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Fracture resistance of roots filled with gutta-percha or RealSeal®

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Abstract

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Aim To evaluate the vertical root fracture resistance of maxillary central incisors filled with different root filling materials and sealers.

Methodology Forty maxillary central incisor root canals were instrumented and divided randomly into four groups. Each group was filled using lateral compaction, with gutta-percha and AH Plus, gutta-percha and RealSeal® sealer, RealSeal® cone and RealSeal® sealer, or RealSeal® cone and AH Plus, respectively. The roots were loaded vertically by a conical spreader tip inserted into the canal and attached to an Instron testing machine until root fracture occurred. The load at fracture and the pattern of fracture were recorded. Mechanical properties of both core materials were tested under compressive loading. Results were analysed statistically by two-way analysis of variance and *post hoc* Tukey's tests. An independent sample *t*-test was used to compare the mechanical properties of the filling materials.

Results Load at fracture of roots filled with gutta-percha and AH Plus (255 ± 74 N) and gutta-percha and RealSeal® sealer (237 ± 38 N) was significantly greater than those filled using the RealSeal® system (163 ± 29 N) and RealSeal® cone with AH Plus sealer (134 ± 17 N). Most fracture lines were in a bucco-lingual direction. In compressive tests of the core materials, RealSeal® had greater flow in response to load than gutta-percha, suggesting more efficient transmission of forces to the canal wall in the fracture tests.

Conclusions The lower fracture resistance of roots filled using RealSeal® is probably the result of more efficient transmission of forces within the canal, rather than a direct effect of the material itself.

Keywords: AH Plus, gutta-percha, RealSeal®, Resilon™, vertical root fracture.

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Introduction

Vertical root fracture (VRF) is defined as a longitudinal fracture confined to the root that usually begins on the internal wall and extends outward to the root surface (Walton 2002). It may be initiated in the crown or at the root apex, or in some cases, along the root between these two points (Pitts & Natkin 1983). The prognosis of a VRF in a root filled tooth is poor (Meister *et al.* 1980). Thus, prevention of VRF is desirable. It would be advantageous if the root filling not only provided an adequate seal but also minimized the risk of VRF.

The ability of a root filling to strengthen (reinforce) the root has been suggested in some studies (Trope & Ray 1992, Lertchirakarn *et al.* 2002), but has been disputed on the grounds that root filling materials do not have the required physical properties (Grande *et al.* 2007, Jainaen *et al.* 2009). Numerous investigations involving a range of materials have shown that they did not increase the fracture resistance of root filled teeth (Apicella *et al.* 1999, Johnson *et al.* 2000, Zandbiglari *et al.* 2006). A new root filling material was introduced in 2004 under the name Resilon™, consisting of core material and a resin-based sealer. Resilon™ is a mixture of thermoplastic synthetic

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polymers and also contains bioactive glasses and radiopaque fillers. Its handling properties were developed to resemble those of gutta-percha. According to recent reports, this adhesive root canal filling system penetrates into the dentinal tubules of the canal wall and simultaneously develops a strong bond between the Resilon™ cone and the sealer (Shipper & Trope 2004, Shipper *et al.* 2004, Gesi *et al.* 2005). It is claimed that it forms a 'monoblock' (Gesi *et al.* 2005, Shipper *et al.* 2005). Because of this monoblock between the intraradicular dentine and root canal filling material, the Resilon™ filled root was claimed to be more resistant to root fracture compared with roots filled using conventional materials (Teixeira *et al.* 2004). This finding has been confirmed in some studies (Hammad *et al.* 2007, Schäfer *et al.* 2007, Baba *et al.* 2010) but not in others (Johnson *et al.* 2000, Gesi *et al.* 2005, Ribeiro *et al.* 2008, Karapinar Kazandag *et al.* 2009, Hanada *et al.* 2010).

The mechanical properties of both sealer cements and core materials have been investigated, as well as the influence of the materials on fracture properties of dentine (Grande *et al.* 2007, Jainaen *et al.* 2009). Both Resilon™ and gutta-percha demonstrate physical properties of elastomeric polymers with low cohesive strength and stiffness (Williams *et al.* 2006), and they do not alter the properties of dentine (Grande *et al.* 2007, Jainaen *et al.* 2009). Thus, the evidence for any effect of root filling materials on VRF resistance is lacking. Therefore, the purpose of this study was to measure the VRF resistance of maxillary central incisors root filled using different pairings of core filling materials (gutta-percha and RealSeal®) and sealers (AH Plus and Realseal® sealer), using a vertical load applied within the canal (Lertchirakarn *et al.* 1999, 2003). To investigate a possible explanation for differences in measured fracture loads, selected compressive properties of the core materials were compared.

Materials and methods

The study protocol was approved by The Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Thailand. Extracted human maxillary central incisor teeth were stored in normal saline with thymol before and during the study. The teeth were obtained from patients aged between 46 and 60 years who had the teeth extracted because of severe periodontitis. The root surface was cleaned thoroughly and examined at 20× magnification with a microscope (Zeiss, Oberkochen, Germany) for signs of root fracture or crack. Any teeth with a crack, root caries, open apex and anatomical irregularities were excluded. Radiographs were taken in both labiolingual and mesiodistal directions to confirm that each tooth had a single canal, similar root canal size, no previous root canal treatment and no root resorption. The root canal size was measured from both radiographic views to determine the same size of root canal. Forty teeth were selected and tested within 6 months after extraction.

Tooth preparation

All teeth were decoronated 2 mm above the cemento-enamel junction with a diamond saw (Isomet, Buehler, IL, USA). Canal patency was established with a size 10 K-file, and the working length was set at 1 mm short of the apical foramen as assessed visually.

Root canal preparation

Each tooth was held in gauze saturated with normal saline during instrumentation. The teeth were instrumented using K-flex files (Kerr Corporation, Orange, CA, USA) to size 45 master apical file, using a step-back technique to flare the canal to size 80. The coronal third was prepared using sizes 3 and 4 Gates-Glidden drills. During instrumentation, 1 mL 2.5% sodium hypochlorite was used for irrigation between file sizes. A size 10 K-file was used to confirm the patency of the apical foramen. Finally, the canal was flushed with 10 mL 17% EDTA followed by 10 mL 5.25% sodium hypochlorite to remove the smear layer (Goldman *et al.* 1982). Then, 10 mL sterile water was used to remove any remaining sodium hypochlorite residue in the root canal, and sterile paper points were used to dry the canal.

Canal filling

Teeth were then randomly distributed into four experimental groups of 10 teeth each, using a random numbers table, and root filled as follows:

Group 1: gutta-percha master cone (Dentsply Maillefer, Ballaigues, Switzerland) and AH Plus sealer (Dentsply DeTrey Gmbh, Konstanz, Germany).

Group 2: gutta-percha master cone and RealSeal® sealer (SybronEndo, Orange, CA, USA).

Group 3: RealSeal® master cone and RealSeal® sealer.

Group 4: RealSeal® master cone and AH Plus sealer.

Root canals were filled using the lateral compaction technique. The sealers were mixed according to the manufacturer's directions. AH Plus was applied to the canal wall with the master apical file. With RealSeal® sealer, the primer was placed into the canal with a microbrush, and the paper points were used to remove excess prime. The master cone was coated with sealer and placed with gentle apical pressure. A size 25 finger spreader (Kerr) was inserted, rotated and withdrawn, and a fine–fine accessory cone of the same material was placed. The process was repeated until the canal was filled completely. Root filling materials were removed 2 mm apical to the CEJ and vertically condensed with a hot plugger (Dentsply Maillefer). The roots in group 2 and 3 were light-cured for 40 s according to the manufacturer's recommendations. The access opening was sealed with Cavit (3M Espe, Seefeld, Germany). Radiographs of the roots were then taken in both labiolingual and mesiodistal directions to confirm the adequacy of the root filling in terms of appropriate length, density and taper (Balto *et al.* 2010). All roots were kept at 37 °C with 100% humidity for 1 week.

Measurement of the force at vertical root fracture

The root surface was covered with silicone paste (Dow Corning 3140 RTV coating; Dow Corning Corp., Midland, MI, USA) up to 2 mm apical to the CEJ, with thickness of approximately 200 μm to simulate a periodontal ligament (Lertchirakarn *et al.* 1999). Each root was then mounted vertically in a PVC ring using dental stone to the depth of 2 mm below the CEJ. A medium-sized (size 60) finger spreader was mounted in an Instron universal testing machine (Instron Corp., Norwood, MA, USA). The root was centred under the spreader on the lower plate, and the spreader was driven downward at a rate of 0.5 mm min^{-1} into the filling material until the root fractured. The amount of force required for fracture was recorded in newton (N) for each root when the applied load suddenly decreased more than 25% (Teixeira *et al.* 2004). The fractured roots were later examined under a light microscope with 20× magnification to determine the fracture pattern, which was categorised into bucco-lingual, mesiodistal and compound fracture.

Compressive testing of root filling materials

For mechanical testing, an electronic dynamometer (Lloyd Instruments Ltd LR10K, Bognor Regis, UK) equipped with a 1000 N load cell was used. Ten cylindrical-shaped specimens of each core material (RealSeal® and gutta-percha), 4 mm diameter × 6 mm high, were prepared by heat-softening the materials (100 °C) and compacting them in an aluminium mould. Five specimens of RealSeal® and gutta-percha cones were compressed at a rate of 0.5 mm min^{-1} until the proportional limit was exceeded. The remaining five specimens were compressed to a load of 150 N, which was then held constant for 10 min to measure creep. The load-deflection curves were obtained by means of NEXYGEN PC-software (Lloyd Instruments Ltd). Load-displacement data were converted to stress-strain data. The modulus of elasticity was measured from the linear portion of the stress-strain curve. Maximum force at deformation of each material was recorded for stress at proportional limit. The creep rate of each material was calculated from slope of the linear regression line after constant load was achieved.

Statistical analysis

Statistical analysis was performed using SPSS (SPSS/PC, Chicago, IL, USA). Two-way ANOVA was used to analyse the mean force at fracture with the core materials and sealers as independent variables. *Post hoc* comparisons amongst groups were performed using Tukey's multiple comparisons. An independent sample *t*-test was used to compare the physical properties of the two materials. All the testing was performed at the 95% level of confidence.

Results

The mean force at fracture for each experimental group is presented in Table 1. Canals filled with gutta-percha and AH Plus (254.51 ± 73.96 N) and gutta-percha and RealSeal® sealer (236.71 ± 38.45 N) had a greater force at fracture than those filled with RealSeal® system (163.24 ± 29.17 N), RealSeal® point and AH Plus (133.50 ± 17.03 N). Two-way ANOVA demonstrated that the type of core material had a highly significant effect on force at fracture ($P < 0.001$), but not the sealer type ($P > 0.05$). *Post hoc* pairwise comparisons showed that the force at fracture of gutta-percha filled

Table 1 The mean force at vertical root fracture (VRF) (mean ± SD) in each experimental group

Group	Force at VRF (N) (mean ± SD)
Gutta-percha + AH Plus	254.51 ± 73.96
Gutta-percha + RealSeal® sealer	236.71 ± 38.45
RealSeal® cone + RealSeal® sealer	163.24 ± 29.17
RealSeal® cone + AH Plus sealer	133.50 ± 17.03

roots was significantly greater than those filled with RealSeal® cone, with both types of sealer ($P < 0.01$), but sealer type did not significantly influence fracture load with the same core material.

All samples from this study were examined for the pattern of fracture. The majority of samples (78%, 31 of 40) fractured in a labiolingual direction. In this majority group, 29% (nine teeth) also fractured in other directions. The primary fracture occurred in a mesiodistal direction in 23% (9 of 40 teeth).

Of the compressive properties measured (Young's modulus, stress at proportional limit, % strain at proportional limit and creep rate; Table 2), only stress at the proportional limit was significantly different between the two materials ($P = 0.017$), with RealSeal® significantly lower than gutta-percha. With increasing load above the proportional limit (Fig. 1), RealSeal® flowed much more readily than gutta-percha.

Table 2 A comparison of selected compressive properties of gutta-percha and RealSeal® (mean ± SD). All samples were tested at 25 °C, with a sample compression rate of 0.5 mm min^{-1}

	Gutta-percha	RealSeal®
Young's modulus (MPa)	270 ± 39	279 ± 44
Stress at proportional limit (MPa)	13.2 ± 1.60	9.6 ± 0.40*
% strain at proportional limit	4.7 ± 0.80	3.6 ± 0.60
Creep rate (% strain per h)	2.2 ± 0.30	2.2 ± 0.40

*Significantly lower than gutta-percha ($P = 0.017$). No other parameters were significantly different between the two materials.

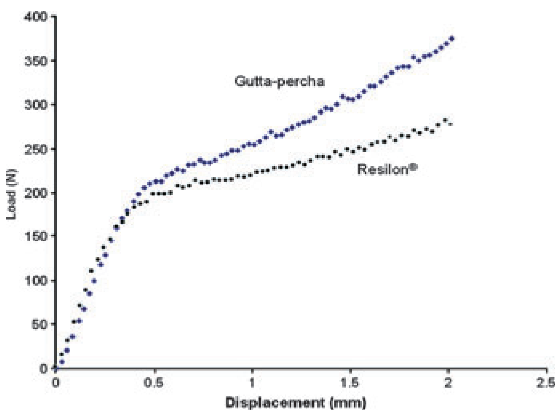

Figure 1 Typical load-displacement curves in compression for gutta-percha and RealSeal®. The two materials have similar elastic modulus (slope of the linear portion of the curves), but RealSeal® has a lower proportional limit and flows more readily than gutta-percha at higher loads.

Discussion

The specimens used in this study were limited to maxillary central incisors obtained from patients aged 46–60 years with advanced periodontal disease. Although the variation of root morphology and root dentine thickness may affect the load at root fracture (Lertchirakarn *et al.* 2003), the strength of experimental teeth might be comparable because they were selected and stored in the same condition and randomly allocated into the experimental and control groups. The root dentine thickness and morphology of all samples were also examined to ensure the same size and shape. However, the force at VRF in this study should not be compared with other experiments but only considered in relation to the force only within this study. The biological variation of tooth structure may influence a range of mechanical properties as does the period of storage, which may affect the integrity of tooth structure, especially collagen. This effect was limited by using teeth within 6 months of extraction.

One possible cause of VRF is stresses generated within the canal during lateral condensation (Meister *et al.* 1980, Tamse 1988), which has been documented clinically and experimentally (Tamse 1988, Lertchirakarn *et al.* 1999, 2003). The experimental technique used to create VRF in this study involved the generation of force within the canal space by means of a spreader inserted into the root filling (Holcomb 1987, Monaghan *et al.* 1993, Lertchirakarn *et al.* 1999). This method creates force distribution from inside the root, and fracture occurs as a result of forces transmitted via the root filling material to the canal wall (Lertchirakarn *et al.* 1999). However, it simulates only one type of VRF, namely fracture of endodontic origin. The pattern of VRF in this study was similar to previous studies (Holcomb 1987, Apicella *et al.* 1999, Lertchirakarn *et al.* 1999, 2002). The majority (78%) of fractures were in a labiolingual direction, in agreement with similar previous studies and clinical VRF.

In the current study, roots filled using gutta-percha as the core material fractured at significantly higher loads than roots filled with RealSeal® core material, regardless of which sealer cement was used. This finding implies that the sealer cement made little contribution to fracture resistance, and the core material was much more important. As both materials are much weaker than dentine (Williams *et al.* 2006), the result cannot be explained by a 'strengthening' or 'reinforcing' effect of the root filling. A better explanation may be that RealSeal® transmits forces to the canal wall more efficiently than gutta-percha. For this reason, the compressive properties of the two materials were compared (Table 2, Fig. 1). The stress and the per cent strain at the proportional limit were lower for RealSeal® than for gutta-percha (Table 2), and above the proportional limit, RealSeal® flowed more readily than gutta-percha (Fig. 1). This difference means that RealSeal® can flow more easily and will distribute stress more efficiently than gutta-percha. This explanation corresponds to the finding of Nielsen & Baumgartner (2006) that Resilon™ allowed deeper spreader penetration into the root filling than gutta-percha with the same controlled pressure. Williams *et al.* (2006) also reported lower cohesive strength and stiffness of Resilon™ than gutta-percha under tensile loading, but did not consider the differences to be clinically relevant.

The other reason may be due to the small amount of the sealers used within the root canals, which may be insufficient to reinforce the filled roots. Previous studies have demonstrated that sealer cements as used in root fillings do not influence the fracture properties of dentine (Grande *et al.* 2007, Jainaen *et al.* 2009).

This experimental study was limited to only VRF, a catastrophic fracture that does not occur commonly under normal function. The load to failure may not directly relate to fracture resistance of bonded root filling materials and root structure. Cyclic loading by applying force in different directions may simulate the chewing force in the clinical situation and may be used to investigate other types of tooth fracture under function (Sagsen *et al.* 2007). This may give more information about fracture under function of root filled teeth.

Conclusions

The fracture resistance of roots filled using a synthetic polymeric material was lower than for roots filled using gutta-percha. This can be explained by more efficient transmission of forces within the canal space, rather than an inherent 'reinforcing' ability of root filling materials.

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