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ORIGINAL RESEARCH

Comparison of the Effects of Three Different Nickel–titanium Rotary Instruments on the Fracture Resistance of Obturated Roots: An *in vitro* Study

[1]Saimanaaz AH Shaikh, [2]Vanitha U Shenoy, [3]Sumanthini MV, [4]Ritesh B Pawar

ABSTRACT

Aim: The aim of the article is to compare the effects of three different nickel–titanium (NiTi) rotary instruments on the fracture resistance of obturated roots.

Materials and methods: A total of 100 permanent mandibular premolars were randomly divided into four groups of 25 teeth each and biomechanical preparation was done: group I: stainless steel K-hand files (HFs), group II: ProTaper NiTi instruments (PT), group III: HyFlex CM NiTi instruments (HCM), and group IV: K3XF NiTi instruments. Following root canal preparation, the canals were obturated using lateral condensation. A light body silicone impression material was used to simulate the periodontal ligament (PDL). Fracture resistance was tested in an Instron testing machine.

Statistical analysis: Data were analyzed with Kruskal–Wallis test.

Results: There was no difference in significance ($p < 0.05$) among the different groups tested with respect to their fracture resistances.

Conclusion: The present study concluded that rotary instrumentation could result in an increased chance for dentinal defects as compared with hand instrumentation. Greater taper rotary NiTi instruments do not increase the fracture susceptibility of roots, which in turn depends on various factors other than instrumentation alone.

Clinical significance: Greater taper achieved by rotary NiTi files during canal preparation facilitates efficient irrigation and complete debridement. Root fracture might occur as a result of microcracks or craze lines that propagate with repeated stress application by occlusal forces and also during canal preparation. Based on the results obtained, it can be decided whether the use of the newer rotary NiTi system contributes to endodontic success and long-term survival of endodontically treated teeth.

Keywords: Dentinal damage, Hand files, Rotary nickel–titanium files.

[1,4]Postgraduate Student, [2]Professor and Head, [3]Professor

[1-4]Department of Conservative Dentistry and Endodontics Mahatma Gandhi Mission's Dental College and Hospital, Navi Mumbai, Maharashtra, India

Corresponding Author: Saimanaaz AH Shaikh, Postgraduate Student, Department of Conservative Dentistry and Endodontics Mahatma Gandhi Mission's Dental College and Hospital, Navi Mumbai, Maharashtra, India, Phone: +918879564175, e-mail: drsaimash2787@gmail.com

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INTRODUCTION

Root canal instrumentation, being one of the most important stages of nonsurgical endodontic treatment, includes debridement of the root canal thus, eliminating vital and necrotic tissues and infected dentin from the root canal system giving rise to a continuously tapered preparation and maintaining the original root canal anatomy. Hand files have been the most commonly used endodontic instruments for root canal preparation, but they have various disadvantages of canal transportation, ledge, zipping, perforations, etc. Nickel–titanium (NiTi) instruments are flexible with enhanced specific geometric design features,[1] thus maintaining the natural canal curvature. However, two problems associated with them are cyclic fatigue and torsional overloading.[2] Technological advancements in rotary NiTi have led to new design concepts and easier, faster, and better root canal shaping. Although they possess many advantages,[3,4] they tend to induce dentinal damage generating cracks on the apical surface,[5] ultimately leading to the development of vertical root fractures (VRFs).[6] Numerous studies[7,8] have reported the use of rotary NiTi files causing cracks in root dentin. Minimum information regarding the craze lines, fracture resistance of roots, and their potential relationship of VRFs with these newer rotary NiTi files (K3XF and HCM) exists in the literature. Thus, the aim of this *in vitro* study is the comparison of the effects of three different NiTi rotary instruments on the fracture resistance of obturated roots.

MATERIALS AND METHODS

A total of 100 permanent single-rooted mandibular premolars were selected, each tooth was decoronated using a diamond disk and mandrel (Mani Inc, India) at or below the cementoenamel junction and standardized to a length of 14 mm. The actual working length was determined by introducing a 10/0.02 K-file (Mani Inc, India) inside the root canal until its tip was visible in the apical foramen and the file was then retracted 1 mm short of the apex and the working length was established. The selected roots were then randomly assigned into four experimental groups (n = 25) by using a method of simple random sampling. Canal preparation was done with a torque-control motor (X-Smart, Dentsply, Maillefer, India) at the recommended torque and speed by the manufacturer for each rotary file system. Group I: Hand stainless steel K-files (HFs): Gates-Glidden drills #4, 3, and 2 were successively used to perform coronal enlargement. Cleaning and shaping of root canals was completed with HFs (Mani Inc, India) in a crown-down manner up to MAF 40/0.02. Group II: PT: root canals were prepared with PT (Dentsply, Tulsa Dental, India) NiTi instruments in a crown-down manner up to F3 (30/0.09). The shaping file SX was used for coronal enlargement followed by S1, S2, F1, F2, and F3 files in sequential manner until the working length. Group III: HCM: the HCM (Coltene/Whaledent, India) files were used in the sequence of 25/0.08 up to two-thirds of the working length, 20/0.04, 25/0.04, 20/0.06, 30/0.04, and 40/0.04 up to the full working length. Group IV: K3XF: K3XF (SybronEndo, India) rotary instrument was used in a crown-down manner. A 25/0.10 K3XF orifice shaper was used to enlarge the root canal. A 40/0.06 was used until it was not able to passively advance, followed by a 35/0.06, 30/0.06, 25/0.06 was used to the working length. Final apical enlargement was done with 40/0.06. Sodium hypochlorite (NaOCl; Prime Dental Products Pvt Ltd, India) in the concentration of 5% was used as an irrigant. A total of 10 mL of 5% NaOCl was used in each root canal during biomechanical preparation. Irrigation of the root canals was done with 2 mL of 5% NaOCl intermittently with a 27-gauge needle and syringe, with irrigating needle penetrating within 3 mm of estimated working length in between each sequence of instruments. The root canal was finally rinsed with 5 mL of normal saline (Althea Pharma Private Ltd, India). Before obturating the root canals, the smear layer was removed using 1 mL of 17% ethylenediaminetetraacetic acid (Dentwash, Prime Dental Products, India) for 1 minute, which was followed by 5 mL of 5% NaOCl. Finally, root canals were irrigated with 5 mL of normal saline. The canals were dried with absorbent points (Sure Endo, Korea, Japan) and were then obturated using lateral condensation technique with gutta percha (Sure Endo, Korea, Japan) and AH Plus sealer (Dentsply, India Pvt. Ltd) followed by sealing the coronal orifice with temporary cement Cavit G (3M ESPE Dental Products US). All obturated roots were mounted vertically in blocks prepared with acrylic resin (Acryln R, India). The PDL simulation was done with light body rubber base material (3M ESPE Express XT light body). A round diamond point (Mani Inc, India) was used to remove the temporary material in the access cavity and shape the root canal access of each root just enough to accept the loading fixture. A loading fixture with spherical tip diameter of 4 mm was attached to the upper jaw of an Instron testing machine (Instron 5567, NVLAP, Norwood, MA) and aligned with the center of the root canal opening of each root. Each acrylic block containing a root, and the fixture were mounted in an Instron testing machine for evaluation of fracture resistance. A vertical loading force was applied at a cross-head speed of 3 mm/minute until root fracture occurred. The force was recorded in Newtons (N). The data obtained were subjected to statistical analysis to compare the fracture resistance among the four groups.

RESULTS

Descriptive data regarding fracture resistance of each group is given in Table 1.

The results were statistically analyzed by Statistical Package for the Social Sciences software (version 16) using nonparametric Kruskal–Wallis test, which was used to test the significance of difference of the mean force in Newtons (N) required for fracture resistance of roots of various groups. Since p value of Kruskal–Wallis Test was less than 0.05, it indicated that there was a significant difference between the means of four groups. A Mann–Whitney U-test (Table 2) was done for the pairwise comparison. The fracture resistance of obturated roots in each group is given in Graphs 1 and 2. The bar graph (Graph 1) depicting the mean of the fracture resistance in Newtons (N) for all tested groups shows that HFs required approximately 253.4992 N to fracture, which was highest among all the tested groups followed

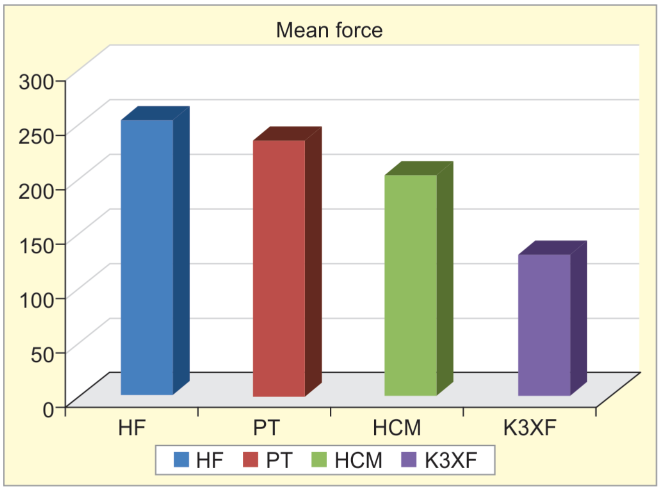
Table 1: The mean force in Newtons (N) required for fracture resistance for all test groups

	Descriptive statistics					
	n	*Mean*	*Standard deviation*	*Standard error*	*Minimum*	*Maximum*
HF	25	253.4992	94.28107	18.85621	111.32	421.89
PT	25	234.8108	78.61423	15.72285	107.40	352.80
HCM	25	203.2164	58.75328	11.75066	93.00	292.13
K3XF	25	130.4032	56.06347	11.21269	69.87	285.96

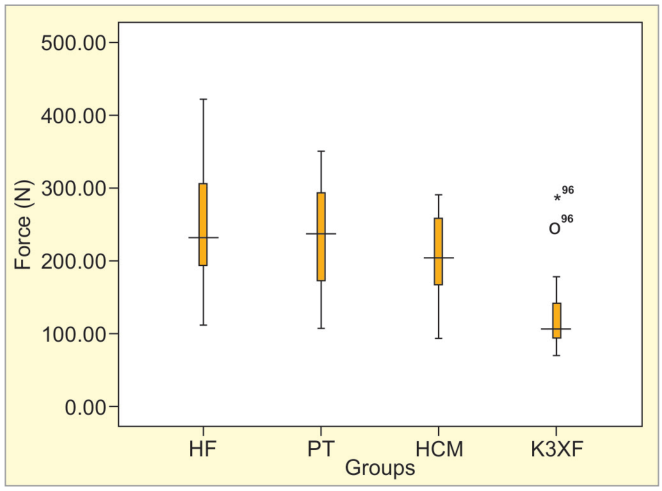
Table 2: Mann–Whitney U-test

Groups		*Mann–Whitney U-test results*				*Interpretation*
		Mann–Whitney	*Wilcoxon W*	*Z*	*p-value*	
HF	PT	291.0	616.0	–0.417	0.677	NS
	HCM	221.0	546.0	–1.775	0.076	NS
	K3XF	72.0	397.0	–4.67	3.0E4E-6	S
Protaper	HCM	230.0	555.0	–1.601	0.109	NS
	K3XF	80.0	405.0	–4.511	6.447E-6	S
HCM	K3XF	112.0	437.0	–3.89	1.001E-4	S

NS: Nonsignificant; S: Significant



Graph 1: Bar graph depicting the mean of the fracture resistance in Newtons (N) for all tested groups



Graph 2: Box plot for all tested groups

by PT requiring approximately 234.8108 N, which was the highest among all the rotary groups. The results obtained from all tested groups are interpreted in the form of box plot (Graph 2). The box area in the box plot represents fracture resistance for all tested groups. The horizontal line represents the median value. The vertical line represents the range of the group. Group I (HF) required approximately 253.49 N to fracture the roots, which was found to be the maximum among all the experimental groups followed by group II (PT) requiring approximately 234.81 N, which was the maximum among the rotary groups. Group III (HCM) and group IV (K3XF) required approximately 203.21 and 130.40 N respectively.

DISCUSSION

The VRFs may occur during endodontic procedures, which may be a precipitating factor. The root may be weakened by instrumentation alone, resulting in excessive removal of dentin during root canal preparation increasing susceptibility to root fracture[9] and generating cracks on the apical surface,[5] which could ultimately lead to VRFs.[6] The use of rotary NiTi instruments might result in an increased risk of dentinal defects occurring[9] probably because these files need significantly more rotation in the canal to complete the preparation when compared with HFs.

During preparation, a canal is shaped by the contact between instrument and dentin walls creating momentary stress concentrations in dentin which are, in turn, determined by the mechanical behavior and cross-sectional and longitudinal design of files. Such stresses may leave dentinal defects and apical cracks in which VRF can initiate.[9]

In the current study, four different instruments were used, one group consisting of HF and the other three groups consisting of different rotary systems namely PT, HCM, and K3XF files. Bier et al[9] and Yoldas et al[7] in their study observed no influence of HFs on the development of dentinal cracks. However, it was observed by Liu et al,[10] Hin et al,[11] and Zandbiglari et al[12] in their study that HFs caused lesser number of cracks when compared with rotary files. These results are in agreement with the current study.

However, it has been stated by Shaheen et al[13] in their study that PT had the highest resistance to fracture, which may be due to increased canal taper of PT preparation in coronal and middle thirds that allowed forces to be better distributed in the apical third of the canal and potentially increase the resistance to fracture of the root.[14] This finding was supported by Lam et al[15] who concluded that greater apical enlargement did not increase the fracture susceptibility of the roots. The results of the above studies are in agreement with the present *in vitro* study.

On the contrary, Bier et al,[9] Kansal et al,[16] Liu et al,[10] and Hin et al[11] observed in their studies comparing PT with other rotary systems other than the ones used in the current study that PT caused significantly more cracks than other rotary systems. Capar et al[17] compared the incidence of cracks in root dentin after root canal preparation with PT Next, HCM, and PT Universal rotary instruments, and observed that PT Next and HCM instruments caused fewer cracks than the PT Universal instrument. However, in the present study, not much of statistically significant difference between the fracture resistance of PT and HCM files was observed.

In the present study, all of the tested rotary instruments had noncutting tips except HFs having an active cutting tip. The PT and HCM instruments have a triangular cross-sectional geometry, whereas K3XF is a modified triple U. In addition, PT Universal has a variable taper design of 7, 8, and 9% for F1, F2, and F3 respectively, whereas HCM and K3XF are available with constant tapers of 4 and 6%.

In this *in vitro* study, extracted human premolars were used as reported by many investigators.[18,19] The root canals were always irrigated with saline before switching to NaOCl in order to avoid any interaction between various irrigants.

Vertical load was applied with a spherical ball tip of diameter 4 mm, which was allowed to contact the flat surface of the prepared roots.[19,20] Root canals were obturated using lateral condensation technique. Periodontal ligament simulation was done using light body elastomeric impression material allowing limited freedom of movement whilst avoiding external reinforcement.[20]

CONCLUSION

The conclusion drawn from this *in vitro* study is that instrumentation with rotary files may increase the chances for dentinal defects when compared with hand instrumentation. Greater taper rotary NiTi instruments, such as PT rotary files did not increase the fracture susceptibility of roots, which, in turn, depended on various factors other than instrumentation alone. It was observed that newer rotary NiTi instruments, such as K3XF and HCM had lower fracture resistance as compared with PT instruments. The effects of various rotary NiTi instruments on the propagation of dentinal cracks, increasing the susceptibility to VRFs, have been extensively studied. Further research needs to be carried out on the fracture resistance of endodontically treated teeth using K3XF and HCM rotary instruments.

CLINICAL SIGNIFICANCE

Greater taper achieved by rotary NiTi files during canal preparation facilitates efficient irrigation and complete debridement. Root fracture might occur as a result of microcracks or craze lines that propagate with repeated stress application by occlusal forces and also during canal preparation. Based on the results obtained, it can be decided whether the use of newer rotary NiTi system contributes to endodontic success and long-term survival of endodontically treated teeth.

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