ORIGINAL ARTICLE

Comparative evaluation of the fracture resistances of endodontically treated teeth filled using five different root canal filling systems

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Abstract

Aim: The aim of this study was to compare the fracture resistances of teeth filled using different root canal sealers and rials.

Materials and Methods: One hundred and twenty single rooted mandibular human incisor teeth with single canals were divided into 5 experimental groups of 20 teeth with 2 control groups of 10 teeth each. After root canal shaping using K3 rotary instruments, root canals were filled as follows: Group 1: (−) control, Group 2: (+) control, Group 3: Gutta-percha/AH Plus, Group 4: Thermafil/AH Plus, Group 5: Resilon/Epiphany self-etch (Epiphany SE), Group 6: Gutta-percha/Epiphany SE ve Group 7: EndoREZ sealer/EndoREZ cone. After the root canal sealers set, the apical 4 mm. portions of the specimens were embedded in cold curing acrylic and a fracture resistance test was applied in a universal testing machine. The load at which fracture occurred was recorded for each group and statistically analyzed using one-way ANOVA and Tukey's honestly significant difference tests.

Results: Resilon/Epiphany SE ve EndoREZ sealer/EndoREZ cone groups had lower fracture resistances compared with the negative control group consisted of teeth without root canal shaping ($P < 0.05$). Gutta-percha/AH Plus, Thermafil/AH Plus and Gutta-percha/Epiphany SE groups showed similar fracture resistances ($P > 0.05$). The fracture resistance of the instrumented, but unfilled positive control group was significantly lower compared with (−) control, Gutta-percha/AH Plus, Thermafil/AH Plus ($P < 0.01$) and Gutta-percha/Epiphany SE ($P < 0.05$) groups. There were no significant differences between the fracture resistances of the Resilon/Epiphany SE and EndoREZ sealer/EndoREZ cone and positive control groups ($P > 0.05$).

Conclusions: Root canal shaping procedures decrease the fracture resistance of teeth, and lateral condensation performed with AH Plus sealer and Gutta-percha and the Thermafil technique were found to be more successful.

Key words: EndoREZ, epiphany self-etch, fracture resistance, resilon, thermafil

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Introduction

Vertical root fractures are occurrences with a poor prognosis, generally resulting in the extraction of the involved tooth. Apart from predisposing factors such as caries with extensive tissue loss, trauma, root configuration and anatomy, dehydration previously existing cracks in dentine, loss of bone support, iatrogenic factors such as overinstrumentation, prolonged application of calcium hydroxide, effect of irrigation solutions, condensation of filling materials with pressure, and intracanal postapplication are also among the etiological factors causing vertical root fractures in endodontically treated teeth.[1-8] The effect of root canal preparation methods, the performed restoration, root canal filling materials and methods and posttreatment

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restoration on fracture resistance have been investigated in many researches.

There are major differences between an endodontically treated tooth and an intact tooth. Dentine loss in anatomic structures such as cusps, shoulders and pulp chamber roof[9] reduction in dentine elasticity[10] and loss of water content[7] predispose teeth to fracture. This being the case; supporting the remaining dental structures is of critical value for the long-term success of the treatment.

The elasticity module is defined as the ratio of stress to strain which is defined as 14.000 MPa for dentine. The elasticity of dentine plays a major role in the provision of a successful bonding mechanism for the root filling. Kinney *et al.*,[11] drew attention to the fact that knowledge of the mechanical properties of dentine was important for understanding how masticatory strains were distributed throughout a tooth, and for predicting how stresses and strains were altered by dental restorative procedures, age and disease. They concluded that the modulus values averaged 29.8 Mpa for peritubular dentine and ranged from 17.7-21.1 Gpa for intertubular dentine, with the lower values obtained for dentine near the pulp. Structures bonding to dentine are expected to possess similar elasticity moduli.

It has been indicated that materials that can bond to root dentine may support the tooth and thus advocated that it would be preferable to use root canal filling materials that can resist against fracture. This has led to the development of the monoblock systems, which help bond dentine and the filling material thus forming a complete unit acting against stresses and reinforcing tooth structure. For a monoblock to be successful, materials constituting the monoblock should have the ability to bond strongly to each other as well as dentine and they should have similar elasticity moduli.[12]

Gutta-percha has been the most frequently used root canal filling material for years for its multiple advantages such as biological compatibility, lack of toxicity or allergic effects, and easy removal from the root canal. It should be used in conjunction with as a sealer since it is unable to adhere root canal walls by itself. Resin based sealers such as AH 26 and AH Plus are generally preferred because of their multiple advantages.

Thermafil system is a thermoplasticized root canal filling system, which has been shown to adapt to the irregularities in the root canal system.[13] The system includes the placement of alpha-phase Gutta-percha coated on a plastic carrier into the root canal followed by heating until a specific temperature.

Resilon (Pentron Clinical, Wallingford CT, USA) is a secondary monoblock system with 2 interfaces and is a synthetic polymer having similar characteristics as Gutta-percha.[12] It is used in conjunction with Epiphany (Pentron Clinical, Wallingford CT, USA), which is a resin based dual-cure composite. The sealer contains self-etch dual cure hydrophilic resin and does not require a primer for bonding to dentine.

Another one of the resin based filling systems is EndoREZ (Ultradent, South Jordan, UT, USA). It is based on chemical bonding between the resin coated Gutta-percha and dual cure root canal sealer. It and represent a tertiary monoblock system as it contains a third interface between the filling material and the root canal wall.[12] It consists of two pastes and is applied into the root canal with the help of a syringe.

The purpose of this study was to comparatively evaluate the effect of Resilon/Epiphany self-etch (Epiphany SE), EndoREZ sealer/EndoREZ cone monoblock systems, Gutta-percha/Epiphany SE filling system, Thermafil/AH Plus system and Gutta-percha/AH Plus with lateral condensation on the fracture resistance of single rooted teeth.

Materials and Methods

One hundred and twenty recently extracted single rooted mandibular human incisor teeth were used in the study. During their selection, care was taken to ensure that the teeth had similar dimensions, mature apices and were devoid of root canal calcifications or resorptions. The teeth were analyzed under an operating microscope (Zeiss, Oberkochen, Germany) at ×25 magnification to confirm that only those without fractures or cracks defects were included. Soft and hard tissue remnants were removed from the root surfaces with an ultrasonic scaler (Cavitron, Siemens, Germany) and curettes. The coronal portions of the selected teeth were removed from the cemento-enamel junction (CEJ) using diamond discs under water cooling. Standardized 13 mm. specimens were obtained. The bucco-lingual diameters of the teeth at the CEJ were also measured using a micrometer in order to obtain standardization. Specimens were sequenced from smallest diameter (5.02 mm) to the greatest (5.63 mm) and distributed by a randomized stratified design among groups. The teeth were preserved in deionized water at 4°C until experimentation.

All specimens, except the negative control group, were instrumented using the K3 nickel-titanium (NiTi) (Sybron Endo, Orange, USA) rotary instruments mounted on a reduction motor handpiece (X-Smart, Dentsply) with the crown down technique. The sequence followed during instrumentation was as follows: A no. 10 file was inserted in the root canal until it was slightly visible from the apical foramen and the working length was established by subtracting 1 mm. from this distance. During instrumentation, a no. 30 file with a 0.04 taper was inserted

until resistance and a no. 25, 0.04 tapered K3 rotary file was used from this point on. The sequence continued this way by changing instruments until resistance was felt and the apical portion was reached. In the apical portion, shaping was completed by instrumentation of smaller to larger instruments. The preparation process was completed by a no. 30, 0.04 tapered instrument. Finally, no. 2 and 3 Gates Glidden burs were used to increase the conicity of the coronal portion. After each file, the root canals were irrigated with 2 ml of 5% NaOCl. When instrumentation was completed, 10 ml of 17% ethylenediaminetetraacetic acid (EDTA) (Vista Dental Products, Wisconsin, USA) solution and 10 ml of 5.25% NaOCl were used as a final rinse for the removal of the smear layer. Distilled water was used as the final irrigant and the root canals were dried using the sterile paper points (Diadent, Diadent Group International, Burnaby, BC, Canada).

The instrumented teeth were divided into 7 groups. Five groups of 20 teeth in each served as the experimental groups and 2 groups of 10 teeth were used as controls.

The controls and experimental groups were treated as follows:

Group 1: (−) Control (n: 10): No shaping or filling

Group 2: (+) Control (n: 10): The teeth were instrumented until 0.04 tapered no. 30 K3 files; however no filling was performed

Group 3: Gutta-percha DiaDent (Diadent, USA)/AH Plus (Dentsply de Trey, Konstanz-Germany) (Lateral condensation)

A K-file compatible with the dimensions of the instrumented root canal was dipped into sealer, placed inside the root canal and rotated counter-clockwise. A previously adjusted no. 30 master cone with a 0.02 taper (Diadent, USA) was dipped into sealer and placed within the canal. The root canal filling was completed using no. 30, 25, 20 spreaders (Dentsply Maillefer) and accessory Gutta-percha cones (Diadent, USA) coated with sealer by the lateral condensation technique. Excess cones in the access cavities were removed with a hand instrument and the root canal orifices were filled with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland).

Group 4: Thermafil (Dentsply-Maillefer, Germany)/AH Plus (Dentsply deTrey, Konstanz-Germany) (Carrier-based thermoplastic technique)

The confirmation of the adjustment of a 0.04 tapered no. 30 Thermafil cone (Dentsply-Maillefer) was checked using a Thermafil verifier (Dentsply-Maillefer). A K-file compatible with the dimensions of the instrumented root canal was coated with sealer and inserted in the root canal until working length and rotated counter-clockwise. A Thermafil cone (Denstply-Maillefer) was heated in a Therma Prep Oven (Tulsa Dental Products) according to the manufacturer's instructions. After waiting for a cooling and a setting period of 3-4 min, excess in the root canal was removed with a heated hand instrument. The root canal orifices were filled with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland).

Group 5: Resilon (Pentron Clinical, Wallingford, USA)/Epiphany SE (Pentron Clinical, Wallingford, USA) (Lateral condensation)

Epiphany self-etch dual-cure (Epiphany SE - Pentron), root canal sealer was prepared. Then, a K-file compatible with the instrumented root canal's dimensions were inserted in the root canal until working length and rotated counter-clock wise. A 0.04 tapered no. 30 Resilon master cone (Pentron) was dipped in Epiphany SE (Pentron) sealer and placed in the root canal until working length. The root canal filling was completed using medium-fine Resilon (Pentron) accessory cones coated with sealer and no. 30, 25, and 20 spreaders. Excess cones were removed using a heated instrument and the root canal filling was polymerized from the coronal portion using "Optilux 501" (Demetron; Kerr Corp., Danbury, CT, USA) halogen light source for 40 s. Later, the root canal orifices were filled with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland).

Group 6: Gutta-percha (DiaDent Diadent, USA)/Epiphany SE (Pentron Clinical, Wallingford, USA) (Lateral condensation)

Epiphany self-etch dual-cure (Epiphany SE - Pentron), root canal sealer was prepared. Then a K-file, compatible with the instrumented root canal's dimensions, were inserted in the root canal until working length and rotated counter-clock wise. A 0.04 tapered no. 30 Gutta-percha master cone (Diadent) was dipped in Epiphany SE (Pentron) sealer and placed in the root canal until working length. The root canal filling was completed using no. 30, 25, 20 spreaders (Dentsply Maillefer) and accessory Gutta-percha cones (Diadent, USA) coated with sealer by the lateral condensation technique. Excess cones in the access cavities were removed with a hand instrument and the root canal orifices were filled with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland). The root canal filling was polymerized from the coronal portion using "Optilu × 501" (Demetron; Kerr Corp., Danbury, CT, USA) halogen light source for 40 s. Later, the root canal orifices were filled with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland).

Group 7: EndoREZ sealer (Ultradent, South Jordan, UT)/EndoREZ cone (Ultradent, South Jordan, UT (Passive lateral condensation).

A Navi Tip of appropriate length was mounted on the ultradent skinny syringe. EndoREZ root canal sealer was prepared using the ultra-mixer tip mounted on ultradent two spence syringe and filled into the skinny syringe. Navi Tip was placed in the root canal until 2-3 mm. shorter than the working length and the skinny syringe was slightly withdrawn, while the sealer was dispensed. The root canal space was filled with the sealer until

orifice and a previously adjusted 0.04 tapered no. 30 EndoREZ master cone was placed in the root canal until working length. Root canal filling was completed by passive lateral condensation technique not to disrupt the resin coating on EndoREZ cones using spreaders and sealer coated EndoREZ accessory cones. Excess cones in the access cavities were removed using a heated hand instrument and the root canal orifices were obturated with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland). The root canal filling was polymerized from the coronal portion using "Optilu ×501" (Demetron; Kerr Corp., Danbury, CT, USA) halogen light source for 40 s. Later, the root canal orifices were filled with a temporary filling material (Coltosol, Coltene/Whaledent, Switzerland). Radiographs were taken from all specimens to confirm the quality of the root canal fillings.

The apical 4 mm. portions of the filled specimens were embedded in cold curing acrylic (Imicryl, Turkey) poured in molds that can be adjusted to an Instron testing device. The specimens were then kept in an incubator (Memmert, Germany) at 37°C for 1 week until polymerization was completed. During fracture testing, the 1.4 mm. diameter rounded tip of the Instron device was positioned with a right angle over the specimens and a force increasing at 1 mm/min was applied until fracture. The load at which fracture occurred was recorded in Newtons.

Statistical analysis

Statistical analysis was performed using the NCSS 2007 and PASS 2008 Statistical Software (Utah, USA) program. Since the parameters were compatible with normal distribution, intergroup comparison of parameters was performed using one-way ANOVA. The Tukey'S honestly significant difference test was used for to determine, which group caused the difference. Significance level was set at $P < 0.05$.

Results

There was a statistically significant difference between the average fracture resistances of groups ($P < 0.01$) [Table 1].

The fracture resistance of the negative control group was significantly higher compared to the Resilon/Epiphany SE ve EndoREZ sealer/EndoREZ groups ($P < 0.05$). On the other hand, no statistically significant difference was determined between the fracture resistances of the negative control and the Gutta-percha/AH Plus, Thermafil/AH Plus ve Gutta-percha/Epiphany SE groups ($P > 0.05$). The Gutta-percha/AH Plus, Thermafil/AH Plus and Gutta-percha/Epiphany SE combinations had comparable fracture resistances with an intact tooth and the completion of the root filling with these materials increased the fracture resistances [Table 2].

The average fracture resistance of the positive control group was significantly lower than the negative control, Gutta-percha/AH Plus and Thermafil/AH Plus groups ($P < 0.01$) and the Gutta-percha/Epiphany group ($P < 0.05$). There was no significant difference between the fracture resistances of the Resilon/Epiphany SE ve EndoREZ sealer/EndoREZ cone groups and the positive control ($P > 0.05$). These combinations did not increase the fracture resistance of the teeth [Table 2].

Discussion

Single rooted human teeth such as maxillary central incisors and canines are generally used in studies evaluating the

Table 1: Average fracture resistances of groups

Groups	*n*	Minimum	Maximum	Mean±SD	*P*
(−) control	10	265.73	659.81	464.36±134.60	*F*: 6.786; *P*: 0.001**
(+) control	10	76.64	392.68	206.01±94.00	
Gutta-percha/AH Plus	20	251.08	636.9	424.02±108.18	
Thermafil/AH Plus	20	140.92	563.85	391.67±108.79	
Resilon/Epiphany SE	20	123.65	523.72	328.72±109.09	
Gutta-percha/Epiphany SE	20	164.21	560.69	347.67±112.27	
EndoREZ	20	124.3	544.32	328.41±104.11	
Post-hoc		2<1, 3, 4**, 6* 1>5, 7*			

SD=Standard deviation; SE=Self-etch; *F*=Oneway ANOVA test.
*$P<0.05$, **$P<0.01$

Table 2: Intragroup comparisons

Groups	Tukey HSD *P*
1-2	0.001**
1-3	0.964
1-4	0.611
1-5	0.030*
1-6	0.097
1-7	0.029*
2-3	0.001**
2-4	0.001**
2-5	0.068
2-6	0.019*
2-7	0.069
3-4	0.967
3-5	0.097
3-6	0.304
3-7	0.095
4-5	0.542
4-6	0.865
4-7	0.536
5-6	0.998
5-7	1
6-7	0.998

*$P<0.05$; **$P<0.01$. HSD=Honestly significant difference

fracture resistances of teeth. Mandibular incisors were preferred in the present study due to the fact that vertical root fractures are more common in this type of teeth and the low susceptibility of these slender rooted teeth to fracture.[5] Although extreme care was taken during standardization and an even distribution of teeth with respect to configurations and diameters, this may not be always possible to achieve. Despite the fact that this factor can be considered as one of the drawbacks, human teeth are nevertheless preferred to make a better resemblance of clinical situations.

Although it is claimed that root canal treatment increases the susceptibility of teeth to vertical fracture, some contradict this belief.[1] It has been indicated that it is not only the root canal procedures that cause weakening of the tooth structure but excessive tissue loss due to caries, trauma and all endodontic procedures.[1] The disruption of the marginal shoulder integrity are also factors that predispose teeth to fracture.[14]

A rounded cross-sectional form obtained following instrumentation has a positive effect on the distribution of forces during filling.[15] Since a rounded cross-sectional form that is more compatible with the original root canal anatomy can be obtained using NiTi rotary instruments and complications such as transportation and instrument fracture are less frequently observed with these systems,[15] K3 NiTi rotary system was used in the present study. During root canal treatment, there is a tendency for the fracture resistance to decrease as the dentine thickness is reduced by the progression of preparation procedure.[16] Therefore; it is proposed that excessive preparation should be avoided in teeth with lower volumes.[16] Apical preparation was completed using 0.04 tapered no. 30 files. The Thermafil cones selected were also size 30 with 0.04 conicity and to ensure standardization between the groups, a 0.04 tapered K3 NiTi rotary instrumentation system was preferred.

The removal of the Type I collagen, chondroitine sulphate and glycosaminoglycans in the dentine with the organic tissue dissolving effect of NaOCl,[17] causes structural changes in the dentine leading to the reduction of elasticity modulus and flexural strength. It has also been stated that the removal of the smear layer provided the penetration of root canal sealers in dentinal tubules, resulting in a better bonding between the dentine and the sealer. The removal of the smear layer with the NaOCl/EDTA combination was determined to increase the bond strength of Ketac-Endo and glass ionomers.[18] It has also been proposed that distilled water should be used as the final rinse to neutralize the effects of irrigation solutions.[19] In this study, distilled water was used for final irrigation following NaOCl and EDTA.

Groups 5, 6 and 7 were light cured from coronal portion. The manufacturers' instructions were strictly followed. Although, depth of light curing is supposed to be limited to a few millimeters, both Epiphany and Endorez Sealer were dual cure and apical portion of the sealer is supposed to cure chemically. Fracture resistance test has been delayed 1 week to allow chemical curing of the sealers following light curing. However, the ideal time for complete setting of the apical portion of these sealers merits further investigation.

The fracture resistances of instrumented, but unfilled teeth were found to be significantly lower compared with both intact teeth ($P < 0.01$) and experimental groups ($P < 0.01$, $P < 0.05$). Leaving roots unfilled following shaping reduces their fracture resistance.[19,20] These results are consistent with the results confirming the reinforcing effect of filling materials on roots.[19,20] Saw and Messer,[21] indicated that in the Thermafil system, minimum condensation is required only in the coronal portion, therefore less force can be applied on the tooth vertically. On the other hand, in some studies, Thermafil showed no statistically significant difference compared with other filling systems (GP/AH26, Beefill).[22] In this study, Thermafil/AH plus system increased the fracture resistance of teeth. The plastic carrier within the Thermafil cone might have affected forces exerted on the roots. Meanwhile; with the help of the 0.04 tapered root canal form prepared in compatibility with the Thermafil cone, the Gutta-percha and the plastic carries might have supported the root canal form and increased fracture resistance.

Gutta-percha is widely used along with resin based AH Plus and accepted as the gold standard. This combination belongs to the 3rd group of the present study and while it exhibits a similar fracture resistance with the negative control, is significantly higher compared to the positive control ($P < 0.01$). Gutta-percha/AH Plus combination applied with the lateral condensation technique shows a fracture resistance comparable with a natural tooth.

There are many studies in the literature in which AH 26 or AH Plus + Gutta-percha are compared with the Resilon system. In some studies, it has been stated that the use of Resilon increases the adhesion to the dentinal walls compared to Gutta-percha.[23,24] On the other hand, some others reported that Gutta-percha had a higher bonding strength.[25,26]

The lower than expected bonding between Resilon and Epiphany might explain why this combination exhibits low bond resistance values.[27] Patil *et al.*,[26] in a push-out study reported a lower bond strength for Resilon/Epiphany SE and EndoREZ systems compared to Gutta-percha/AH Plus. Despite the differences in methodologies, Resilon/Epiphany SE and EndoREZ groups exhibited lower fracture resistances compared to Gutta-percha/AH Plus.

Nunes *et al.*, showed that AH Plus, an epoxy resin based sealer has a better adhesion compared to epiphany and

is able to penetrate dentinal tubule with its flowability and setting time. This results in the provision of a micromechanical bonding between root canal sealer and root dentine.[28] Methacrylate based sealers are highly affected by the cavity configuration factor (C factor), which is very high in long root canals. Methacrylate based sealers undergo polymerization shrinkage and the bonding between sealer-core and sealer-dentine might not be adequate to withstand forces generated during polymerization.[29] Although there are contradictory views,[30] it has been indicated by some authors that dual cure resin based sealers are unable to reinforce root dentine and increase fracture resistance.[19,20,31] The results of the present study also show that Resilon/Epiphany SE and EndoREZ sealer/EndoREZ cone are unable to increase fracture resistance.

Stoll *et al*.,[32] supported the view that new generation root canal sealers can be used in conjunction with Gutta-percha without causing any clinical disadvantage and the monoblock concept is not only valid for Resilon only but for Gutta-percha as well.[32] The present study evaluated whether there is any difference in fracture resistances by using Epiphany SE with both Gutta-percha and Resilon. Gutta-percha/Epiphany SE showed a higher fracture resistance compared to Resilon/Epiphany SE and was comparable with the intact teeth in the negative control group. The use of Gutta-percha in conjunction with adhesive systems should be further investigated.

Conclusions

Root canal shaping procedures decrease the fracture resistance of teeth, and lateral condensation performed with AH Plus sealer and Gutta-percha and the Thermafil technique were found to be more successful.

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