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Original Article

Dentistry Section

Impact of Root Canal Taper on Fracture Resistance of Endodontically Treated Teeth Prepared by Hero Shaper and RaCe File Systems: An In-vitro Study

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ABSTRACT

Introduction: Tooth fracture is one of the most undesirable phenomena in Endodontically Treated Teeth (ETT) and usually leads to tooth extraction. Basically, removal of any hard tissue from the canal walls raises the chance of root fracture.

Aim: To evaluate the impact of root canal taper on fracture resistance of ETT prepared by two different file systems (Hero Shaper and RaCe file systems).

Materials and Methods: This in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Sangli and Praj Metallurgical Laboratory Pune, Maharashtra, India, frome February 2021 to November 2021. The study included 44 freshly extracted mandibular premolar teeth were randomly divided into four groups. Group 1a had Hero Shaper 4%, group 1b had 6% Hero Shaper, group 2a had RaCe 4% and group 2b had RaCe 6% file system. After cleaning and shaping the root canals, obturation was completed using cold lateral compaction and root canals were embedded in standardised autopolymerising acrylic resin blocks, subjected to a vertical load in universal testing machine to cause vertical root fracture. The forces required to induce fractures were measured in Newtons. Data was analysed by using independent t-test and two-way Analysis of Variance (ANOVA) test for intergroup comparison. A p-value≤0.05 was considered as statistically significant.

Results: Among instrumented groups, group 1a (Hero Shaper 4%) showed higher fracture resistance of 372.5 Newtons and group 2b (RaCe 6%) showed lowest fracture resistance of 314.56 Newtons as compared to other groups. Statistically significant difference (p-value=0.026) was seen in the mean fracture resistance among group 1a and 1b, and group 2a and 2b. At pair-wise comparison there was statistically significant difference in group 1a and group 2a (p-value=0.016).

Conclusion: Amongst the instrumented groups, Hero Shaper file system showed the higher fracture resistance, than RaCe file system. Marked reduction in fracture resistance of ETT was seen with the use of greater taper instruments.

Keywords: Biomechanical preparation, File taper, Nickel-titanium rotary files, Root fracture, Stiffness of files, Universal testing machine

INTRODUCTION

The susceptibility of endodontically treated teeth to fracture is mainly associated with excessive loss of tooth structure due to caries or trauma, access cavity preparation, dehydration of dentin, undesirable effects of irrigating solutions, excessive pressure during filling procedures, instrumentation with rotary files and preparation for intraradicular postspace [1-4].

The introduction of Nickel-Titanium (NiTi) alloy has revolutionised root canal preparation over the past two decades. These instruments have much greater flexibility owing to their low elastic modulus and high torsional resistance [5]. Rotary systems facilitate debridement of canals, and the higher instrument tapers with different file design, metallurgical alloys, and rotational motion lead to superior canal wall cleanliness and reduce the concerns regarding bacterial elimination of canal walls. However, there are some concerns regarding the excessive removal of radicular dentin because of increased instrumentation taper [1].

Hero Shaper (HS; Micro Méga, Besançon, France) is a second generation full-sequence system have the triple helix cross-section. The other modification is that the handle has been shortened to improve access, helix angle increases from the tip to shank to reduce threading pitch of blade which varies depending on the taper. By altering these parameters, it is said to increase the efficacy, the flexibility, and the strength of the instruments. Hero Shaper files have large inner core, a positive rake angle, and, incorporated into the design to increase the files efficacy and safety. A good number of studies on this system make it a baseline for the evaluation of rotary instruments [6-8].

The other system is the Reamer with Alternating Cutting Edges (RaCe) FKG Dentaire, La Chaux-de-Fonds, Switzerland. The RaCe system consists of instruments that are manufactured from a conventional austenite NiTi electropolishing surface treatment and have a non cutting safety tip and triangular cross-sectional design except for smaller instruments (15/0.02 and 20/0.02). These smaller instruments have square cross-sectional design. Alternating cutting edges avoid the screwing effect and have the advantage of operating with extremely low torque. This instrument can produce centered canal shape and adequately clean and shape the canals [6-8].

The studies conducted by Sabeti M et al., Zandbiglari T et al., and Krikeli E et al., noticed decrease in fracture resistance with the use of increased tapered rotary instruments [1,9,10]. However, studies done by Lam PP et al., and Hegde MN et al., concluded that increase in taper did not influence the fracture resistance of Endodontically Treated Teeth (ETT) [11,12].

To the best of authors knowledge there is only few scientific evidence that compared the effect of the two different files with two tapers on the fracture resistance of the teeth [1,9,10]. Keeping in view the advances in file systems for cleaning and shaping, the present study proposed to evaluate and compare fracture resistance of endodontically treated teeth prepared by Hero Shaper 4%, 6% and RaCe 4%, 6% file system.

MATERIALS AND METHODS

This in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Sangli and Praj Metallurgical Laboratory Pune, Maharashtra, India, frome February 2021 to November 2021. The study was approved by the Institutional Ethical Committee on December 13th 2019 (Letter number - 2019-20/D-30).

The sample size was calculated from GPower Software using data obtained from previous studies [1,9,10]. The calculated sample size was 11 per group.

Inclusion criteria: Mandibular premolar teeth with single root and single canal, non carious teeth with mature apex, teeth free of any defects were included in the study.

Exclusion criteria: Teeth with open apex, multiple canals, calcifications, fractures, or craze lines, curved roots were excluded from the study.

Sample Preparation

Single rooted 44 mandibular premolar teeth extracted for the orthodontic treatment were collected and stored in saline. Storage time for the teeth was limited to six months. Preoperative radiographs were taken to ensure inclusion criteria. All teeth were decoronated using a flexible diamond disk in a slow speed handpiece under copious amount of water coolant to standardised length of 13 mm as measured from the apex to the Cementoenamel Junction (CEJ) [Table/Fig-1].

[Table/Fig-1]: All samples after decoronation.

To standardise the working length, an instrument of size 10 k file was inserted into the canal till the tip of was first visualised at the apical foramen. The working length was determined by subtracting 1 mm from this length, and initial apical preparation of all teeth was done with No 15 K file. Then the teeth were randomly allocated to two groups of different file systems.

Group 1: Instrumentation with Hero shaper file system. Group 1 was divided into two groups:

- Group 1a): Instrumentation with 4% taper using Hero Shaper file system.
- Group 1b): Instrumentation with 6% taper using Hero Shaper file system.

Group 2: Instrumentation with RaCe file system. Group 2 was divided into two groups:

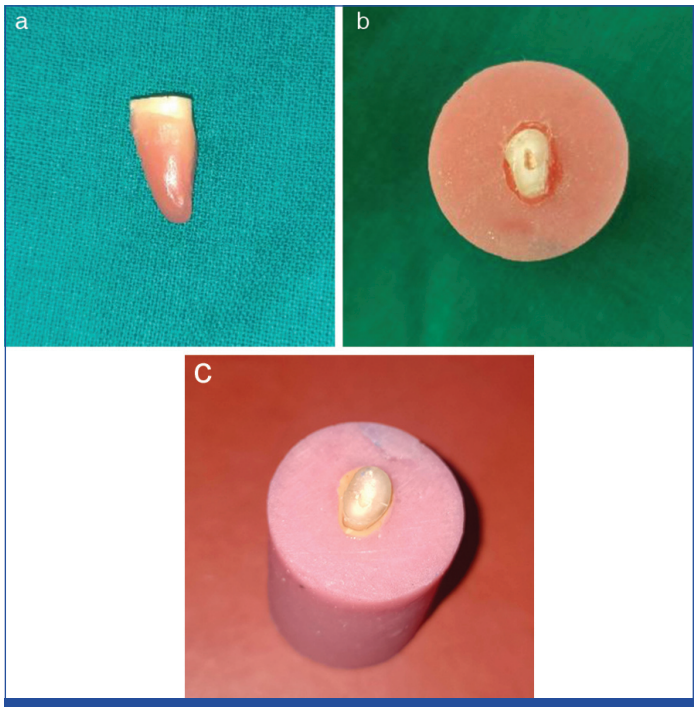
- Group 2a): Instrumentation with 4% Taper using RaCe file system
- Group 2b): Instrumentation with 6% Taper using RaCe file system

Study Procedure

The instrumentation was done by using X-Smart endomotor (Dentsply) as per manufacturer's instructions. The canals with respective groups were enlarged to the size 30. Irrigation of the canals was done with 2 mL of 3% Sodium hypochlorite (NaOCl) after each instrument.

The smear layer was removed by flushing the root canals with 5 mL 17% EDTA solution for 1 min. The canals was finally rinsed with 5 mL normal saline and dried with absorbent paper points. After drying, the canals were obturated using gutta percha and AH Plus (Dentsply) sealer, using cold lateral compaction technique. Excess gutta percha was removed from canal orifices using a hot plugger and postobturation radiographs was taken.

For all specimens, the root surface was covered with a paste of light body silicon-based impression material to simulate a periodontal ligament and kept in 100% humidity for 24 hour [Table/Fig-2]. All roots were then mounted vertically in self cure acrylic resin block using custom made molds. The resistance offered was tested using the universal testing machine (Asian Universal testing machine) for root samples of all groups against vertical fracture.



[Table/Fig-2]: a) Wax covered on root surface; b) roots were then mounted vertically in self cure acrylic resin block using custom made molds; c) Wax is replaced by light body impression material.

A modified stainless-steel plunger (5 mm in diameter) was centered on root canal filling material and a compressive load was applied vertically at a crosshead speed 1 mm/min until fracture occurs. The fracture moment was determined when a sudden drop in a force occurred as observed on the testing machine display. The highest force required to fracture each sample was recorded in Newtons.

STATISTICAL ANALYSIS

The data was analysed with help of SPSS software version 20. Level of significance was kept at 5%. Comparison of fracture resistance of teeth among four groups (Hero Shaper 4%, Hero Shaper 6%, RaCe 4%, RaCe 6%) was done two-way Analysis of Variance (ANOVA) test. Independent t-test was used to compare the mean and standard deviation among the groups.

RESULTS

Among instrumented groups, group 1a (Hero Shaper 4%) showed higher fracture resistance of 372.5 and group 2b (RaCe 6%) showed lowest fracture resistance of 314.56 as compared to other groups. With the increase in taper of the rotary instrument, the fracture resistance of the teeth decreased. Root canal instrumented with 4% file system (group 1a and group 2a) showed higher fracture resistance as compared to their respective 6% file system (group 1b and group 2b) [Table/Fig-3].

For root canal instrumented with group 1a, the mean fracture resistance was found to be 372.500 N. Whereas, the mean fracture

Sample No.	Group 1a	Group 1b	Group 2a	Group 2b
1	369	354.55	400.45	270.2
2	323	387.3	330.45	341.5
3	339	218.2	309	247.9
4	468.8	400.85	296	321.6
5	379	299.7	292.85	304.5
6	392.1	334.15	252.7	401.7
7	365.2	332.7	340.8	309.7
8	337	290.5	325.7	312.8
9	358.4	325.8	298.5	323.5
10	396	313.5	365.2	335
11	370	401.25	379.3	291.76
Mean	372.5	332.59	326.45	314.56

[Table/Fig-3]: Fracture resistance of different groups in Newtons.

resistance for samples instrumented with group 2a was found to be 326.450 N. The difference was statistically significant (p-value =0.016). However, no statistically significant difference was present in- group 1a and 2a , and group 1b and 2b (p-value=0.074), and group 1a and 1b (p-value=0.061), and group 2a and 2b (p-value=0.510), group 2b and 1b group (p=0.384) [Table/Fig-4].

Groups	N	Mean	Standard deviation	Standard error mean	Mean difference	't'	p-value
Group 1a and 1b	22	352.545	50.387	10.743	32.040	2.314	0.026*
Group 2a and 2b	22	320.505	40.986	8.738			
	N	Mean	Std. Deviation	Std. Error mean	Mean difference	't'	p-value
Group 1a and 2a	22	349.475	46.595	9.934	25.900	1.830	0.074
Group 1b and 2b	22	323.575	47.265	10.077			
	N	Mean	Std. Deviation	Std. Error mean	Mean difference	't'	p-value
Group 1a	11	372.500	39.186	11.815	39.909	1.983	0.061
Group 1b	11	332.591	54.037	16.293			
	N	Mean	Std. Deviation	Std. Error mean	Mean difference	't'	p-value
Group 2a	11	326.450	43.098	12.994	11.890	0.671	0.510
Group 2b	11	314.560	39.907	12.032			
	N	Mean	Std. Deviation	Std. Error mean	Mean difference	't'	p-value
Group 1a	11	372.500	39.186	11.815	46.050	2.622	0.016*
Group 2a	11	326.450	43.098	12.994			
	N	Mean	Std. Deviation	Std. Error mean	Mean difference	't'	p-value
Group 1b	11	332.591	54.037	16.293	18.031	0.890	0.384
Group 2b	11	314.560	39.907	12.032			

[Table/Fig-4]: Comparison of mean difference of fracture resistance of teeth in between group using different tapered and different file system.
Test applied- independent group t-test *Indicate significant difference at p≤0.05; N- sample size

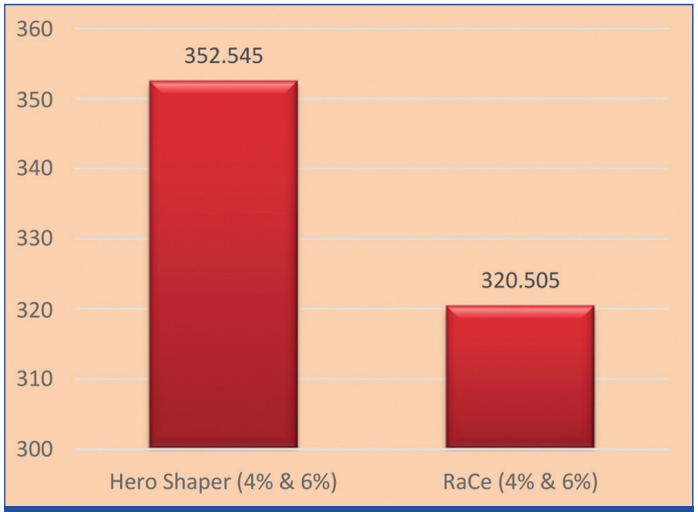
From the results of two-way ANOVA on comparing fracture resistance of teeth there was statistically significant difference (p-value=0.022) in the mean fracture resistance of teeth instrumented with Hero Shaper and RaCe file system groups. [Table/Fig-5]. Hence, it can be inferred that the samples instrumented with Hero Shaper files showed greater fracture resistance as compared to RaCe file group [Table/Fig-6].

DISCUSSION

In present study, among the instrumented groups, the Hero Shaper 4% exhibited highest fracture resistance. The reason might be that

A-Source	Sum of squares	Df	Mean square	F	Sig.
Group	11292.498	1	11292.498	5.714	0.022
Subgroup	7378.651	1	7378.651	3.733	0.060
Group * Subgroup	2158.941	1	2158.941	1.092	0.302
Error	79055.767	40	1976.394		
Total	99885.857	43			

[Table/Fig-5]: Comparison of fracture resistance of teeth among four groups using different rotary instruments.
R Square=0.209 (Adjusted R Square=0.149)
Df: Degree of freedom; F: Frequency
Test applied- Two-Way-ANOVA test



[Table/Fig-6]: Comparison of fracture resistance of teeth instrumented with two different file system.

RaCe is stiffer than the Hero Shaper, causing more instrument memory, which in turn would remove more material [13]. In present study samples instrumented with 4% Hero Shaper showed better fracture resistance. This finding may be a result of Hero Shaper instruments having a longer pitch and positive rake angles for better dentin cutting efficacy. The smaller taper also reduced instrument stiffness [6-8]. Tooth fracture has been described as a major problem in dentistry, third most common cause of tooth loss after dental caries and periodontal disease [14,15]. It is proved that after the endodontic treatment, teeth become weaker than the untreated teeth and are known to present a higher risk of fracture failure. Hence, attention should be paid to unnecessary removal of dentin during endodontic treatment, in order to maintain the strength of the teeth [16]. Historically, the increased brittleness of dentine due to loss of moisture is one of the prime reasons for the increased susceptibility of fracture in endodontically treated teeth [17].

Capar ID et al., in their study found that the HyFlex and ProTaper Next tend to cause fewer dentinal cracks when compared to ProTaper Universal instrument hence, stiffer instruments can increase the susceptibility of crack formation and propagation leading to various root fractures [18]. In the present study, the teeth instrumented with 6% taper showed lower fracture resistance compared to 4% group (p-value=0.074). The results of the present study was in accordance with the studies conducted by Sabeti M et al., Zandbiglari T et al., and Krikeli E et al., who noticed decrease in fracture resistance with the use of increased tapered rotary instruments [1,9,10].

NiTi files shape the canal in a relatively safe manner and with a reduced incidence of iatrogenic errors and instrument fracture [19]. Kim HC et al., reported a potential relationship between the design of NiTi instruments and the incidence of vertical root fracture and concluded that stiffer file designs generated higher stress concentrations in the apical root dentin during shaping of a curved canal [19]. Excessive taper may results in excessive removal of

Author's name and year of study	Place of study	Sample size	Files compared	Parameters assessed	Conclusion
Sabeti M et al., 2018 [1]	Tehran, Iran	78 (30- for tapering and 40 for access cavity assessment)	4 taper, 6 taper, 8 taper-Twisted Files	Impact of access cavity design and root canal taper on fracture resistance of endodontically treated teeth	Increasing the taper of the root canal preparation can reduce fracture resistance. Moreover, access cavity preparation can also decrease fracture resistance; however, CAC in comparison with TAC had no significant influence.
Zandbiglari T et al., 2006 [9]	Munster, Germany	84	GT files, FlexMaster, stainless steel hand instrument	Influence of instrument taper on the resistance to fracture of endodontically treated roots	The roots were significantly weakened by the preparation with greater taper instruments. An obturation by using AH Plus sealer did not increase the fracture resistance.
Krikeli E et al., 2018 [10]	Thessaloniki, Greece	58	Hand files 2%, Mtwo rotary files 4% and 6%	In-vitro comparative study of the influence of instrument taper on the fracture resistance of endodontically treated teeth	The fracture resistance of the roots prepared with rotary files up to 40/.06 was lower than that of unprepared root under in-vitro experimental conditions.
Khatod K et al., 2015 [7]	Wardha, India	40	Hero Shaper and RaCe files	Comparative evaluation of centering ability of hero shaper and race using computed tomography	Canals prepared with RaCe had more canal transportation at all the three levels of root canal (coronal, middle and apical). Canals instrumented with Hero Shaper were well centered at all the three levels of root canal (coronal, middle and apical).
Veltri M et al., 2004 [20]	Siena, Italy	30	Hero Shaper and Mtwo NiTi instruments	A comparative study of endoflare–hero shaper and mtwo NITI instruments in the preparation of curved root canals	The systems tested here were effective in preparing curved canals in extracted teeth.
Yang GB et al., 2007 [21]	China	40	ProTaper and Hero Shaper files	Shaping ability of progressive versus constant taper instruments in curved root canals of extracted teeth	The canals instrumented with Hero Shaper had less transportation and were better centered in the apical region, probably because their smaller taper reduced instrument stiffness.
Present study	Sangli, India	44	4%, 6% taper- Hero Shaper and RaCe files	Impact of root canal taper on fracture resistance of endodontically treated teeth with hero shaper and race file system.	Endodontic instrumentation with Hero Shaper 4% or 6% files showed significant difference in fracture resistance than RaCe file system. The use of greater taper instruments caused marked reduction in fracture resistance of ETT and thereby questioning its usage.

[Table/Fig-7]: Similar studies from the literature [1,7,9,10,20,21].

dentin and further cause weakening of root, thereby reducing the fracture resistance of tooth [16]. Stiffness is related to many factors like size, taper, cross-section, method of manufacturing, and the material out of which the instrument is made [8]. The results of the present study are in accordance with Khatod K et al., Veltri M et al., and Yang GB et al., [7,20,21]. Similar studies have been tabulated in [Table/Fig-7] [1,7,9,10,20,21].

Limitation(s)

The age factor while collecting extracted teeth was not taken into account. Furthermore, the negative influence of root canal irrigants may have weakened the root dentin. Moreover, the method used for testing fracture load was static load in the study whereas in intraoral condition a dynamic load is applicable.

CONCLUSION(S)

Within the limitations of the present study, it can be concluded that endodontic instrumentation with RaCe file system showed significant decrease in fracture resistance than Hero Shaper 4% or 6% files. Highest fracture resistance was seen in Hero shaper 4% and least in RaCe 6%. The use of greater taper instruments caused marked reduction in fracture resistance of ETT and thereby questioning its usage. Further investigations into other types of newer NiTi instruments and in other groups of teeth may give further insights as to the effects of different rotary NiTi instruments on fracture resistance of teeth and predisposition to vertical root fracture.

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