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Original research

Evaluation of fracture resistance of roots-filled with various root canal sealers at different time periods

Emel Uzunoglu Özyürek[1], Sevinç Aktemur Türker[2]

Purpose

The reinforcement effect of 3 various root canal sealers (AH 26, MTA Plus sealer and BioRoot RCS) and gutta-percha at different time periods (1 week and 1 month) were evaluated in the present study.

Materials and Methods

Single-rooted, single-canalled, cracks-free 80 mandibular premolars were decoronated to a length of 13mm. Group PC (positive control, n=10): samples were left unprepared and unfilled. Seventy samples were prepared by using the ProTaper Rotary System up to F4. Group NC (negative control, n=10): samples were left unfilled. Remaining 60 samples were assigned into 3 groups; Group 1: AH 26 + F4 gutta-percha (GP); Group 2: MTA Plus sealer + F4 GP and Group 3: BioRoot RCS + F4 GP. Filled samples were divided into subgroups according to storage time: Samples in Groups 1A, 2A, and 3A were stored for 1 week; while Groups 1B, 2B and 3B were stored for 1 month at 100% humidity to allow the complete setting of the sealers (n=10, for each). A universal testing machine at a crosshead speed of 1.0 mm/min was used for fracture testing. For each specimen, the force at the time of fracture was recorded and the data were analyzed statistically.

Results

The highest fracture resistance values were obtained in Group PC, while the lowest values were obtained in Group NC. Groups PC and NC were statistically different from each other and from other groups, regardless of time (p<0.05). Fracture resistance values of Group AH 26/GP were statistically different from MTA Plus sealer/GP (p<0.05) and were statistically similar with BioRoot RCS/GP, irrespective of time. Within group comparisons revealed that there were no statistically differences between samples filled with same sealer at different time periods.

Conclusion

Root canal preparation caused decreased fracture resistance. All sealers increased the force values needed to fracture the filled samples compared to unfilled ones. Time factor had no effect on the fracture resistance values.

Keywords: *Calcium silicate sealer; root canal obturation; vertical root fracture; time; endodontics*

ORCID IDs of the authors: E.U. 0000-0001-5032-9996; S.A.T. 0000-0001-8740-2480

[1]Associate Professor, Hacettepe University, Faculty of Dentistry Department of Endodontics, Ankara, Turkey

[2]Associate Professor, Bülent Ecevit University, Faculty of Dentistry Department of Endodontics, Zonguldak, Turkey

Corresponding Author: Emel Uzunoglu Özyürek
E-mail: emel_dt@hotmail.com

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Introduction

One of the major aims of the endodontic treatment is to reinforce the remaining tooth structure with root canal filling materials after chemical and mechanical preparation (1). These filling materials, placed within the root space, might prevent vertical root fractures, which could arise during or following root canal treatment and often lead to extraction of the tooth (2). However, there are conflicting results regarding whether the strength of roots could be enhanced after conventional root canal filling with gutta-percha and sealer, *in vitro* (3-7).

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El-Ma'aita *et al.* (8) reported that mineral trioxide aggregate (MTA) supported the tooth structure and as a result MTA filled roots resisted against vertical root fractures (8). Calcium releasing ability (9) and bioactivity (10) of MTA increase its popularity and this leads to tricalcium silicate-based sealers (TSBSs) production. TSBSs have ability to form hydroxyapatite and a bond between dentin and filling material during the setting process, as a result of this process, mineral infiltration zone is formed (11).

BioRoot RCS (Septodont, Saint-Maur-des-Fosses, France) and MTA Plus sealer (Avalon Biomed Inc, Bradenton, FL) are recently introduced silicate-based sealers to the dental market. BioRoot RCS is a water-based sealer. Powder part of BioRoot RCS is composed of tricalcium silicate, povidone (stickiness agent), and zirconium dioxide (contrast medium); while the liquid part of it is composed of calcium chloride (curing accelerator) with polycarboxylate as an aqueous solution (12,13). BioRoot RCS releases calcium hydroxide after setting (12) and a calcium phosphate phase is formed when it contacts with physiologic solution (13). Micro–computed tomographic analysis revealed that using AH Plus sealer decreased the percentage of voids significantly compared to BioRoot RCS, but no differences were observed regarding fluid flow and microsphere penetration (14). Sealer penetration and interaction with the dentin walls patterns showed diversity between these 2 sealers (14). Powder part of MTA Plus sealer can be mixed with a liquid or a gel. MTA Plus sealer has similar composition to ProRoot MTA however, its particle size is finer than ProRoot MTA (15). In order to obtain root canal sealer, powder could mix with gel, which improves its handling properties and washout resistance (16). DeLong *et al.* (17) reported favorable push-out bond strength values with MTA Plus sealer combined with single gutta-percha cone.

There are several studies evaluating the effects of TSBSs on the fracture resistance of endodontically treated teeth (5-7); so, the aim of this study was to compare the effect of di-/tri-calcium silicate-based root canal sealers on the resistance of endodontically treated roots to vertical root fracture over different time intervals. Epoxy resin sealer (AH 26 Dentsply de Trey, Konstanz, Germany) was employed as reference material for comparison. The null hypotheses of this study were as follows: first, the root canal sealer has no influence on the vertical root fracture resistance of endodontically treated teeth. Second, the resistance to vertical root fracture of endodontically treated teeth filled with different sealers and gutta-percha does not change over time.

Materials and Methods

Sample characteristics and preparation

Eighty extracted caries-free, single rooted, human mandibular premolar teeth were used. Teeth examination was carried out under an operating microscope (Zeiss, Oberkochen, Germany) in order to exclude teeth with microcracks. A digital caliper was used to measure the mesiodistal and buccolingual diameters of the coronal surface. Then, the mean of these dimensions was obtained. If the dimensions of specimens presented a difference of 20% from the mean, they were discarded in order to obtain standardized samples (18). Furthermore, the root canal morphology was determined with buccolingual and mesiodistal radiographs and then, the teeth were randomly assigned into the experimental groups according to root canals shape as round and oval. Until utilization, teeth were stored in deionized water under 4 °C. The specimens were decoronized at the cemento-enamel junction to create length in 13 mm. Randomly selected 10-decoronized samples were represented positive control group (Group PC). The root canals of the remaining 70 teeth were instrumented using the ProTaper rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to F4 with torque controlled endodontic motor (X Smart Plus, Dentsply Maillefer). After each file, 2 mL of 5.25% NaOCl was used to irrigate the root canals. Following last NaOCl irrigation, 2 mL of 17% EDTA was used to remove smear layer for 3 min and finally distilled water was used. Paper points (Dentsply Maillefer) were used to dry the canals. Following instrumentation, 10 teeth were assigned as negative control group without further intervention (Group NC). Remaining 60 teeth were divided into 3 main groups according the root canal sealers were used during root canal filling: Group 1: AH 26 + F4 Gutta-percha (Dentsply Maillefer), Group 2: MTA Plus sealer + F4 Gutta-percha, Group 3: BioRoot RCS + F4 Gutta-percha. Following root filling, excess gutta-percha was removed with heat and an appropriate plugger was used to compact the coronal material. A temporary filling material (Coltosol, Coltene, Whaledent Inc., Altstaetten, Switzerland) was placed over the obturation materials. The 10 teeth from each experimental group (Subgroups 1A, 2A and 3A) were stored at 37 °C at 100% humidity for 1 week to allow the sealers to set, while the remaining 10 (Subgroups 1B, 2B and 3B) were stored under same conditions for 1 month before fracture resistance test.

Fracture Resistance Test

Fracture resistance of each sample was tested at the end of the respective time period. However, samples in groups PC and NC were tested at the end of 1st month. Four millimeters of the roots were embedded into the self-cure acrylic resin (Imicryl, Konya, Turkey), that was poured to the cylindrical molds (diameter: 15mm, height: 13 mm), exposing 9 mm of the roots. Similar methodology and set-up were used in

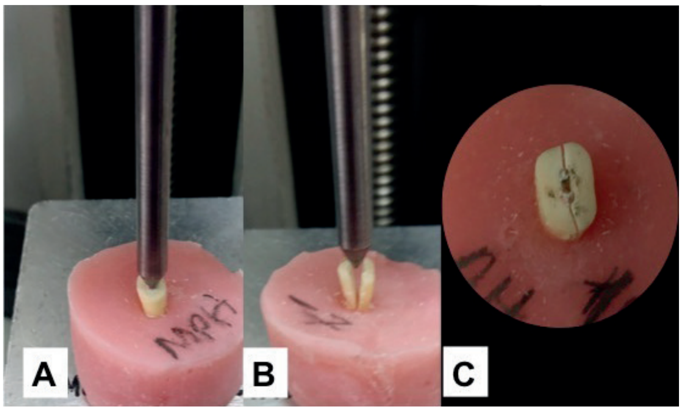

Figure 1. *Representative sample of groups mounted on Universal testing machine (A), vertical root fracture at the end of test (B), example of non-restorable vertical root fracture in buccolingual direction (C).*

Table 1: *Experimental groups and fracture resistance values (FRV) of tested samples in Newtons. (*Different superscript letters mean statistical difference between groups p<0.05).*

Groups	Time periods		
	1Week	1 Month	P Value
AH 26/GP	296.89±38.75 [a]	334.05±29.31 [a]	0. 056
MTA Plus/GP	258.91±37.79 [abd]	275.34±36.76 [b]	0.393
BioRoot RCS/GP	288.85±45.68 [a]	294.51±52.50 [ab]	0.768
Group PC	474.21±62.86 [c]		
Group NC	205.19±15.28 [d]		

previous studies (1-6). Following the removal of temporary filling material, lower plate of the universal testing machine (Instron, Canton, MA, USA) was used for the mounting of the samples (Figure 1A). A vertical compressive loading (rate: 1 mm/min) was applied via spherical steel tip (diameter: 2 mm) to the coronal surfaces of roots until the fracture occurred (Figure 1B-1C). The force required to fracture each specimen was recorded and expressed in Newton.

Statistical analysis

Statistical analysis was performed using SPSS package program (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY, USA). Univariate analysis of variance (two-way ANOVA) with Bonferroni post-hoc test was used to compare the obtained statistical data ($p<0.05$). Fractures modes were also recorded as favorable (root fractures at the cervical third were classified as restorable) and catastrophic (fractures at the middle and apical thirds were classified as non-restorable) (19). Confidence interval was set to 95% and $p<0.05$ was considered statistically significant.

Results

The results are shown in Table 1. The highest fracture resistance values were obtained in Group PC, while the lowest values were obtained in Group NC. Groups NC and PC were statistically different from each other and from other groups, regardless of time ($p<0.05$) (Table 2). Fracture resistance values (FRV) of samples filled with AH 26/GP were the highest at the end of each time period, except group PC. FRV of AH 26/GP filled samples were statistically similar with FRV of BioRoot RCS /GP filled samples, while they were statistically different from FRV of MTA Plus sealer/GP filled samples ($p<0.05$), irrespective of time (Table 2).

At the end of 1st week, FRV of AH 26/GP and BioRoot RCS/GP filled samples were statistically different than Group NC and Group PC ($p<0.05$). FRV of MTA Plus sealer/GP filled samples were statistically different from Group PC ($p<0.05$). At the end of 1st month FRV of AH 26/GP filled samples were statistically different from Groups NC, PC and MTA Plus Sealer/GP ($p<0.05$). FRV of BioRoot RCS/GP and MTA Plus sealer/GP filled samples were statistically different both from Groups NC and PC ($p<0.05$). Within group comparisons revealed that there was no statistically significant differences between FRV of samples filled with same sealer at different time periods (Table 1). The most frequent fracture mode was non-restorable fractures in buccolingual direction in all groups (Table 3).

Table 2. *Fracture resistance values (FRV) of samples in Newtons, regardless of time. (*Different superscript letters mean statistical difference between groups p<0.05.)*

Groups	FRV * Mean±SD. (N)
AH 26/GP	315.47±38.50 [a]
MTA Plus/GP	267.12±37.25 [b]
BioRoot RCS/GP	291.68±47.99 [ab]
Group PC	474.21±62.86 [c]
Group NC	205.19±15.28 [d]

Table 3. *Fracture modes of experimental groups (BL: buccoolingual; MD:mesiodistal).*

Groups	Time periods			
	1Week		1 Month	
	Fracture Modes			
	Restorable	Non-restorable	Restorable	Non-restorable
AH 26/GP	2 (BL)	8 (7 BL, 1 MD)	1 (BL)	9 (BL)
MTA Plus/GP	-	10 (BL)	-	10 (BL)
BioRoot RCS/GP	1 (BL)	9 (BL)	-	10 (9 BL, 1 MD)
Group PC	10 (BL) Non-restorable			
Group NC	1 (BL) restorable and 9 (BL) Non-restorable			

Discussion

Fracture resistance of endodontically treated teeth has been evaluated in many *in vitro* studies (1-7). Fracture test, performed with the universal testing machine, is the basic method in which progressively increasing vertical loads are applied to teeth until fracture occurs and force at fracture is recorded as Newtons. All parameters except root canal sealers were tried to be standardized in the present study: such as root canal preparation technique, root canal obturation technique; irrigants used during preparation; formation of sealers as liquid and powder; buccolingual and mesiodistal dimensions of selected teeth; storage conditions of teeth. However, this is a difficult task and the potential differences among the groups might be considered as one of the limitations of the present study. Under these limitations, first hypothesis of this study is accepted; however, second one is rejected. Root canal fillings with different sealers and gutta-percha were statistically reinforced the samples compared to group NC.

Different steps of endodontic treatment such as mechanical preparation, obturation and irrigation may weaken the root structure and create susceptible roots to fracture (2,20). Different filling materials are used in order to reinforce the endodontically treated teeth against the root fractures (1,3-7). Root canal sealers, as a complementary part of the obturation, are used to fill the gaps between gutta-percha cones and root canal walls as well as the voids between individual gutta-percha cones (21). Several studies reported that filled samples with gutta-percha and different sealers showed significantly superior fracture resistance than the group NC, as in present study (5,6). On the other hand, there were also studies that reported no clear benefits with the use of root canal sealers in reinforcing endodontically treated teeth in the literature (3,4).

Root canal filling has to be done three dimensionally without voids to prevent bacterial microleakage and to reinforce the tooth structure. Moinzadeh *et al.* (22) reported that cold lateral compaction of gutta-percha resulted in significantly more voids compared with single gutta-percha cone obturation combined with a TSBS, particularly coronally. Considering this information, single-cone technique was used in the present study.

The reinforcement effect of calcium hydroxide, epoxy resin, glass ionomer, methacrylate resins, MTA, polyketone, silicone- or zinc oxide-eugenol (ZnOE) based root canal sealers were evaluated on the endodontically treated roots (1,3-7). Biocompatibility and bioactivity of tricalcium silicate cements are high (10) and they are used to repair lateral root perforations or to fill root-ends initially (23). BioRoot RCS and MTA Plus sealer are recently introduced calcium silicate-based sealers to the dental market. BioRoot RCS was not as cytotoxic as Pulp Canal Sealer and it preserves mouse pulpal stem cells' osteo-odontogenic intrinsic properties (24). Lower flow and higher film thickness values were obtained with BioRoot RCS than that specified for sealers in ISO 6876 (25). These properties could contribute to the resistance of filled roots against vertical fractures. Guneser *et al.* (7) reported that BioRoot RCS might have the potential to increase fracture resistance values of prepared teeth against vertical forces as in the present study.

MTA Plus sealer, which has particle size 50% smaller than ProRoot MTA (15), is marketed as a calcium silicate-based material that can be used during root canal filling, root-end filling, and pulp capping procedures (26). Physicochemical properties of MTA Plus sealer such as calcium ion release, hydration reaction and pH did not change when powder was mixed either with water or gel. However, mixing powder with gel improved the compression, porosity liquid absorption and setting time of MTA Plus sealer compared to distilled water mixture (27). In the present study, gel was used to prepare the root canal sealer. FRV of samples that were filled with MTA Plus sealer/GP were lower in both test periods compared to other samples either filled with BioRoot RCS/GP or AH 26/GP. It has been reported that the chemical composition of MTA Plus sealer was similar to ProRoot MTA (15); however, its porosity, water solubility, and water sorption were higher compared to ProRoot MTA (25). This could be one reason of lower fracture resistance values obtained with MTA Plus sealer.

The highest fracture resistances were recorded in AH 26 group in all evaluated periods among tested sealers. Although Viapiana *et al.* (14) reported that there were more voids in root canals filled with BioRoot RCS/GP compared to an epoxy-resin based sealer (AH Plus)/GP, there were no significant differences between AH 26 and BioRoot RCS regarding fracture resistance. According to the results of present study, higher values were obtained at the end of first month compared to first week, however these differences were statistically insignificant. Hoppe *et al.* (28) reported that push-out bond strength of AH Plus combined with lateral compaction of gutta-percha increased insignificantly at the end of 6 months compared to 24h. El Maita *et al.* (8) showed that vertical root fracture resistance did not change with AH Plus sealer/GP obturation over a period of 6 months. On the other hand, authors reported a significant increase for MTA (8). Turker and Uzunoğlu (29) reported that the highest bond strength for white MTA was seen at the end of 28-day period. Current results were consistent with previous results evaluating epoxy-resin based sealer (AH 26). On the other hand, increase in forces to fracture samples that were filled with TSBSs was insignificant in the current study. Regarding the direction of fractures observed in the present study, most of them occurred in the buccolingual direction as previous studies in which force applied vertically to the samples (3,6,7).

Conclusion

Under the limitations of this study, it could be concluded that the root canal preparation lowered the fracture resistance values. All sealers increased the force values needed to fracture the filled samples compared to unfilled ones but the time factor had no effect on the reinforcement effect of root canal sealers.

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Türkçe öz: *Çeşitli kök kanal dolgu patlarıyla doldurulan dişlerin farklı zaman dilimlerindeki kırılma dayanımlarının değerlendirilmesi. Amaç: Üç farklı kök kanal dolgu patı (AH 26, MTA Plus sealer ve BioRoot RCS) ve gütaperka ile doldurulan örneklerin 1. hafta ve 1. ayın sonundaki kırılma dayanımı değerlerini incelemektir. Gereç ve Yöntem: Seksen adet tek köklü, tek kanallı, çatlaksız alt çene küçük azı dişi kök boyu 13 mm olacak şekilde dekoronize edilmiştir. Grup PK (pozitif kontrol, n=10): örnekler şekillendirilmemiş ve doldurulmamıştır. Geri kalan 70 örnek en son kullanılan eğe F4 olmak üzere ProTaper döner eğe sistemi ile şekillendirilmiştir. Grup NK (negatif kontrol, n=10): şekillendirilen örnekler doldurulmamıştır. Geri kalan 60 örnek 3 gruba ayrılmıştır: Grup 1: AH 26 + F4 gütaperka konu (GP), Grup 2: MTA Plus Sealer + F4 GP, Grup 3: BioRoot RCS + F4 GP. Doldurulan örnekler saklama süresine göre alt gruplara ayrılmıştır. Grup 1A, 2A ve 3A'daki örnekler 1 hafta; Grup 1B, 2B ve 3B'deki örnekler 1 ay süreyle %100 nemli ortamda bekletilmiştir (n=10/grup başına). Tüm örnekler daha sonra evrensel test cihazında kırılma dayanımı testine maruz bırakılmıştır. Her bir örnek için, kırılma anındaki kuvvetler kaydedilerek uygun istatistiksel analizler yapılmıştır. Bulgular: En yüksek kırılma dayanımı değerleri (KDD) Grup PK'da gözlenirken, en düşük KDD Grup NK'da gözlenmiştir. Grup PK ve NK zamandan bağımsız olarak istatistiksel açıdan hem birbirinden hem de diğer gruplardan farklı bulunmuştur (p<0.05). Zamandan bağımsız olarak yapılan analizde, AH 26 patı/GP ile doldurulan örneklerin KDD'sinin BioRoot RCS/GP ile doldurulan örnekler ile istatistiksel olarak benzerlik gösterdiği (p>0,05), fakat MTA Plus sealer/GP ile doldurulan örneklerden daha yüksek olduğu bulunmuştur (p<0,05). Grup içi yapılan karşılaştırmalar aynı pat ve GP ile doldurulan örneklerin bir hafta ve bir ay sonunda elde edilen KDD arasında anlamlı bir farklılık olmadığını göstermiştir (p>0,05). Sonuçlar: Kök kanal şekillendirmesi anlamlı bir şekilde KDD'nin düşük çıkmasına neden olmuştur. Tüm patlar NK grubuna kıyasla KDD'de artışa yol açmışlardır. Zamanın KDD üzerinde istatistiksel olarak anlamlı bir etkisi bulunamamıştır. Anahtar kelimeler: Kalsiyum silikat kök kanal dolgu patı; kök kanal dolgusu; vertikal kök kırığı; zaman; endodonti.*

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