International Endodontic Journal

doi:10.1111/j.1365-2591.2009.01571.x

Fracture resistance of roots using different canal filling systems

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Abstract

Karapinar Kazandag M, Sunay H, Tanalp J, Bayirli G. Fracture resistance of roots using different canal filling systems. *International Endodontic Journal*, **42**, 705–710, 2009.

Aim To evaluate the fracture resistance of teeth filled with various canal filling materials.

Methodology The crowns of 100 single-rooted teeth were removed leaving 12 mm of the roots. The canals were shaped using Endo-Sequence files. Following instrumentation, 80 teeth were divided into four groups. The remaining 20 teeth were divided into two groups. The teeth in each group were filled as follows: Group 1: AH-Plus + Gutta-percha (Cold lateral compaction), Group 2: Resilon + Epiphany (Cold lateral compaction), Group 3: ActiV GP cone + ActiV GP sealer, Group 4: ActiV GP sealer + Gutta-percha (Cold lateral compaction), Group 5: No instrumentation or filling, Group 6: Instrumentation but no filling. After the sealers had set, the roots were embedded in acrylic moulds and subjected to a compressive loading at a rate of 1 mm min^{-1}. The load at which fracture occurred was recorded and statistically analysed using Kruskal–Wallis one-way analysis of variance and Z-tests.

Results The fracture values of the experimental teeth were significantly higher than those of the instrumented but unfilled group ($P < 0.05$). Teeth in the AH-Plus + lateral compaction group had higher fracture resistance compared with the ActiV GP sealer + Gutta-percha group ($P < 0.05$).

Conclusions Systems aiming to obtain a monoblock system were not superior to the conventional AH-Plus + Gutta-percha technique in terms of fracture resistance. The fracture resistance of roots using ActiV GP + lateral compaction Gutta-percha was significantly reduced compared with the AH-Plus + Gutta-percha group.

Keywords: ActiV GP, Epiphany, fracture resistance, monoblock, Resilon.

Received 30 July 2008; accepted 22 February 2009

Introduction

Root filled teeth may be more susceptible to fracture because of excessive loss of tissue, dehydration of dentine and excessive pressure during filling procedures (Helfer *et al.* 1972, Sornkul & Stannard 1992). It has been indicated by some authors that the dentine of root filled teeth is 'dessicated and inelastic' (Rosen 1961) whilst others have suggested that vertical root fractures most often occur in teeth after root canal treatment (Bender & Freedland 1983). A further reason that predisposes root filled teeth to fracture has been shown to be excessive widening of root canals (Sornkul & Stannard 1992).

The elasiticity of dentine plays a major role in the provision of a successful bonding mechanism for the root filling. Kinney *et al.* (1996) 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 Gpa for peritubular dentine and ranged from 17.7 to 21.1 Gpa for intertubular dentine, with the lower values obtained for dentine near the pulp. Marshall

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et al. (1997) concluded that tubule orientation had no appreciable effect on the elastic behaviour of normal dentine, and that the elastic properties of healthy dentine could be modelled as an isotropic continuum with a Young's modulus of approximately 16 GPa and a shear modulus of 6.2 GPa.

The endodontic literature has recently become familiar with the term 'monoblock' with interest in the application of dentine adhesive technology to endodontics. Tay & Pashley (2007) indicated that replacement monoblocks created in the root canal spaces may be classified as primary, secondary, or tertiary depending on the number of interfaces present between the bonding substrate and the bulk material core. Adhesive dental materials are now available that may offer an opportunity to reinforce the root filled tooth through the use of bonded sealers in the root canal system (Johnson *et al.* 2000).

Resilon (Pentron Clinical, Wallingford, CT, USA), one of the commercially available bondable root filling materials may be used for either lateral or warm vertical compaction techniques and it represents a secondary monoblock system where there are two interfaces, one between the sealer and primed dentine and the other between the sealer and Resilon (Tay & Pashley 2007). It is applied using a methacrylate-based sealer, commercially known as Epiphany (Pentron Clinical, Wallingford, CT, USA). It has been reported that when the canals are filled with Resilon in combination with Epiphany, a monoblock is formed and teeth after canal filling with these materials are more resistant to vertical fractures than teeth filled with Gutta-percha and sealer (Teixeira *et al.* 2004).

Some studies have evaluated the fracture resistance of teeth filled using the Resilon + Epiphany filling system. Ulusoy *et al.* (2007) determined that the use of AH-Plus + Gutta-percha increased the fracture resistance of instrumented root canals compared with Resilon + Epiphany and Ketac-Endo Aplicap + Gutta-percha. Hammad *et al.* (2007) concluded that filling of canals with resin-based filling materials (Resilon and EndoRez) increased the resistance of root filled teeth to vertical root fracture. Ribeiro *et al.* (2008) in their study evaluating the influence of different endodontic materials on root fracture susceptibility, determined that core materials (Gutta-percha or Resilon) combined with sealers, were not able to increase root fracture resistance in canals subjected to chemomechanical preparation.

ActiV GP (Brasseler USA, Savannah, GA, USA) is a root filling system marketed as a monoblock system by using conventional Gutta-percha cones that are surface coated with glass–ionomer fillers using a proprietory technique (Tay & Pashley 2007). Tay & Pashley (2007), in a review of monoblock systems in endodontics, indicated that there is limited information regarding this technique due to the fact that the system is rather new. The author, based upon bacterial leakage studies commented further that it is unlikely that the use of ActiV GP system will improve the fracture resistance of root filled teeth. A review of the current literature shows that there is yet no published information regarding the fracture resistance of teeth filled using the ActiV GP system. However, there are reports on the sealing properties, bacterial leakage and push-out bond strengths of this material (Monticelli *et al.* 2007a,b, Toledano *et al.* 2007, Fisher *et al.* 2007).

The purpose of this laboratory study was to assess the fracture resistance of single-rooted teeth root filled using the Resilon + Epiphany adhesive system, ActiV GP using its proprietory cone as a single-cone technique and ActiV GP sealer using the lateral compaction technique and compare these results with those obtained by the conventional AH-Plus + Gutta-percha cold lateral compaction technique.

Materials and methods

One hundred recently extracted caries-free single-rooted human teeth having approximately similar dimensions were used. The selected teeth consisted of maxillary central and lateral incisors and mandibular premolars having similar dimensions and were evenly distributed into groups. The teeth were examined under an operating microscope (Zeiss, Oberkochen, Germany) and those with microcracks were excluded. Bucco-lingual and mesio-distal radiographs were taken for determining root canal morphology and the teeth were evenly distributed in terms of both round and oval shaped canals into the experimental groups. The teeth were stored in deionized water under 4 °C until use. The crowns of the experimental teeth were removed at the cemento-enamel junction to create 12 mm long specimens. The root canals of the experimental teeth were shaped using the Endo-Sequence (Brasseler) .06 tapered files. The protocol utilized for this technique in large root canals was as follows: After accessing the canals, the orifices were enlarged using Gates Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland). The canals were enlarged in a crown-down fashion, using successive Endo-Sequence files (Brasseler) for large canals, that is using sizes 50, 45, 40 and 35 files. The canals were enlarged until a size 35 master apical file with .06 taper. The root canals were irrigated with 2 mL of 5.25% NaOCl after each file. Following this procedure, irrigation with 2 mL of 17% EDTA solution for 3 min was performed. A final rinse was performed with distilled water. The canals were dried with sterile paper points (Diadent, Diadent Group International, Burnaby, BC, Canada).

Following instrumentation, 80 teeth were divided into four groups. The remaining 20 teeth were divided into two groups having 10 teeth in each and served as controls.

The experimental groups were filled using the following methods:

Group 1: AH-Plus (Dentsply de Trey, Konstanz-Germany) + Gutta-percha (Diadent, Diadent Group International) (Lateral compaction)

Sealer was placed onto the canal walls by rotating the master apical file counter clockwise. Master apical file (Size 35, 0.6 taper) coated with AH-plus (Dentsply) was inserted into the canal. A Gutta-percha master point (Diadent) size 35, .02 taper was dipped in sealer and inserted into the canal. Lateral compaction was applied by using size 30, 25, 20 spreaders (Dentsply Maillefer) and size 30, 25, 20 accessory cones (Diadent). Excess material was seared off and condensed with a plugger 1 mm below the canal opening.

Group 2: Resilon (Pentron Clinical Wallingford, USA) + Epiphany (Pentron Clinical) Lateral compaction

Epiphany primer (Pentron) was inserted into the root canals and excess primer removed with size 35, .06 tapered paper points. Epiphany sealer (Pentron) was placed using the tips provided with the Resilon + Epiphany kit. After placing a size 35, .06 taper resilon cone to the appropriate working length, medium-fine Resilon accessory cones dipped in resin sealer and size 30, 25, 20 spreaders were used for lateral compaction. Excess material was seared off and condensed with a plugger 1 mm below the canal orifice. After this procedure, the material was cured in the root canal with visible light for 30 s.

Group 3: Activ GP Gutta-percha cone (Brasseler, Savannah, USA) +ActiV GP sealer (Single cone)

A size 35, .06 taper master apical file coated with sealer was inserted into the canal and rotated counter clockwise. A size 35, .06 taper ActiV GP Gutta-percha cone (Brasseler) was dipped in sealer and inserted into the canal until working length. Excess material was seared off and condensed with a plugger 1 mm below the canal orifice.

Group 4: Activ GP sealer (Brasseler, Savannah, USA) + Gutta-percha (Diadent) (Lateral compaction)

Sealer was placed onto the canal walls by rotating the master apical file counterclockwise. A size 35, 0.6 taper master apical file coated with Activ GP sealer (Brasseler) was inserted into the canal. A size 35, .02 taper Gutta-percha point (Diadent) was selected and coated with sealer and inserted into the canal. Lateral compaction was applied using size 30, 25, 20 accessory cones dipped in sealer. Spreaders were used as described in Group 1. Excess material was seared off and condensed with a plugger 1 mm below the canal orifice.

The control groups of 10 teeth in each were treated as follows:

Group 5

The canals in this group were not shaped or filled.

Group 6

The canals in this group were shaped but not filled.

Following root filling, the coronal 1 mm of the filling materials were removed and the spaces filled with a temporary filling material (Coltosol, Coltene, Whaledent Inc., Altstaetten, Switzerland) The teeth were stored at 37 °C at 100% humidity for 14 days to allow the sealers to set.

During lateral compaction, sizes 25 and 30 stainless steel spreaders (Dentsply Maillefer) were used. This process was repeated, compacting the cones until the spreader no longer advanced beyond the coronal one third of the canal. Excess Gutta-percha was removed with heat and the coronal material was compacted with an appropriate plugger. These procedures were conducted by one operator who is a specialist in endodontics.

Acrylic resin cylinders 15 mm diameter and 13 mm in height were obtained using cylindrical moulds. Self-cure acrylic resin (Imicryl, Konya, Turkey) was used in the preparation of the cylinders. Three millimetres of the roots were embedded in the acrylic cylinders

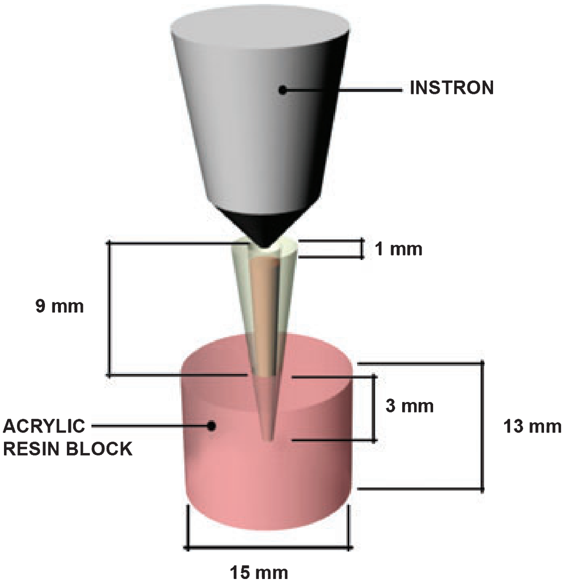

Figure 1 Diagram representing the loading conditions.

exposing 9 mm. This set-up was similar to the methodology used by Apicella *et al.* (1999). The temporary filling material was removed and the specimens were mounted on the lower plate of the universal testing machine (Instron, Canton, MA, USA) and a compressive loading was applied vertically to the coronal surfaces of roots with a loading rate of 1 mm min^{-1} until fracture occurred. The load at which failure occurred was recorded and expressed in Newtons. Statistical analysis was performed using NCSS package programme (NCSS 2007, Kaysville, Utah, USA) The diagram representing the loading conditions is shown in Fig. 1. For statistical analysis, Kruskal–Wallis one-way analysis of variance was used for the comparison of groups. A Z-test was used in the Kruskal–Wallis multiple comparison.

Results

The distribution of the median fracture values for each group is shown in Table 1. The fracture values of the experimental teeth were significantly higher than the instrumented but unfilled group (Group 6) ($P < 0.05$). Teeth in Group 1 filled with AH-Plus using the lateral compaction technique had the highest resistance to fracture and were significantly less susceptible to breakage compared with Group 4 where ActiV GP sealer was used with the lateral compaction technique ($P < 0.05$).

Table 1 Median fracture values obtained for the experimental groups in terms of Newtons

Obturation material and filling technique	Median fracture values (N)
AHPLUS + Gutta-percha (lateral compaction)	521.15^{a}
Resilon + Epiphany sealer (lateral compaction)	$416.85^{a,b}$
ActiV GP + single cone	$500.50^{a,b}$
ActiV GP + lateral compaction	410.45^{b}
Negative control	420.10^{ab}
Positive control	284.80

Values with the same supercript are not statistically different.

Discussion

In the present investigation, care was taken to standardize the experimental teeth and balance them with respect to shape and dimensions. However, this is not a simple task and the potential differences between the groups of this study may be considered as one of the drawbacks. All other variables, apart from the filling technique was standardized.

Although root filled teeth are claimed to be more susceptible to fracture, there are reports which dispute this possibility. Sedgley & Messer (1992) found that teeth do not become more brittle following root canal treatment. They stated that other factors may be more critical to failure and concluded that it is rather the cumulative loss of tooth structure from caries, trauma, and restorative and endodontic procedures that led to susceptibility to fracture. Reeh *et al.*(1989) reported that the amount of coronal tooth structure, in particular marginal ridge integrity, seemed to be more important. They added that the largest losses in stiffness were related to the loss of marginal ridge integrity. They determined that MOD cavity preparations resulted in an average of 63% loss in relative cuspal stiffness and concluded that endodontic procedures did not weaken teeth with intact marginal ridges (Reeh *et al.* 1989).

Versluis *et al.* (2006) indicated that root canal preparations resulting in a rounder cross section may have a positive effect on force distribution inside a root canal during filling. Although round shaped canals enable a better distribution of stresses within the root canal, it is a fact that with the rotary instrumentation system used, a rounded shape is achieved. Thus, the difference between the final shapes in the present study are not expected to have a significant influence on the stress exerted during filling.

The irrigation procedure was standardized for all the filling techniques. Apicella *et al.* (1999) in a study investigating the fracture resistances of teeth filled with different techniques, used a final rinse of EDTA followed by NaOCl to enhance the bonding of Ketac-Endo to the dentinal surface of the root. Some authors advised against the use of acidic solutions (Weiger *et al.* 1995). In the present study, a final irrigation with distilled water was performed to neutralize the effects of the irrigating solutions.

The fracture resistance of adhesive root filling systems have been assessed in some studies. Sagsen *et al.* (2007) determined no statistically significant difference in terms of fracture resistance between AH 26 and Gutta-percha, Resilon with Epiphany and Gutta-percha with MCS canal sealer. The results of the present study are similar to these findings as there was no statistically significant difference between the first three groups. Similarly, the fracture resistances of all the experimental groups were significantly higher than the instrumented but not filled group. This confirms the reinforcing effect of the filling materials.

To serve the monoblock concept, resin-based dental materials have been proposed as a means to reinforce a root filled tooth through the use of adhesive sealers in the root canal system (Teixeira *et al.* 2004). One of these materials is the Resilon + Epiphany system. Recently, some criticism has been brought regarding its adhesive and reinforcing properties. The modulus of elasticity of Resilon was found to be 86.6 ± 43.2 MPa under dry conditions and 129.2 ± 54.7 MPa after 1 month of water sorption (Williams *et al.* 2006). Considering that the modulus of elasticity of root dentine is 16 000–18 000 MPa and the fact that the similarity of the elasticity moduli of the components play a major role in the creation of a successful monoblock system, it appears that both Gutta-percha in combination with AH-Plus and the Resilon + Epiphany system do not differ in terms of providing the monoblock system and the fracture values obtained with these two techniques were not statistically different.

It has been suggested that similar to Gutta-percha, Resilon is not stiff enough to provide a mechanically homogeneous unit with root dentine (Williams *et al.* 2006). The reason for the production of adhesive systems inside the root canal is mainly dependent upon the reinforcement of root canal dentine, thus increasing fracture resistance. It has been suggested that materials that adhere to the root canal dentin surface will strengthen the remaining tooth structure (Ungor *et al.* 2006).

AH-Plus in combination with Gutta-percha has been selected as one of the materials tested and is a representative of an epoxy resin sealers that is commonly used with Gutta-percha. It is noteworthy that root instrumentation reduces resistance to fracture and Group 1, though not statistically significant had a higher resistance compared with the uninstrumented and unfilled tooth. This result implies that teeth filled using AH-Plus in combination with Gutta-percha using the lateral compaction method have no difference than a natural tooth in terms of resistance.

In tertiary monoblock systems, a tertiary interface exists as an external coating on the surface of the Gutta-percha (Tay & Pashley 2007). In the present study, ActiV GP, a glass–ionomer based tertiary monoblock system as suggested by Tay & Pashley (2007) was used as one of the experimental groups. The results of the present study indicate that ActiV GP combined with its glass–ionomer sealer is not superior to the other systems in terms of root reinforcement. On the other hand, when the sealer was used in combination with traditional Gutta-percha cones using the lateral compaction technique, a statistically significant reduction occurred in the fracture resistance of the experimental teeth compared with the AH-Plus + Lateral compaction group. The reason for this lower fracture values compared with the AH-Plus group may be attributed to the excessively thin sealer remaining that may hamper the adhesive property of the material.

(Tay *et al.* 2005a). Glass–ionomer sealers have been shown to adhere to the hydroxyapatite component of enamel and dentine (Weiger *et al.* 1995, Çobankara *et al.* 2002). Ketac-Endo Aplicap, a glass–ionomer based root canal sealer in combination with the lateral compaction technique has been investigated by Ulusoy *et al.* (2007) in terms of root fracture resistance. These authors determined lower fracture resistance values for this filling system compared with the AH 26 + Gutta-percha group, which is similar to the results obtained in the present study. There are relatively few studies that assess the properties of this recently developed system (Monticelli *et al.* 2007a,b) .The results obtained with ActiV GP should be interpreted with caution as there is no equivalent material with similar properties to this product.

ActiV GP system is recommended to be used with a single-cone obturation technique. Although the utilization of single-cone techniques has been questioned, it has been proposed by some authors that root canal sealing systems claiming to create bonds along the sealer-Gutta-percha interface may be used effectively with a single-cone obturation technique (Tay & Pashley 2007).

Conclusions

Resilon/Epiphany and ActiVGP/ActivGP Sealer techniques were not superior to the conventional AH-Plus + Gutta-percha technique in terms of fracture resistance. The fracture resistance of teeth filled with ActiV GP sealer in combination with lateral compaction was significantly lower than that of teeth filled with laterally condensed Gutta-percha and AH-Plus sealer.

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