

FRACTURE RESISTANCE OF ROOTS AFTER INSTRUMENTATION WITH TWO NICKEL-TITANIUM ROTARY SYSTEMS AT DIFFERENT WORKING LENGTHS

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ABSTRACT

Background and Aim: The aim of the study was to evaluate the fracture resistance of roots after instrumentation with two nickel-titanium rotary systems at different working lengths.

Materials and Methods: One hundred-twelve human maxillary two-rooted premolars were used. Teeth were divided into 2 main groups according to their working lengths, (14 or 16 mm). Each group was then assigned into 3 subgroups to be prepared with different root canal instruments [ProTaper Universal (PTU), ProFile GT Series X (GTX), and K-flexofiles] (n=16). The remaining teeth were used as the control groups. The specimens were loaded vertically at 1 mm/min crosshead speed until root fracture occurred. Data were evaluated statistically using Kruskal-Wallis and Mann Whitney U ($p < 0.001$) tests.

Results: Fracture resistance of control groups were higher than that of all experimental groups ($p < 0.001$). PTU+16 mm group was found less resistant to fracture than other groups ($p < 0.001$) whereas no statistically significant differences were found among other experimental groups ($p = 0.012$).

Conclusion: Fracture resistance could decrease whilst the active 16 mm of the instrument is used inside the canal especially with PTU rotary system in two-rooted maxillary premolars.

Keywords: Fracture Resistance, Nickel-titanium Rotary Files, Root Fracture, Working Length.

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FARKLI ÇALIŞMA BOYLARINDA İKİ DÖNER EĞE SİSTEMİ İLE GENİŞLETME SONRASI KÖKLERİN KIRILMA DİRENCİNİN İNCELENMESİ

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ÖZ

Amaç: Bu çalışmanın amacı; iki döner eğe sistemi ile farklı çalışma boylarında genişletilmesi sonrasında köklerin gösterdikleri kırılma direncini değerlendirmektir.

Gereç ve Yöntem: Bu çalışmada 112 adet iki köklü üst küçük azı dişi kullanıldı. Tüm dişler çalışma boyları 14 mm ve 16 mm olacak şekilde iki ana gruba ayrıldı. Her bir ana grup her birinde 16 diş olacak şekilde ProTaper Universal (PTU), ProFile GT Series X (GTX) ve K-flexofiles ile genişletilmek üzere 3 alt gruba ayrıldı (n=16). 14 mm ve 16 mm çalışma boyuna ayarlanmış 2 kontrol grubunda ise genişletme yapılmayan 8'er diş bulunmaktaydı. Dişler genişletildikten sonra her bir örneğe dik gelecek şekilde dakikada 1 mm hızla yük uygulandı ve kırılmanın gerçekleştiği değer kaydedildi. Verilerin istatistiksel analizi için Kruskal-Wallis ($p < 0.05$) ve Mann Whitney U testleri ($p < 0.001$) kullanıldı.

Bulgular: Kontrol grupları deney gruplarına göre kırılmaya istatistiksel olarak daha fazla direnç gösterdi ($p < 0.001$). PTU+16 mm grubu diğer gruplara göre kırılmaya istatistiksel olarak daha az direnç gösterirken ($p < 0.001$) diğer deney grupları arasında istatistiksel olarak anlamlı bir fark yoktu ($p = 0.012$).

Sonuç: İki köklü üst küçük azı dişlerin kanalları genişletilirken PTU döner eğelerin 16 mm'lik aktif çalışan kısmının tamamının kullanıldığı köklerin kırılmaya yatkın hale gelebileceği gösterilmiştir.

Anahtar Kelimeler: Kırılma Dayanımı, Nikel Titanyum Döner Eğeler, Kök Kırığı, Çalışma Boyu

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INTRODUCTION

The fractures occur in teeth during or after root canal treatment. Several factors such as tooth type, canal wall thickness, root canal diameter, cross-sectional shape, caries removal, access cavity preparation, root canal instruments and instrumentation techniques, the size of master apical file, irrigation with high concentrations of sodium hypochlorite, long-term intracanal dressings with calcium hydroxide, filling and restorative procedures might all be involved in the increased risk for tooth fracture.¹⁻¹¹

It is generally accepted that resistance to fracture is directly related to the amount of remaining tooth structure. Root canal instrumentation includes both enlarging and shaping of the root canal system to allow effective disinfection by antimicrobial agents. It involves dentin removal and, therefore, may compromise the strength of the roots.¹² The endodontically treated tooth, which is already compromised due to substantial loss of tooth structure, can be further weakened with aggressive instrumentation, increasing the susceptibility of the teeth to root fracture.¹³ For this reason, preparation size, selected instrument and preparation techniques are very important.

Advances in rotary nickel-titanium (NiTi) endodontic instruments have led to new designs and techniques of root canal preparation. Design features, such as NiTi core diameter, cross-sectional shape, rake angle, cutting/noncutting tips, radial lands, varying tapers and flute depth, may affect the behavior of the file^{10,14} and, therefore, may influence the generation of root fractures. ProTaper Universal (PTU) (Dentsply Maillefer, Ballaigues, Switzerland) and ProFile GT Series X (GTX) (Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) are files widely used, with each having different design features. PTU rotary files were designed with a variable taper over the length of their cutting blades, allowing each instrument to prepare a specific area of the canal to reduce torsional loads, instrument fatigue, and the potential for breakage.¹⁵ GTX rotary files are manufactured with M-wire technology, which is believed to significantly increase resistance to cyclic fatigue and file separation.¹⁶ These files are reported to have more open blade angles, variable width lands, and 1-mm maximum shank diameter. Land widths at the tip and shank ends are half the size of the lands in the middle region of the flutes.¹⁷ The variable-width lands are reported to increase the area of debris retention so as to decrease the number of cycles needed to prepare the canal and thus the risk of instrument failure because of cyclic

flexural fatigue.¹⁸ The aim of this study was to evaluate the fracture resistance of roots instrumented with two brands of NiTi rotary files (PTU and GTX) at different working lengths (WLs) (14 and 16 mm).

MATERIALS AND METHODS

One hundred-twelve freshly extracted human maxillary premolars were used, each with two separate roots; no visible root caries, fractures or cracks on examination with a x4 magnifying glass; no signs of internal or external resorption or calcification; and a completely formed apex. Preoperative mesiodistal and buccolingual radiographs were taken of each root to confirm the canal anatomy. Extracted teeth were stored in normal saline with thymol before and during the study.

Crowns of the teeth were removed at the cemento-enamel junction. According to the WLs, all the teeth were divided into two groups (14 or 16 mm). One of the roots in each tooth to be 14 or 16 mm was sufficient for us. But, all the other canals were instrumented in each tooth to reflect clinical conditions during instrumentation. A 10-K file was placed in the canal until it was visible at the apical foramen. The WL was determined by subtracting 1 mm from apex.

The selected tooth specimens were then randomly assigned into six experimental (n=16) and two control (n=8) groups according to simple randomization method.

PTU+16 mm group. Root canals with 16 mm WL were instrumented with the PTU rotary files to a size F3 (size 30, 9-5% taper) file as the master apical file by using a constant speed of 250 rpm and 1.8-2.2 N.cm torque with a torque controlled electric motor (X-Smart; Dentsply Maillefer, Ballaigues, Switzerland). During the preparation, the root canal was irrigated with 2 mL of 2.5% NaOCl solution after each file. When instrumentation was complete, a final flush was applied using 5 mL 17% EDTA and 5 mL 2.5% NaOCl. The canals were dried with paper points.

PTU+14 mm group. Root canals with 14 mm WL were instrumented as there in PTU+16 mm group.

GTX+16 mm group. Root canals with 16 mm WL were instrumented with the GTX rotary files to a size .06/30 file as the master apical file by using a constant speed of 300 rpm and 1.75 N.cm torque with a torque controlled electric motor (X-Smart). During the preparation, the root canal was irrigated with 2 mL of 2.5% NaOCl solution after each file. When instrumentation was complete, a final flush was applied using 5 mL 17% EDTA and 5 mL 2.5% NaOCl. The canals were dried with paper points.

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GTX+14 mm group. Root canals with 14 mm WL were instrumented as there in GTX+16 mm group.

Manual+16 mm group. Root canals were prepared to an ISO size 30 K-Flexofile (Dentsply Tulsa) at WL with a stepback technique. The coronal portion of each canal was enlarged with Gates Glidden burs (Mani Inc., Tochigi, Japan) sizes 1-3 in a slow-speed contra-angle handpiece. During the preparation, the root canal was irrigated with 2 mL of 2.5% NaOCl solution after each file. During irrigation procedures, a 30-gauge round tip special endodontic irrigation needle (KerrHawe SA, Bioggio, Switzerland) was used without bending by proceeding to the deepest point of the canal. Each instrument was used in 4 canals and was then discarded in all groups; however, the instruments that were deformed before reaching this number were discarded. When instrumentation was complete, a final flush was applied using 5 mL 17% EDTA (1 min.) and 5 mL 2.5% NaOCl. The canals were dried with paper points.

Manual+14 mm group. Root canals with 14 mm WL were instrumented as there in Manual+16 mm group.

Control+16 mm group. Root canals with 16 mm WL were used as a control and not instrumented.

Control+14 mm group. Root canals with 14 mm WL were used as a control and not instrumented. Each instrument was used in 4 canals and was then discarded in all groups; however, the instruments that were deformed before reaching this number were discarded.

Roots were then wrapped in one layer of plastic film (Reynolds Inc., Richmond, VA, USA) to simulate the periodontal ligament.¹⁹ Apical root-ends were embedded along their

long axis in self-curing acrylic blocks, leaving 9 mm of each root exposed. Thereafter, the specimens were mounted in a universal testing machine (Lloyd Instruments, Fareham, Hampshire, UK), and a steel ball with a modified shape was mounted on the testing machine. The tip was lowered to contact the entire coronal surface of the roots and subjected to a gradually increasing axial force (1 mm/min), directed vertically parallel to the long axis of the roots. Force was applied to the root until it fractured. The forces necessary to fracture each root were recorded in newtons (N).

All statistical analyses were performed with SPSS, 13.0 (SPSS for Windows; SPSS Inc, Chicago, IL, USA). As the data were not normally distributed, the Kruskal-Wallis test, the nonparametric equivalent of one-way variance analysis, was used and the median of the groups were compared. Furthermore, dichotomous comparisons were made using the Mann-Whitney U test in order to determine the groups where a difference was present ($p < 0.001$).

The failure type was recorded and a distinction was made between favorable fractures (would allow repair) and catastrophic fractures (nonrestorable). The favorable failure type was located at the cervical third whereas catastrophic failure was extending thorough the middle and/or apical thirds.

RESULTS

The fracture resistance values of the test groups are presented in Table 1. All the experimental groups decreased fracture resistance of roots at different proportions. Control groups were resistant to fracture than all experimental

Table 1. Fracture Strength Details of the Groups (Newtons)

Group	n	Min.	Max.	Median	Mean $\pm$ SD	Failures types, n(%)	
						Favorable	Catastrophic
PTU + 16 mm ^A	16	201	550	319	345.25 $\pm$ 85.66	2 (12.5) ^A	14 (87.5) ^A
PTU + 14 mm ^B	16	208	694	492	481.93 $\pm$ 124.28	4 (25) ^A	12 (75) ^A
GTX + 16 mm ^B	16	204	716	502	457.68 $\pm$ 180.15	4 (25) ^A	12 (75) ^A
GTX + 14 mm ^B	16	291	703	469	469.00 $\pm$ 140.69	4 (25) ^A	12 (75) ^A
Manual + 16 mm ^B	16	303	698	479	480.12 $\pm$ 80.41	3 (18.75) ^A	13 (81.25) ^A
Manual + 14 mm ^B	16	262	679	486	469.18 $\pm$ 125.07	3 (18.75) ^A	13 (81.25) ^A
Control + 16 mm ^C	8	701	802	725	738.12 $\pm$ 33.13	2 (25) ^A	6 (75) ^A
Control + 14 mm ^C	8	647	759	705	704.75 $\pm$ 32.91	2 (25) ^A	6 (75) ^A

The same superscript letters indicate statistically no significant values ($p > 0.001$ for fracture strength, $p > 0.05$ for failure types).

groups ($p < 0.001$). PTU+16 mm group was found less resistant to fracture than other groups ($p < 0.001$) whereas no statistically significant differences were found between the other experimental groups ($p = 0.012$).

The modes of failure are listed in Table 1. Catastrophic failure was the most frequent type of failure in all groups. There were no significant differences among the groups in terms of failure type ($p > 0.05$).

DISCUSSION

A successful endodontic treatment is believed to depend on thorough chemomechanic instrumentation of the root canal system including effective disinfection by antimicrobial agents. This procedure has potential to induce root damage, which could ultimately lead to the development of root fractures.²⁰ Canal preparation involves dentin removal and, therefore, may compromise the strength of the roots.¹² Furthermore, contacts between instrument and dentin walls during preparation create many instant stresses in dentin surfaces.⁹ Excessive stresses can be increased risk of root fracture.²¹ Shemesh et al.²² and Adorno et al.⁷ reported that canal instrumentation could produce significant dentin defects such as fractures, craze lines, and incomplete cracks. In another study, Adorno et al.²³ examined the effect of root canal preparation methods on the development of apical cracks. No significant difference was found when using stainless steel hand files with either stepback or crown-down methods, but apical cracks were more likely to appear when the WL was same as the complete root canal length than when it was 1 mm short of the complete canal length. Recent in vitro study of the same group¹⁰ concluded that instrumentation with NiTi rotary files (ProFile, K3 and EndoWave) could potentially cause cracks on the apical root surface regardless of the file design. In addition, more cracks were observed when using larger file sizes. Similar results had been shown that roots instrumented with System GT was significantly weaker than those instrumented with either lower taper FlexMaster rotary files or hand K-files.²⁴ However, in another study³ in which canals had been instrumented with hand or two NiTi rotary files (Lightspeed and System GT), researchers found that the greater apical enlargement achieved with Lightspeed and the increased canal taper achieved with System GT did not significantly increase root fracture susceptibility compared with K-file preparations.

Two brands of NiTi rotary files with different cross-sectional geometries and taper but comparable sizes (size 30) were selected for this study. PTU files with a convex triangular

cross-section with notch, noncutting tip, 16 mm long working part and a progressively changing taper shaft and GTX files with a triangular-round edge cross-section, noncutting tip, variable width lands, 11.66 mm long working part and constant taper. Furthermore, a stainless steel hand files (K-Flexofile, 2% taper) were used to compare the rotary files with the conventional files. Previous studies^{9,25,26} have shown that root canal instrumentation with ProTaper files caused maximum reduction of fracture resistance because of aggressive dentin removal and higher stresses. Bier et al.²⁵ showed that canal preparation using ProTaper, ProFile, and System GT rotary NiTi files induced significantly more dentinal defects (craze lines and fractures) (16%, 8%, and 4% of teeth, respectively) than hand and S-Apex rotary files. Unlike the other rotary systems, S-Apex is the only system available with an inverted taper and may result in a parallel preparation. In a finite element analysis study⁹ researchers found that PTU induced the highest stress concentration in the root dentin and had the highest tensile and compressive principal strain components at the external root surface. The aim of this study was to evaluate the possible effects of PTU, GTX and K-Flexofile on the fracture resistance of roots after instrumentation. Files were used at two different working lengths (14 and 16 mm). According to the results, all the experimental groups decreased fracture resistance of roots at different proportions. PTU instrument at 16 mm WL showed less resistant to fracture than other groups whereas no statistically significant differences were found between the other PTU instrument at 14 mm WL, GTX and manual groups. We know that root canal files not only prepare canals to different sizes, but also to different shapes and tapers. These design variations can alter the forces on roots during instrumentation and increase defects that predispose a root to fracture. Used PTU files present 16 mm long working part, GTX files present 11.66 mm long working part and K-flexofiles present 16 mm long working part were reached maximum taper size respectively 1.22 mm, 0.99 mm and 0.6 mm. For this reason, greater taper of PTU that works at 16 mm WL, remove excessive dentin particularly on coronal part of the canal. This condition could decrease the fracture resistance of roots in this group. On the other hand, according to the results of the present study, catastrophic failure was the most frequent type of failure in all groups, and there were no statistically significant differences between rotary instrumentation, hand instrumentation and control groups. Sathorn et al.²⁷ studied the effects of intrinsic

factors of roots on fracture susceptibility and pattern, and found that dentinal removal is not the only factor associated with reduced fracture resistance, and does not always result in increased fracture susceptibility.

Tooth type significantly affects the risk of tooth fracture during or after root canal instrumentation. Maxillary and mandibular premolars have both recorded a high prevalence of tooth fracture.²⁸ Wu et al.² reported that instrumented mandibular premolars have a high risk to fracture than the uninstrumented mandibular premolars. The force required to fracture the instrumented mandibular premolars was 30% lower than that required to fracture their noninstrumented counterparts, whereas the force required for the instrumented canines was only 2% lower than for their noninstrumented counterparts. Two rooted maxillary premolars were selected for this reason. All the canals were instrumented in each tooth to reflect clinical conditions. When the roots were mounted in a universal testing machine, the tip of steel ball contacted the entire coronal surface of the selected roots.

The measurement of fracture resistance using human teeth is not a simple task. In the present study, the inner diameter of the root canal seems to be standardized, but the remaining dentinal wall thickness varies most probably among specimens. This will have great impact on the load registered at fracture. It is needed to take the wall thickness into consideration in calculating the stress at fracture.

CONCLUSION

Based on the results from this study, the fracture resistance could lower whilst the active 16 mm of the instrument inside the canal especially when PTU rotary is used for root canal preparation in two-rooted maxillary premolars.

CONFLICTS OF INTEREST: The authors have no declared financial interests in any company manufacturing the types of products mentioned in this article.

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