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Original Article

Comparative Study of the Influence of Instrument Taper on the Fracture Resistance of Endodontically Treated Teeth Using Hand and Rotary Files

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Abstract

Aim: To evaluate and compare the influence of instrument taper on the fracture resistance of endodontically treated teeth with hand, twisted, and protaper rotary files.

Materials and Methods: All teeth were sectioned at 13mm from the anatomic apex using a diamond-coated bur under water cooling and then were allocated to four groups. Instrumentation was done in the four groups with respective files, following the manufacturer's protocol. During instrumentation, the root canal was irrigated with 2.5% sodium hypochlorite (NaOCl) solution. After instrumentation, a final irrigation procedure was done using 5 ml distilled water, and roots were obturated using single cone technique with gutta percha and AH plus as the canal sealer. The roots were then placed in acrylic blocks in order to create an artificial periodontal ligament. All specimens were tested with a universal testing machine until the root fracture occurred.

Conclusion: Teeth instrumented with 2% hand K files has the highest fracture resistance followed by teeth instrumented with 4% taper Twisted files (TFs), 6% taper TFs and 6% taper ProTaper files.

Key words: Endodontic treatment, Fracture resistance, Rotary files

INTRODUCTION

Root canal therapy is the most thorough and perfect method for the endodontic and periapical disease. Root canal preparation is the key procedure for root canal therapy.[1] Root canal procedure comprises of three intricate processes, first, the access opening, second, cleaning and shaping, disinfection, and third, obturation of the root canal space. Out of the 3 processes, cleaning and shaping procedures are of paramount importance as it is responsible for the eradication of microorganism with the help of irrigants and for subsequently shaping it so that the canal is adequately obturated by an inert filling material.[2] However, many studies showed that the teeth after root canal therapy may have an inclination towards longitudinal fracture in the tooth root. There was a close correlation between the degree of root canal preparation and tooth resistance to fracture.[3] Stainless steel root canal instruments clean the canal superficially and can create canal aberrations such as ledges, zips, and elbows. To eliminate these shortcomings of stainless steel instruments, nickel-titanium (Ni-Ti) instruments have been developed.[4] Using NiTi engine-driven instruments for root canal preparation has become the fundamental of endodontic treatments.[5] These instruments have many advantages such as less operation time, increased cleanliness of root canal walls, and fewer procedural accidents (apical canal transportation, perforations and ledges). These properties mostly stem from the increased flexibility of NiTi alloy which helps in the preservation of root canal curvatures. However, it is stated that engine-driven instruments may damage root dentin by forming craze lines and microcracks. During root canal preparation, thinned dentinal walls and increased

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strain can lead to microcrack formation especially at the apical area.[6]

Introduction 2 Technological innovations in rotary NiTi files have led to new concepts of root canal instrumentation including an increased taper of preparation.[7] A higher taper of mechanical preparation offers sufficient enlargement of the root canal entailing better removal of debris and smear layer, improvement of irrigant flow, and better distribution of stresses during both lateral and vertical gutta-percha compaction. However, possible excessive removal of dentin raised concerns regarding the susceptibility of roots to fractures.[8] Although multiple factors contribute to file separation, cyclic fatigue has been shown as one of the leading causes. Fatigue failure usually occurs by the formation of microcracks at the surface of the file that starts from surface irregularities often caused by the grinding process during the manufacturing.[9] During each loading cycle microcracks develop, propagating getting deeper in the material, until complete separation of the file occurs. All endodontic files show some irregularities on the surface, and inner defect, as a consequence of the manufacturing process, and distribution of these defects influence fracture strength of the endodontic instruments.[10]

Vertical root fracture (VRF) is a complication in both endodontically and non endodontically treated teeth, usually leading to extraction. Predisposing factors for root fractures have been discussed thoroughly in the literature, and various classifications have been proposed.[11] Mechanical preparation affects both the geometry and volume of root canals, leading to stresses to the root dentin leading to, dentinal defects. The root canal preparation instruments and methods used combined might all be involved in the increased risk for root fracture during and subsequent to root canal treatment.[12] Introduction 3 Many factors can contribute to VRFs, thus making the assessment of their individual contributions challenging, especially when measured under *in vitro* experimental conditions. Previous studies have attempted to compare the susceptibility to fractures of endodontically treated teeth that were instrumented with hand and Rotary Instruments of Different Tapers. Methodologic Limitations Concerning Both The standardization and randomization of the sample combined with the instrumentation and experimental techniques used have produced a variety of results.[13] ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) is amongst the pioneer engine-driven instruments that employ full 360° rotation with a convex triangular cross-section and multiple tapers within the shaft. The ProTaper Universal (PTU) system is comprised shaping (SX, S1, and S2) and finishing (F1, F2, and F3) instrument. PTU rotary files, which have been used for years, that enable an active cutting motion and the removal of relatively more dentin coronally. PTU rotary files are made from a conventional superelastic NiTi wire. In previous studies, the PTU system was associated with more cracks than other rotary NiTi instrument.[14] Recently, a new system has been introduced called Twisted File Adaptive (TF Adaptive) (Axis/Sybron Endo, Orange, CA). TF design increases flexibility and allows the file to be adjusted to intracanal torsional forces.[15]

The objective of this study was to examine the influence of instrument taper on the fracture resistance of endodontically treated roots, using hand and rotary files (protaper and twisted) under *in vitro* experimental conditions.

MATERIALS AND METHODS

Forty human maxillary single-rooted mandibular premolars extracted for periodontal reasons were selected for this *in vitro* study [Figure 1]. Samples were collected from the department of oral and maxillofacial surgery, Bharati Vidyapeeth Deemed University Dental College and Hospital, Pune. A consent form along with subject information sheet was given to parents/patients explaining the entire procedure. Identity of all the patients was kept confidential. Strict anonymization was observed while collecting the teeth. After extraction, the soft tissues, dental calculus, and stains were immediately removed from the teeth. The teeth were stored in distilled water until the time they were intentionally fractured.

Inclusion Criteria

Single rooted, single canal extracted teeth with sound roots, extracted because of periodontal or orthodontic reasons.

Exclusion Criteria

- Presence of caries
- Presence of roots cracks or perforations.

Figure 1: Single rooted single canal mandibular premolars were collected

Sample Preparation

All teeth were sectioned at 13 mm from the anatomic apex using a diamond coated bur [Figure 2] under water cooling and then were allocated to 4 groups. Instrumentation was done in the four groups with respective files, following the manufacturer's protocol. During instrumentation, the root canal was irrigated with 2.5% sodium hypochlorite (NaOCl) solution. After instrumentation, a final irrigation procedure was done using 5 ml distilled water, and roots were obturated using single cone technique with gutta percha and AH plus as the canal sealer. The roots were then placed in acrylic blocks in order to create an artificial periodontal ligament. All specimens were tested with a universal testing machine until the root fracture occurred.

Experimental groups

The selected teeth were randomly divided into four groups of 10 [Figure 3] each based on the files used. Group-I Hand Instruments (2% TAPER):

- Group-II TFs (4% TAPER)
- Group-III TFs (6% TAPER)
- Group-IV Protaper Files (6% TAPER) [Table 1].

Fracture Testing

All the samples were subjected to testing using Universal Testing Machine [Figure 4]. The roots were tested with a universal testing machine. A steel conical tip tapered at 60° was aligned with the center of the canal orifice of each specimen. Force was applied with 1-mm/min crosshead speed until root fracture occurred. The load necessary to cause fracture was recorded in Newton.

Statistical Analysis

Descriptive and inferential statistical analyses were carried out in the present study. Results on continuous measurements were presented on Mean SD. The level of significance was fixed at $P = 0.05$ and any value ≤ 0.05 was considered to be statistically significant. Analysis of variance (ANOVA) was used to find the significance of study parameters between the groups (Intergroup analysis). Further post hoc analysis was carried out if the values of the ANOVA test were significant.

The Statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data and Microsoft Word and Excel were used to generate graphs, tables, etc.

Table 1: Experimental groups

Groups	Instruments	Sample
Group 1	Hand instruments (2% Taper)	10
Group 2	Twisted Files (4% Taper)	10
Group 3	Twisted Files (6% Taper)	10
Group 4	Protaper Files (6% Taper)	10

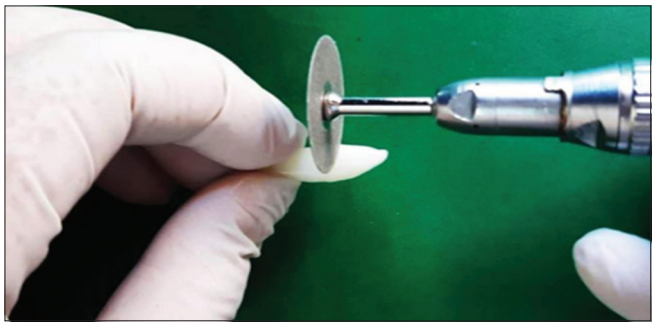


Figure 2: Samples were decoronated with a diamond disc

RESULTS

Group I has a statistical significant difference between Group II, III, and IV.

- When Group II was compared with Group IV, it was seen to have statistically significant difference
- When Group II was compared with Group III, it was seen to have no statistically significant difference

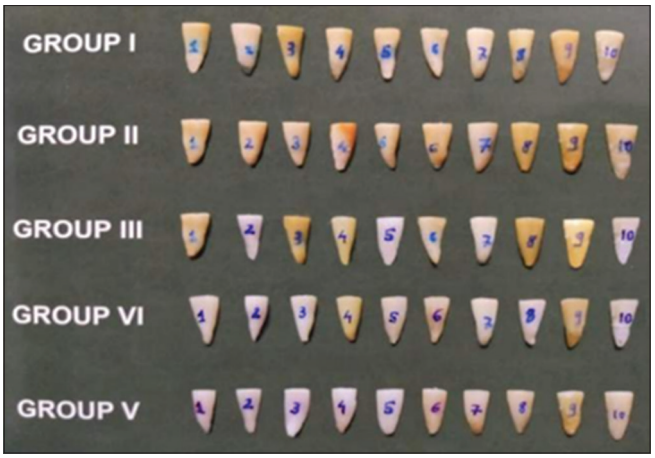


Figure 3: Samples were randomly divided into 4 groups

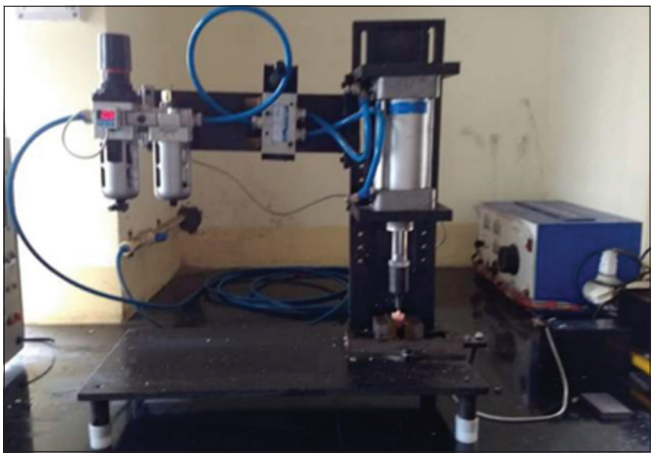


Figure 4: Sample subjected under universal testing machine after mounting on an acrylic block

- When Group III was compared with Group II and Group IV, there was statistical significant difference with Group IV whereas there was no statistical significant difference with Group II [Graph 1].

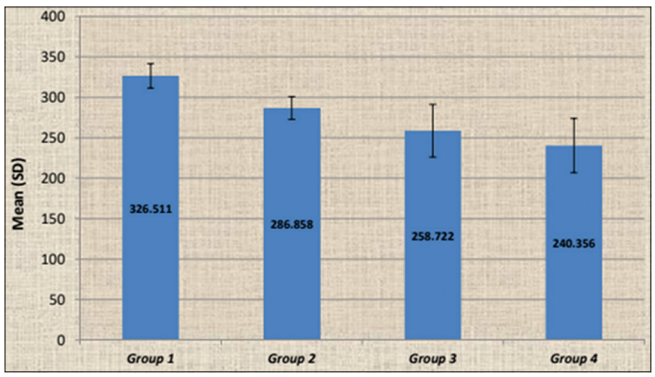
DISCUSSION

The main objective of root canal treatment is to shape and clean the root canal system effectively by maintaining original configuration of the canal. It also aims to create tapered funnel preparation with increase in diameter to facilitate effective irrigation and three-dimensional obturation of root canal space. However, possible excessive removal of dentin raised concern for susceptibility of root fractures.[16]

VRF is a complication in endodontically treated teeth leading to extraction. Removal of caries, access cavity preparations and canal instrumentation techniques, diameter of prepared canals are the predisposing factors for VRFs.[1]

Rotary nickel-titanium files safety and efficiency are collectively determined by design of file, the manner in which the file is used and the method of manufacturing. Excessive taper can result in excessive removal of dentin and weakening of the root.[17]

In recent decades, advances in rotary nickel-titanium instruments have led to new design concepts for better root canal shaping and success. Working with NiTi engine-driven instruments for biomechanical preparation of the root canal has become the fundamental of today's endodontic treatments. These instruments have many benefits including less operating time, less procedure-related accidents, and increased cleanliness of root canal walls. They are being increasingly used as they cause less fatigue to the dentist and make the procedure less time intensive.[2]



Graph 1: Mean values of fracture load of the 4 groups

Research data suggests that in the formation of dentinal fractures, shape, and taper of the files as influencing factors could play an important role. Crack formation in the walls of the root canal is of utmost concern during the use of rotary systems and it can further lead to VRF and adversely affect the prognosis of the tooth in the long run and this kind of fracture is one of the annoying complications of root canal treatment leading to extraction of tooth in most of the cases.[18] Bier *et al.* have also reported that fractures do not occur immediately after preparation of canal. Although, craze lines (4% to 16%), might develop into fractures during retreatment or after long term functional stresses such as chewing and misbalanced occlusal forces.[19]

Resistance to tooth fracture is an important aim in endodontics because such fractures may decrease the long-term survival rate. Experimental studies have shown that excessive removal of dentin during root canal preparation, post space preparation, and obturation procedures with spreader can create fractures in teeth.[13,15]

Whether hand or rotary instrumentation is used, it must be kept in mind that all canal instrumentation techniques will inevitably weaken the root structure. The present study compared the fracture resistance of teeth instrumented with different tapered NiTi files, i.e., 6% protaper, 4% and 6% TFs, and 2% hand files. In this present study, 40 standardized samples, i.e., 40 single-rooted human extracted premolars were used because they are more prone to fracture. They were mounted in acrylic socket to simulate periodontal ligament. The 40 samples were divided into four groups (n = 10) Group I: instrumented with 2% tapered hand files Group II: instrumented with 4% tapered TF Group III: instrumented with 6% tapered TF Group IV: instrumented with 6% tapered TF.

The use of hand and TFs in this study has compared a similar instrument design with an engine-driven mode and on hand use. The study included protapers so that it provided an opportunity to compare a nonstandard tapered "ProTaper" instrument with a standard tapered instrument. The gold standard of comparison in the study was with that of time tested conventional ISO standard 0.02 tapered K-files.

TF is recently developed to enhance super elasticity and provide superior mechanical properties. The TF Adaptive technique consists of 3 files This instrument can change to a reciprocation mode, with specifically designed clockwise and counterclockwise angles that vary from 600 to 0 up to 370 to 50. Depending on the amount of pressure placed on the file, the manufacturer claims that this adaptive technology TF design increase flexibility and allow the file to be adjusted to intracanal torsional forces.[20]

Compared to other systems, the protaper file demonstrates completely new design features. The following innovations characterize the ProTaper system: (1) Progressive taper (2) Modified guiding tip (3) Varying tip diameters (4) New cross section of the instruments (5) Varying helical angel and pitches. One of the main unique design features of ProTaper is varying taper within one file ranging from 3.5% to 19% which makes it possible to shape specific sections of the root canal with one file.[21]

In this study, roots were obturated using single cone technique with gutta percha and AH plusas the canal sealer. Gutta percha was used as it is by far the most popular and commonly used root canal filling material. AH plus was used in this study as it has good apical sealing ability. In this study, all the samples mounted in acrylic blocks were subjected to testing in universal testing machine until root fracture occurred Force was applied with 1-mm/min crosshead speed until root fracture occurred. The load necessary to cause fracture was recorded in Newton. Graph 1 shows the mean values of fracture load of the 4 groups and it was observed that Group I (2% taper hand instruments) showed highest fracture resistance followed by Group II (4% taper TFs), Group III (6% taper TFs) and the least was shown by Group IV (6% taper protaper files). The values thus obtained were analyzed statistically. ANOVA was used to find the significance of study parameters between the groups (Intergroup analysis). The $P < 0.001$**, which means one or more groups are statistically highly significant, i.e., there is statistical significant difference between the groups. Further *post-hoc* analysis was carried out since the values of the ANOVA test were significant. When Group I was compared with the other three groups, it was seen to have statistical significant difference with Group II (0.007), Group III (<0.001), and Group IV (0.001). In this study, it was observed that samples instrumented with hand K files (Group I), showed higher fracture resistance than the samples instrumented with rotary twisted (Group II and III) and ProTaper files (Group IV), which was in accordance with most of the studies. In this present study, conventional hand instrumentation with 2% taper K files must have weakened the roots least when compared to the other groups. In many studies, it was found out that hand instrumentation with 0.002 tapered K files removed least amount of dentin at all levels as compared to other files. Previous studies also showed that canals prepared with conventional hand instrumentation techniques using 0.002 tapered instruments left more RDT, which provided strength to the roots than various rotary NiTi instruments. This is in concurrence with earlier studies by Zandbiglari *et al.*, Wilcox *et al.*, McCann *et al.*, and Katz and Tamse *et al.* They had compared the force required to fracture uninstrumented and instrumented teeth with rotary and hand files and concluded that engine-driven rotary instrumentations tend to weaken the roots more.[22-25] When Group II (4% taper TFs) was compared with Group III (6% taper TFs), no statistical significant difference was seen (0.083), which can be attributed to the same file design and kinematics which was in accordance with the studies conducted by Krikeli *et al.*, and Singla *et al.* Krikeli *et al.* had compared Mtwo rotary files while Single *et al.* had compared Profile files of different taper, i.e., 0.002,0.004 and 0.006 and found out that the highest fracture resistance was shown by 0.002, followed by 0.004 and least by 0.006 which was similar to the results of our study.[1,26] However, Group II had statistically significant difference when compared with Group IV (6% taper ProTaper files) (<0.001), which were instrumented with 6% protaper file which was in accordance with the studies of Wilcox *et al.* and Zandbiglari *et al.* which emphasized that fracture resistance was related to how much dentin was removed during canal preparation and concluded that the more root dentin was removed, the more likely a root was to fracture.[22,23] When Group III (6% taper TFs) was compared with Group IV (6% taper ProTaper), no statistically significant difference (0.386) was seen which can be attributed to the same taper size and approximately same amount of dentin removal which led to no statistical significant difference when compared for fracture resistance. In a study done by Yoshimine *et al.*, it was observed that ProTaper instrumentation caused greater widening of canals with increased tendency to ledge or zip formation compared to other files.[27] During instrumentation, root canal geometry is formed by various momentary contacts between the files and the dentinal walls. These contacts induce stresses on the canal walls, producing dentinal defects that can increase the susceptibility of the tooth to fracture. The level of these contact stresses depends on the mechanical behavior of the files, something mainly determined by their cross-sectional and longitudinal design, torque settings, number of rotations, and kinematic.[28,29] From the results of this present study it can be concluded that teeth instrumented with 2% tapered hand instruments have the highest fracture resistance followed by 4% tapered TFs and 6% tapered TF and the least by 6% tapered ProTaper files. Nonetheless, under clinical conditions, both tooth pathology and root canal anatomy should be taken into consideration when the apical size and taper of preparation are chosen. The cleaning efficacy of root canal instrumentation and the resultant vertical fracture strength of the roots are two parameters contributing to the success of root canal treatment. Moreover, specimen preparation and the direction of the force applied in this study are different from the clinical conditions.[1,30]

CONCLUSION

Within the limitations of this *in vitro* study, it can be concluded that Teeth instrumented with 2% hand K files have the highest fracture resistance followed by teeth

instrumented with 4% taper TFs, 6% taper TFs, and 6% taper ProTaper files.

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