance to fracture compared with other file systems.

**[Table/Fig-4]:** Comparison between similar studies [20-22].

after completion of all endodontic and prosthetic procedure and the affected tooth or root has an unfavourable prognosis [9,10].

In the present study, 150 extracted mandibular premolars were selected in the age range of 15 to 30 years, because upto this age, roots of mandibular premolars are completely matured [15]. Aydin B et al., reported in his study that microhardness of enamel and dentin was in acceptable range when the teeth were stored in deionised water [12]. So, all the teeth were stored in deionised water till their usage. For the purpose of standardisation in the present study, the coronal parts of the teeth were removed in such a way that remaining root length is 13 mm for all the samples. To stimulate clinical condition, roots were coated with addition silicon impression material (light body) to reproduce periodontal ligament space and then placed on acrylic block to create situation which resembles patients mouth condition. The main purpose of putting an addition silicon impression material is that it resembles like a periodontal ligament and to compensate some of the vertically applied force though it is hard to accurately reproduce the periodontal ligament [4,12,13].

To access the vertical root fracture universal testing machine was used as suggested by Çiçek E et al., [14]. Most of the studies in which a compressive force had to be applied were done with the help of a universal testing machine because in universal testing machine the amount of force at which the sample gets fractured is accurately measured [4-6]. The diameter of the tip used was 1 mm, similar to the study done by Capar ID et al., and tip was placed at the centre of the sample to reproduce the condition similar in patient's mouth [4].

In the present study, Group-5 (control group) performed better followed by Group-1 (Vortex blue). Maximum amount of force to fracture the samples were needed in Group-1 (Vortex blue) as compared to other groups. The mean amount of force needed for Vortex blue samples were 457.96 N, whereas for Group-4 (ProTaper Gold) mean force was 349.44, which was the least amongst all the groups.

Various factors can affect the results, like amount of taper of the file, cross-section design, metallic properties of the files, motion which is used to prepare the canals. Vortex blue file is made up of M-wire technology. A titanium oxide layer on the file's surface interacts with

light rays to produce an optical phenomenon that gives Vortex Blue its distinctive blue colour. In the present study, Vortex blue showed maximum amount of force need to fracture and it means that Vortex blue causes less amount of dentinal crack formation as compared to other groups [4,6,9,10,14,16]. According to Das S et al., the files made up of a M-Wire technology shows less amount of dentinal crack formation, these results are correlate with the results of the present study [13]. According to Mandava J et al., Vortex blue file creates less amount of dentinal crack formation than Hyflex EDM and these results correlate with the present study [15]. The possible reason for Vortex blue to be better than other is because it has variable helical angle cutting blade with triangular cross-section. The coronal portion of the file has a lower helical angle (fewer flutes), which promotes effective debris removal, while the apical portion has a higher helix angle (more flutes), which promotes enhanced strength with a reduced risk of dentinal crack formation [15,17-22]. Group-4 ProTaper Gold showed the least amount force needed to fracture the samples. The possible reason for this could be because of cross-section of the file, proper gold has convex triangular cross-sectional area which ultimately leads to decreased dentinal debris removing area as compared to other files. Comparative evaluation has been done with similar studies in [Table/Fig-4] [20-22].

### Limitation(s)

The present study was an in-vitro study and clinical simulations were not used. There are several reasons associated with vertical root fracture, of which only the biomechanical preparation side of it was considered in present study. Other reasons such as shearing force which can increase the susceptibility to vertical root fracture were not considered.

### CONCLUSION(S)

Within the limitations of present study the following conclusion may be drawn, that Vortex Blue file showed the best result. Maximum amount of force needed to fracture the samples were prepared with Vortex blue file. ProTaper Gold file shows minimum amount of force needed to fracture the sample. Further future studies and research is needed comparing these files with other newly introduced file systems for better clinical understanding.

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