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Resistance to fracture of roots filled with three different techniques

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Abstract

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Aim To compare the fracture resistance of roots filled with different materials.

Methodology Thirty-four freshly extracted human maxillary central incisor teeth with similar dimension were selected. Crowns were sectioned at the cemento-enamel junction, and the length of the roots were adjusted to 13 mm. Following the preparation of the root canals and final irrigation with EDTA and saline, the 10 root canals in group 1 were filled with Resilon cones and Epiphany sealer, the 10 root canals in group 2 were filled with gutta-percha and AH 26 and the 10 root canals in group 3 were filled with gutta-percha and MCS Canal Sealer. All materials were used with a cold lateral condensation technique. Four root canals remained unfilled and were used as a control group. Tests for fracture strength were performed using a universal testing machine and a round tip that had a diameter of 4 mm. The force was applied vertically with a constant speed of 1 mm min^{-1}. For each root, the force at the time of fracture was recorded in Newtons. Results were evaluated statistically with ANOVA and Tukey Honestly Significant Difference (HSD) tests.

Results The mean force of fracture values was 1043 N, 967 N, 859 N and 517.5 N for groups 3, 1 and 2 and the control group, respectively. There was a significant difference ($P < 0.01$) between the experimental groups and the control group. No significant differences were found between the three experimental groups.

Conclusions All the materials used in the present study reinforced the prepared root canals.

Keywords: endodontic treatment, fracture resistance, sealers.

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Introduction

Root filled teeth are more susceptible to fracture than teeth with intact pulps (Oliveira *et al.* 1987, Assif & Gorfil 1994). The reasons cited include the dehydration of dentine after the endodontic procedures (Helfer *et al.* 1972, Jameson *et al.* 1993) and the brittleness of root filled teeth because of loss of tooth structure during the endodontic and restorative procedures (Reeh *et al.* 1989, Gutmann 1992). The final restoration following the root canal treatment is of major importance for the outcome and inappropriate restorations may even lead to the extraction of the tooth (Steele & Johnson 1999). It has been suggested that bonded restorative materials should be used to reinforce the weakened tooth structure (Jagadish & Yogesh 1990, Fissore *et al.* 1991).

Vertical root fractures are severe complications that are mostly seen in root filled teeth and often lead to extraction (Fuss *et al.* 2001). Fractures can result from excessive lateral condensation forces during the root filling (Lertchirakarn *et al.* 1999) and restorative procedures following the root canal treatment (Sornkul & Stannard 1992). There are studies that report the relation between root canal treatment and vertical root fractures and it has been shown that the incidence of

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vertical root fractures in root filled teeth is higher than those without root filling (Chan *et al.* 1999). It has also been reported, however, that vertical root fractures result largely from operative procedures performed in the root canal after the root canal treatment (Cohen *et al.* 2003).

Endodontic sealers can be grouped according to their basic components such as zinc oxide-euogenol, calcium hydroxide, resins, glass–ionomers, iodoform or silicone (Gutmann & Witherspoon 2002). Ideally, sealers should seal the canal laterally and apically and have good adaptation to root canal dentine (Grossman 1982). Bonding of endodontic sealers to root dentine may enhance the fracture resistance of root filled teeth and their use has been suggested to reinforce the root filled teeth (Johnson *et al.* 2000). It was reported that Epiphany primer (Pentron, Wallingford, CT, USA) conditions the dentinal surface of root canals and Epiphany sealer (Pentron) bonds both to root dentine and Resilon cones (Pentron) forming a 'monoblock' that has good adaptation to the canal walls (Teixeira *et al.* 2004a,b).

The aim of the present study was to evaluate the fracture resistance of root canals filled with either gutta-percha and a resin-based sealer, gutta-percha and a zinc oxide eugenol–iodoform-based sealer or a recently developed synthetic polymer-based core material and a dual curable resin composite sealer.

Materials and methods

Thirty-four recently extracted human maxillary central incisor teeth that were approximately of the same dimension were selected and stored in saline solution until required. The crowns of the teeth were sectioned at the cemento-enamel junction and all the roots were adjusted to 13 mm. Patency of the apical foramen was determined with a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). The working length was established 1 mm short of the apical foramen. Root canals were instrumented to a size 40 file and flared using the numbers 2, 3 and 4 Gates-Glidden drills (Dentsply Maillefer). Throughout the instrumentation, irrigation with 1 mL of 2.5% NaOCl was provided and a final rinse of 1 mL of 17% EDTA was used in order to remove the smear layer. Finally, root canals were flushed with saline solution and dried with paper points.

Group 1

Ten root canals were filled with Resilon cones and Epiphany sealer (Pentron). Epiphany primer (Pentron) 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.

Group 2

Ten root canals were filled with gutta-percha (SPI Dental Mfg. Inc., Inchon, Korea) and AH 26 (Dentsply De Trey, Konstanz, Switzerland) using a cold lateral condensation technique. AH 26 was mixed according to the manufacturer instructions and placed into the root canal with a lentulo spiral filler.

Group 3

Ten root canals were filled with gutta-percha and MCS Canal Sealer (Lone Star Technologies, Westport, CT, USA) using a cold lateral condensation technique. MCS Canal Sealer was mixed according to the manufacturer instructions and placed into the root canal with a lentulo spiral filler.

A number 40 master gutta-percha or Resilon cone that fitted to the working length was selected and the adaptation of the master cones and the quality of the root canal fillings in groups 1, 2 and 3 were controlled with periapical radiographs. After the master cone was inserted, room for accessory cones was created consecutively using the numbers 35, 30, 25, 20 and 15 finger spreaders (Dentsply Maillefer). In each root canal, approximately five accessory cones were inserted. Composition of the materials used in the experimental groups are shown in Table 1.

Group 4

Four root canals were left unfilled and used as control.

After filling, the roots were stored at 37 °C in 100% humidity for 7 days in order to allow the sealers to set.

Cylindrical moulds (20 mm diameter and 20 mm length) were prepared using the elastomeric impression material (Provil P-Soft; Heraeus-Kulzer, Dormagen, Germany). Self-cure acrylic resin (Meliodent; Bayer Dental, Leverkusen, Germany) was placed in the mould and the apical 6 mm of roots were embedded with the remaining 7 mm exposed. A universal testing machine (Hounsfield Test Equipment H50 KM; Salfords Redhill, UK) was used for the strength test. The acrylic blocks including the roots were placed on the lower plate of

Table 1 Composition of the materials

Epiphany Primer	Acidic monomer solution in water, HEMA
Epiphany sealer	Mixture of UDMA, PEGDMA, EBPADMA and BISGMA resins, silane-treated bariumborosilicate glasses, barium sulphate, silica, calcium hydroxide, bismuth oxychloride with amines, peroxide and photo initiator
Resilon cone	A compound of polyester, difunctional methacrylate resin, bioactive glass, radio-opaque fillers and colouring agent
AH 26	Epoxy resin, bismuthoxide, methenamine, silver and titanium dioxoide
MCS canal sealer	Iodoform and zinc oxide eugenol

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.

Statistical method

Descriptive statistics including the mean, SDs and minimum and maximum values were calculated for each of the four groups tested. Comparisons of means were tested using ANOVA and Tukey HSD tests. All statistical analysis were performed using the SPSS software package (Version 10.0; SPSS Inc., Chicago, IL, USA).

Results

The mean forces at fracture was 967 N, 859 N and 1043 N for Resilon and Epiphany, gutta-percha and AH 26 and gutta-percha and MCS Canal Sealer, respectively. For the control group, the mean force was 517.5 N. There was a significant difference between group 1 and the control group ($P < 0.001$), group 2 and the control group ($P < 0.01$) and group 3 and the control group ($P < 0.001$). No statistically significant differences were found amongst the three experimental groups. Descriptive statistics including the mean, SDs and minimum and maximum values for each of the four groups is presented in Table 2.

Table 2 The mean force of fracture, SDs and minimum and maximum values for each group (in Newtons)

Groups	Sample size	Mean force of fracture values	SDs	Min	Max
Resilon + Epiphany sealer	10	967.0	235.3	700.0	1450.0
AH 26 + gutta-percha	10	859.0	135.6	700.0	1160.0
MCS + gutta-percha	10	1043.0	64.9	900.0	1120.0
Control	4	517.5	49.9	450.0	560.0

Discussion

There is a perception that root canal treatment weakens tooth structure and predisposes teeth to fracture. Excessive instrumentation is shown to enhance this weakening effect (Sornkul & Stannard 1992, Cobankara *et al.* 2002) and it has been reported that the incidence of vertical root fractures is greater in root filled teeth (Lertchirakarn *et al.* 2002). Root filled teeth are more brittle than teeth with pulps and there is a general trend to restore them with a reinforcing material (Ausiello *et al.* 1997, Pilo *et al.* 1998).

Previous studies have demonstrated the reinforcement of root filled teeth with bonded restorative materials (Hernandez *et al.* 1994, Ausiello *et al.* 1997). Similarly, root filling materials that bond to dentine in the canal could enhance the fracture resistance of roots. Johnson *et al.* (2000) recommended the use of adhesive sealers in the root canal system to reinforce the root filled teeth. Kataoka *et al.* (2000) and Gogos *et al.* (2003) reported that using bonding agents within the root canal system enhanced the shear bond strength of the root canal sealers to root dentine.

Previous studies have demonstrated that the difficulty of obtaining uniform fracture strengths for human teeth because of natural variations in tooth morphology (Eakle 1986, Marshall 1993). When extracted teeth are used, factors such as mesio-distal width, bucco-lingual width and length should be standardized. In the present study, all the roots were similar in size and the lengths of the roots were standardized. After the instrumentation of the root canals, final irrigation was completed using EDTA in order to remove the smear layer (Weiger *et al.* 1995). The removal of smear layer has been shown to increase the sealing effect and adaptation of root canal sealers to dentine (Pallares *et al.* 1995, Economides *et al.* 1999, Sevimay & Dalat 2003).

In several studies, tests for fracture strength were performed using the cyclic loading (Heydecke *et al.* 2001, Fokkinga *et al.* 2005) applying the force in different directions in order to simulate the clinical conditions. However, in many studies, it has been reported that applying the force vertically to the long axis of the tooth transmits the force uniformly (Chen *et al.* 2000, Lindemuth *et al.* 2000, Dias de Souza *et al.* 2002). In the present study, a single load to fracture was applied vertically as in many other studies that evaluated the effect of root canal sealer on the fracture resistance of root filled teeth (Apicella *et al.* 1999, Cobankara *et al.* 2002, Lertchirakarn *et al.* 2002, Teixeira *et al.* 2004a,b).

In the current study, the ability of different filling techniques to reinforce the teeth was evaluated. AH 26 is a resin-based sealer and an MCS is a zinc oxide eugenol and iodoform-based sealer; Epiphany is composed of a synthetic polymer-based core material (Resilon), a dual curable resin composite sealer (Epiphany sealer) and a self-etch primer (Epiphany primer). Epiphany primer used in the present study contained HEMA that is a hydrophylic component that can flow on the dentine surface moistened by the dentine itself and irrigating solutions; it provides both mechanical and chemical adhesion (Nakabayashi *et al.* 1992).

A number of studies have been performed on the sealing effect of Resilon and Epiphany sealer (Shipper *et al.* 2004, Teixeira *et al.* 2004a,b). Teixeira *et al.* (2004a,b) reported that, after conditioning with Epiphany primer, the 'monoblock' formed by bonding of Epiphany sealer both to the Resilon cones and the root canal walls reduced the microleakage compared with the gutta-percha fillings. It has also been reported that there was less microbial leakage compared with gutta-percha and AH 26 when root canals were filled using the Resilon and Epiphany sealer (Shipper *et al.* 2004). However, studies evaluating the strengthening effect of Resilon and Epiphany sealer compared with AH 26 and other root canal sealers are rare (Teixeira *et al.* 2004a,b).

In the study of Teixeira *et al.* (2004a,b), it was reported that the groups filled with Resilon cones and Epiphany sealer were more resistant to fracture than the groups filled with AH 26 and gutta-percha. The authors attributed the reinforcing effect of Resilon groups to the 'monoblock' that forms within the root canal; they also found no difference between the experimental groups and the unfilled control group.

In the current study, all the experimental groups were significantly more resistant than the control group. In other words, all the filling materials appeared to strengthen the roots. However, in contrast to the findings of Teixeira *et al.* (2004a,b), no significant difference was found between the group filled with Resilon cones and Epiphany sealer and other experimental groups. This difference between the findings of two studies may be due to the length of the specimens exposed to force during the mechanical testing. In the study of Teixeira *et al.* (2004a,b), 9 mm of roots was exposed to force and in the present study 6 mm of roots was exposed to the force. Furthermore, it has been stated (Johnson *et al.* 2000) that the small amount of the materials used within the root canals might be insufficient to reinforce the filled roots. The high SD values obtained in the present study may be due to the variations between the structures of root dentine of the tested samples related to age or dentine sclerosis.

Conclusions

All the three filling materials strengthened the prepared root canals.

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