Orijinal Araştırma

# Effects of Different Rotary Systems and a Resin-based Root Canal Filling on Fracture Resistance of Endodontically Treated Roots

## Farklı Döner Alet Sistemleri ve Bir Rezin İçerikli Kök Kanal Dolgusunun Endodontik Tedavi Görmüş Köklerin Kırılmaya Direncine Etkileri

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**Özet**

Bu çalışmanın amacı, üç farklı döner NiTi kanal aleti (K3, RaCe, ProTaper) ve bir rezin içerikli kök kanal patının (Epiphany/Resilon) endodontik tedavi gömüş köklerin kırılmaya direncine etkilerinin karşılaştırılmasıdır. Doksan sekiz adet çekilmiş insan alt çene premolar diş kökleri ratgele olarak 3 deney (n=28) ve 1 kontrol (n=14) grubuna ayrıldı. Dişlerin kronları mine-sement sınırından itibaren kesilerek uzaklaştırıldı. Deney gruplarında kök kanalları K3 (K3 Grubunda), RaCe (RaCe Grubunda) ve ProTaper (ProTaper Grubunda) kök kanal aletleri ile prepare edildi. Sonra her deney grubundan 14 dişin kök kanalı Epiphany/Resilon kök kanal dolgusu ile lateral kondensasyon yöntemi kullanılarak dolduruldu. Diğer dişlerin kök kanalları doldurulmadı. Kontol grubundaki (n=14) dişlere hiç bir işlem uygulanmadı. Örnekler içerisi akrilik rezin dolu bakır anolara yerleştirildikten sonra, universal test cihazı ile kökler kırılana kadar vertikal kuvvet uygulandı. Elde edilen veriler tek yönlü varyans analizi ve Bonferroni düzeltmeli *PostHoc* testleri kullanılarak analiz edildi. Kontrol grubunun kırılma direnci diğer tüm gruplara göre daha yüksek bulundu ($p<0.05$). Deney gruplarında (sadece prepare edilen), RaCe grubu ProTaper grubundan daha yüksek kırılma direncine sahipti ($p<0.05$). Buna karşın, K3 grubu ile diğer deney grupları (ProTaper, RaCe) arasında bir farklılık gözlenmedi ($p>0.05$). Kök kanal dolgulu deney grupları arasında bir farklılık bulunmadı ($p>0.05$). Döner kök kanal aletleri dişleri önemli derecede zayıflatmaktadır, bununla birlikte kanalları Epiphany/Resilon ile doldurmak bu direnç kaybını kısmen tolere etmektedir.

**Anahtar Kelimeler:** Diş Kırıkları, Kök Kanal Preparasyonu, Kök Kanal Dolgusu.

**Abstract**

The aim of this study was to compare the effects of three different rotary NiTi instruments (K3, RaCe, ProTaper) and a resin-based root canal filling (Epiphany/Resilon) on fracture resistance of endodontically treated roots. Ninety eight freshly extracted human mandibular premolar teeth roots were divided randomly into three experimental groups (n=28) and a control group (n=14). Teeth were sectioned at the cemento-enamel junction with a multipurpose bur. Root canals were instrumented with either K3 (K3 Group), RaCe (RaCe Group), or ProTaper (ProTaper Group) rotary instruments in experimental groups. Fourteen roots from each group were then filled with lateral condensation technique using Epiphany/Resilon root canal filling. Other ones were left unfilled. Controls (n=14, intact tooth) received no treatment. Specimens were then mounted in copper rings, were filled with a self-curing polymethylmethacrylate resin, and the force required to cause vertical root fracture was measured using a universal testing device. Fracture force of the roots was recorded and the results in the various groups were compared. Data was analyzed statistically using one way variance analysis and Post Hoc with the Bonferroni correction tests. Control group was significantly stronger than all groups with instrumented and filled roots ($p<0.05$). Among the instrumented groups, RaCe group was significantly stronger than ProTaper group ($p<0.05$). Whereas, the K3 instruments, produced a similar amount of fracture resistance in the canal walls compared with the other instruments (ProTaper, RaCe). There was no significance among the filled groups ($p>0.05$). It was concluded that rotary NiTi instruments significantly weakened the teeth, however, filling the canals with Epiphany/Resilon partially tolerated this weakening.

**Key Words**: Tooth Fractures, Root Canal Preparation, Root Canal Filling.

## Introduction

Endodontically treated teeth seems be more susceptible to root fracture than those with intact pulps (1, 2). It can be caused by numerous factors including root canal instrumentation, intracanal irrigation or medication, post placement, root filling phase, and trauma (3-11). However, conclusive epidemiyological evidence of weakening in the root-filled teeth is still lacking. It is generally accepted that the amount of remaining dentin is directly related to the strength of the tooth (10).

Several treatment procedures such as caries removal, access preparation, and root canal instrumentation lead to a loss of tooth structure or may weaken the dentin (2, 11). For this reason, any material or treatment protocol that can compensate for this weakening effect would be useful.

Recently, a large number of instrumentation techniques and new endodontic rotary NiTi instruments have been introduced for ideal root canal preparation. Advanced instrument designs including noncutting tips, radial lands, different cross-sections and varying tapers have been developed to improve working safety, to shorten working time, and to maintain the original canal shape (12). Relatively new designs of rotary NiTi instruments were introduced as ProTaper (Dentsply Maillefer, Ballaigues, Switzerland), RaCe (FGK, La Chaux-de-Fonds, Switzerland), K3 (SybronEndo, West Collins, CA, USA), and Mtwo (VDW, Munich, Germany).

Root canal fillings can be grouped according to their basic components such as zinc oxide-euogenol, calcium hydroxide, resins, glass-ionomers, iodoform or silicone (13). Ideally, sealers should seal the canal laterally and apically and have good adaptation to root canal dentin (14). In recent years, a thermoplastic synthetic polymer-based root canal filling material, Resilon (Pentron, Wallingfort, CT, USA), has been developed. Resilon includes bioactive glass and radiopaque fillers. It performs like gutta-percha and has the same handling properties. The sealer, Epiphany (Pentron), is a dual curable dental resin composite sealer. Resilon points and Epiphany sealer fill the root canals by adhering to one another and to the root canal walls, thus forming a "monoblock" structure (6, 15). Bonding of root canal sealers to root dentin may enhance the fracture resistance of root-filled teeth and their use has been suggested to reinforce the root-filled teeth (6,7,15,16).

The aim of this study was to compare the effects of three different rotary NiTi instruments (K3, RaCe, ProTaper) and a resin-based root canal filling (Epiphany/Resilon) on fracture resistance of endodontically treated roots.

## Materials and methods

### *Tooth Selection and Preparation*

Ninety eight freshly extracted human mature mandibular premolars that were macroscopically similar in size and with straight and single-root canals (as verified radiographically) were selected. Radiographs and an operating microscope were used to ensure that the teeth did not have root caries, fractures, multiple canals, lateral radicular canals, calcifications, periradicular resorptive changes, or excessive curvatures. Selected teeth were cleaned of debris and soft tissue remnants and were stored in physiological saline solution at +4 °C until required. The teeth were sectioned at the cemento-enamel junction (CEJ) with a multipurpose bur (Dentsply Maillefer) in a high speed handpiece with continuous water spray. The length of roots was adjusted to approximately 15 mm. Patency of the apical foramen was determined with a #15 K-file (Dentsply Maillefer). When the file tip appeared flush with the apical foramen, the length of the file was recorded; the working length (WL) was determined to be 1 mm short of the measured length. The roots were then randomly divided into three experimental groups (n=28) and a control group (n=14). The groups were prepared as follows;

***K3 Group (n=28).*** Root canals were instrumented by rotary NiTi K3 instruments were used in a crowndown manner using a gentle in-and-out motion. Instrument sequences were: size 25, .06 taper was used half of the WL, size 20, .06 taper was used between half and two thirds of the WL, instruments of size 20, .04 taper, 25, 04 taper, and 30, .04 taper were used to the WL.

***RaCe Group (n=28).*** Root canals were instrumented by rotary NiTi RaCe instruments were used in a crowndown manner using a gentle in-and-out motion. Instrument sequences used were: size 25, .06 taper was used half of the WL, size 25, .04 taper was used between half and two thirds of the WL, instruments of size 20, .02 taper, 25, .02 taper, 30, .02 taper were used to the WL.

***ProTaper Group (n=28).*** Root canals were instrumented by rotary NiTi ProTaper instruments were used in a crowndown manner using a gentle in-and-out motion. Instrument sequences used were: SX (size 19, .035-.19 taper) instruments were used until resistance was encountered (coronal flaring), S1 (size 17, .02-.11 taper) and S2 (size 20, .04-.115 taper) instruments were used two thirds of the WL and F1 (size 20, .07-.055 taper), F2 (size 25, .08-.055 taper), F3 (size 30, .09-.05 taper) instruments were used of the WL.

***Control Group (n=14).*** No instrumentation or filling was attempted in the teeth.

The root canal instrumentations were completed using a Tri Auto ZX (Morita, Kyoto, Japan) endodontic handpiece. Throughout the instrumentation, irrigation with 2.5 mL of a 2.5% sodium hypochlorite (NaOCl) was provided after each instrument and at the end of instrumentation with 1 mL of 17% ethylene diamine tetraacetic acid (EDTA) was used. Finally, the root canals were flushed with saline solution and dried with paper points.

After instrumentation, experimental groups were subdivided into two subgroups of 14 roots each. Root canals in the first subgroup were filled with lateral condensation technique using Epiphany/Resilon root filling material (Pentron, Wallingfort, CT, USA), and the second group was not filled. First subgroups' filling procedure was applied as follows.

Epiphany primer was inserted into the root canals, excess primer was removed with a paper point and the Epiphany sealer was placed with a lentulo spiral filler. A master Resilon cone was placed into the root canal and cold lateral condensation was carried out using the accessory Resilon cones. All the specimens were then stored at 37 °C in normale saline for 7 days to allow the filling materials to set completely before mechanical testing was performed.

### *Preparation for Mechanical Testing*

The root surface was covered with a silicone paste from 2 mm apical to the CEJ to stimulate a periodontal ligament and was kept in 100% humidity for 24 h. Thereafter, copper rings, 25 mm in length and 10 mm in diameter, were filled with a self-curing polymethylmethacrylate resin (Vertex; Dentimex, Zeist, Netherland), and the roots were vertically placed into the resin, leaving 9 mm of buccal root coronal to it. The acrylic was allowed to harden for 20 min, and the copper rings containing the root were placed on a specially designed steel pad. This steel pad was placed into a universal testing machine (Instron, Canton, MA, USA) (Fig. 1). The acrylic blocks including the roots were placed on the lower plate of the machine; the upper plate of the machine included a round tip that had a diameter of 4 mm. This round tip contacted the coronal surface of the roots, which were subjected to a slowly increasing vertical force (1 mm $min^{-1}$) until the fracture occurred. The force showed a sharp drop at fracture and this value was recorded in Newtons.

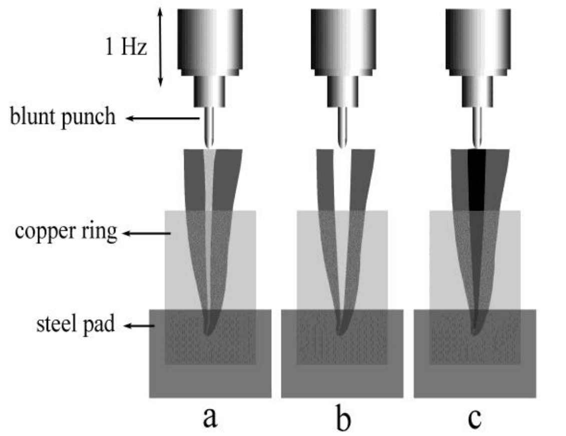


**Figure 1.** Schematic illustration of strength testing; a. control sample (intact tooth), b. only instrumented sample, c. filled sample.

***Statistical Analysis***

Statistical tests were performed using SPSS (Version 10.0, SPSS Inc., Chicago, IL, USA). Data was analyzed statistically using one-way analysis of variance and *Post Hoc* with the Bonferroni correction tests. The level of statistical significance was set at *P*=0.05.

**Results**

Descriptive statistics including the mean, standard deviation (SD), and minimum and maximum values for each of the four groups is presented in Table 1. The control group (intact teeth) was significantly stronger than all groups with instrumented and filled roots (p<0.05). Among the instrumented groups, RaCe group was significantly stronger than ProTaper group (p<0.05). Whereas, the K3 instruments, produced a similar amount of fracture resistance in the canal walls compared with the other instruments (ProTaper, RaCe). There was no significance among the filled groups (p>0.05).

**Table 1.** Force required to cause vertical root fracture.

| Group | Root canal filling | *N* | Force (in Newton) required to cause vertical root frature mean (SD) | minimum | maximum |
|---|---|---|---|---|---|
| **K3 group** | No | 14 | 460.86 (132.71) | 297 | 656 |
| | Yes | 14 | 539.64 (116.28) | 341 | 717 |
| **RaCe group** | No | 14 | 538.50 (81.64) | 407 | 686 |
| | Yes | 14 | 596.21 (103.70) | 349 | 743 |
| **ProTaper group** | No | 14 | 438.43 (71.13) | 352 | 608 |
| | Yes | 14 | 527.50 (101.58) | 319 | 705 |
| **Control** | | 14 | 696.86 (127.06) | 476 | 961 |

**Discussion**

The success of endodontic therapy is related to the appropriate execution of the different treatment phases. During root canal instrumentation, the removal of dentin tissue is necessary to promote cleaning and disinfection, as well as to prepare root canal system to receive the filling material (3). It is generally accepted that this unavoidable loss of dentin may weaken the root and create and increased risk of fracture (1-4). For this reason, there is a general trend to restore them with a reinforcing material.

Increasing the taper of the canal preparation by removing more dentin from the canal wall diminished the structural integrity of the root (3). Using finite-element analysis, Ricks-Williason et al. (17) found the magnitude of generated radicular stresses to be directly correlated with the simulated canal diameters. Wilcox et al. (18) found that root surface craze lines formed on roots where greater percentages of the canal wall were removed. Zandbiglari et al. (3) demonstrated that fracture resistance of instrumented roots is significantly lower when canals are prepared with instruments with a increasing taper. As a consequence, the authors recommended that excessive coronal enlargement of the root canal must be avoided to prevent unneccessary weakening of the root. Rundquist & Versluis (19) reported that with increasing taper, root stresses decreased during root filling but tended to increase for masticatory loading. Besides, root fracture originating at the apical third is likely initiated during filling, whilst fracture originating in the cervical portion is likely caused by occlusal loads. Sathorn et al. (20) showed that the dentin thickness not the only determining factor. Also curvature of the external proximal root surface, canal size and shape all interact in influencing susceptibility and pattern of fracture. Conversely, it has been reported (21) that no significant correlation exists between fracture load and size of the root, size of the prepared canal, width of the canal walls after instrumentation, and taper of the root or of the canal. Lam et al. (22) found that increased apical enlargement (with LS instruments) and increased taper (GT instruments) do not weaken roots any more than conventional stepback technique and may even increase fracture resistance. The results of the present study demonstrated that the root canals instrumented by the ProTaper instruments were significantly weaken the tooth structure than RaCe instruments. Whereas, the K3 instruments, produced a similar amount of fracture resistance in the canal walls compared with the other rotary instruments (ProTaper, RaCe). This differential performance could be attributed to the different designs of these three instruments. ProTaper instruments have progressively increasing tapers, a convex triangular cross-sectional design, and a modified guiding tip (16). K3 instruments have a radial land relief in combination with a positive rake angle, and an asymmetrical constant tapered active file design with variable helical flute and variable core diameter (16).

As for, RaCe instruments have a triangular cross-sectional design with sharp cutting edges, with the exception of the .02 taper size 20 files, which have a square cross-section and a negative rake angle (16). Dentin tissue is a dense and resilient material; instruments having a positive rake angle (such as; ProTaper and K3) actually work like a shaver on the dentin surface. Whereas, an instrument that has a negative rake angle (such as; RaCe) is less efficient and requires more energy to cut dentin.

To date, numerous root canal filling materials have been proposed to reinforce teeth with root canal treatment through the use of different fillings (1,3,4,6-10). However, it is still controversial whether or not these fillings increase the strength of root dentin. One of these is resin-based fillings. The adhesion between dental structures and these fillings is the result of a physicochemical interaction across the interface, allowing the union between filling material and root canal wall (23). This process is important in static and dynamic situations. In static circumstances, the adhesion eliminates spaces that allow the infiltration of fluids into the filling/dentin interface. In dynamic situations, the adhesion is necessary to avoid the filling dislodgment during operative procedures (24).

Teixeira et al. (6) reported that this new polycaprolactone-based filling material may reinforce teeth, thus becoming more resistant to vertical root fracture. On the other hand, Stuart et al. (25) reported no significant differences in reinforcement of endodontically treated roots of immature teeth when resilon, gutta-percha, and a self curing composite resin were compared with unfilled controls. This was further substantiated by Williams et al. (26) who reported that the stiffness of resilon and gutta-percha were too low to reinforce roots after root canal therapy. In the current study, the ability of a resin-based filling epiphany/resilon to reinforce the teeth after root canal instrumentation with three different instrument systems was also evaluated. According to the our results, no statistically significant differences among the filled groups were observed. Between the instrumented and filled groups there were significant differences. Instrumentation techniques were significantly weaken the tooth structures. Hovewer, this weakening partially tolerated with Epiphany/Resilon root canal filling system but not intact teeth.

Previous studies have demonstrated that the difficulty of obtaining uniform fracture strengths for human teeth because of natural variations in tooth morphology (27, 28).

When extracted teeth are used, factors such as mesio-distal width, bucco-lingual width ad length should be standardized. In the present study, all the roots were similar in size and the lengths of the roots were standardized. Additionally, Wu et al. (29) showed in an in vitro study that vertical root fracture occasionally occurs in maxillary and mandibular premolars because of exposing to high masticatory loads and small mesio-distal root diameters. It is important to establish which procedures in the endodontic theraphy may decrease the fracture of these teeth. For this reason, mandibular premolars were chosen in this study.

**Conclusions**

It was concluded that rotary NiTi instruments significantly weakened the teeth, however, filling the canals with Epiphany/Resilon partially tolerated this weakening. Further investigations into other types of rotary NiTi instruments or root canal sealers and in other groups of teeth may give further insights as to the effects of those materials on fracture resistance of teeth and susceptibility to vertical root fracture.

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