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Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine

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Abstract

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Aim To assess the push-out bond strength of two new calcium silicate-based endodontic sealers in the root canals of extracted teeth.

Methodology Thirty extracted single-rooted central incisors of similar sizes were selected randomly and distributed to three groups ($n = 10$). All canals were instrumented using ProTaper rotary instruments to achieve tapered canal walls. Irrigation was performed using 5 mL 2.5% NaOCl between each instrument, and the smear layer was removed using 5 mL 17% EDTA. The canals were filled with three different sealers using a cold lateral compaction technique: group 1: AH Plus + gutta-percha, group 2: I Root SP + gutta-percha and group 3: MTA Fillapex + gutta-percha. Three horizontal sections were prepared at a thickness of 1 mm ±0.1 in the apical, middle and coronal parts of each root. The test specimens were subjected to the push-out test method using a Universal Test Machine (Instron, Canton, MA, USA) that carried 1-mm, 0.5-mm and 0.3-mm plungers for coronal, middle and apical specimens, respectively. The loading speed was 1 mm min^{-1}. The push-out data were analysed by two-way analysis of variance (ANOVA) and the *post hoc* Holm–Sidak test, with significance set at $P < 0.05$.

Results In the coronal specimens, there was no significant difference between the sealers. In the middle and apical segments, there was no significant difference between I Root SP and AH Plus groups. However, the I Root SP and AH Plus had significantly higher bond strength values than the MTA Fillapex ($P < 0.05$). In terms of root segments, the bond strengths in the middle specimens and the apical specimens were higher compared with the bond strengths in the coronal specimens ($P < 0.05$). There were no significant differences between the bond strengths in the middle and apical specimens.

Conclusion MTA Fillapex had the lowest push-out bond values to root dentine compared with other sealers.

Keywords: I Root SP, MTA Fillapex, push-out bond strength.

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Introduction

The bond strength of root fillings within canals has been assessed frequently (Gesi *et al.* 2005, Ungor *et al.* 2006, Jainaen *et al.* 2007, Ureyen Kaya *et al.* 2008, Alfredo *et al.* 2008). It has been suggested that the push-out test provides a better evaluation of bonding strength than the conventional shear test because using the push-out test, fracture occurs parallel to the dentine–bonding interface, which makes it a true shear test for parallel-sided samples (Drummond *et al.* 1996, Ureyen Kaya *et al.* 2008). Interfacial strength and dislocation resistance between the root filling material and the intraradicular dentine have been evaluated using thin-slice push-out tests (Gesi *et al.* 2005, Skidmore *et al.* 2006, Ungor *et al.* 2006).

A new endodontic sealer, I Root SP root canal sealer (Innovative BioCreamix Inc, Vancouver, Canada), has

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recently been introduced. According to the manufacturer's description, I Root SP is a convenient, premixed, ready-to-use, injectable white hydraulic cement paste developed for permanent root canal filling and sealing applications. I Root SP is an insoluble, radiopaque and aluminium-free material based on a calcium silicate composition, which requires the presence of humidity to set and harden (Zhang *et al.* 2010).

Another recently introduced root canal sealer is an MTA-based root canal sealer, MTA Fillapex (Angelus Solucxoes Odontologicas, Londrina, Brazil). According to the manufacturer, it contains salicylate resin, diluting resins, natural resin, nanoparticulated resin, bismuth trioxide and MTA. They also claim it has high radio-opacity, low solubility and low expansion during setting, and it promotes deposition of hard tissue (http://www.angelus.ind.br/en/endodontics/mta_fill-apex/).

The aim of this study was to compare the push-out bond strength of an epoxy-based root canal sealer AH Plus (Dentsply DeTrey GmbH, Konstanz, Germany), with two new calcium silicate-based root canal sealers, I Root SP and MTA Fillapex, to root canal dentine. The null hypothesis tested was there was no significant difference in push-out bond strength between sealers.

Material and methods

Thirty extracted single-rooted human maxillary incisor teeth of similar sizes were selected randomly. The crowns of each tooth were sectioned at the cemento-enamel junction using a water-cooled diamond disc. The roots were adjusted to 13 mm in length, and the working length established 1 mm short of the apex. The teeth were stored in saline solution until required.

All teeth were instrumented using ProTaper rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland). The master apical file was ProTaper F3. Five millilitres of 2.5% NaOCl was used for irrigation between each instrument with a final rinse of 5 mL, 17% EDTA for 1 min, followed by copious amounts of distilled water. Each canal was dried with paper points.

The roots were divided into three experimental groups:

Group 1: The root canals were filled with cold lateral compaction using gutta-percha and AH Plus. Seventy-five milligrams of AH Plus was mixed according to the manufacturers' instructions and placed into the root canals with a lentulo spiral filler.

Group 2: The root canals were filled with cold lateral compaction using gutta-percha and I Root SP. Seventy-five milligrams of I Root SP was prepared according to the manufacturers' instructions and placed into the root canals using the syringe.

Group 3: The root canals were filled with cold lateral compaction using gutta-percha and MTA Fillapex. Seventy-five milligrams of MTA Fillapex was mixed according to the manufacturers' instructions and placed into the root canals with a lentulo spiral filler.

The teeth were stored at 37 °C and 100% humidity for 7 days to allow setting of the sealers. Each specimen was then sectioned perpendicular to the longitudinal axis of the root using a low-speed diamond-coated saw (Minitom, Struer, Denmark) under water cooling. Three sections were prepared at a thickness of 1 mm ±0.1 in the apical, middle and coronal parts of each root. The coronal specimens were taken 1 mm after the coronal side of the root, the middle specimens were taken from the fifth mm of the coronal side of the root, and the apical specimens were taken from the eighth mm of the coronal side of the root. The thickness of each section was measured with a digital calliper.

The root filling in each specimen was subjected to loading using a universal testing machine (Instron, Canton, MA, USA) that carried a 1 mm diameter cylindrical plunger for the coronal specimens, a 0.50 mm diameter plunger for the middle specimens and a 0.30 mm diameter plunger for the apical specimens. The plunger only contacted the root filling during loading. The loading speed was 1 mm min^{-1} until dislodgement of the filling material occurred. The values at the time of dislodgement were recorded in Newtons for each specimen.

The force needed to dislodge the filling material (in kN) was transformed into tension (in MPa) (Costa *et al.* 2010). The upper and lower diameters of the specimens were calculated individually, and the following formula was used (Costa *et al.* 2010): Mpa = F/SL. SL was calculated using the following equation: $SL = \pi (R + r) g$; where SL = sealer adhesion area; $\pi = 3.14$; R = mean radius of the coronal canal, in mm; r = mean radius of the apical canal, in mm; g = height relative to the tapered inverted cone, in mm. Apical and coronal aspects of each slice were scanned with a digital scanner. The images were transferred to Photoshop, and the r values of the specimens were measured.

All statistical analyses were performed with SPSS, 13.0 (SPSS for Windows; SPSS Inc, Chicago, IL, USA). The normality test of Shapiro–Wilk and Levene's variance homogeneity test were applied to the data. The data were normally distributed, and there was homogeneity of variance amongst the groups. Two-way analysis of variance (ANOVA) and the *post hoc* Holm–Sidak test were used for the analysis of data; the independent variables were root canal filling material and root canal third ($P = 0.05$).

Results

There was a significant difference ($P < 0.05$) between the filling materials. AH Plus and I Root SP had significantly higher values than MTA Fillapex ($P < 0.05$).

Amongst the push-out bond strength of the coronal specimens of the groups, there were no significant differences between the groups.

Amongst the push-out bond strength of the middle specimens of the groups, AH Plus had significantly higher values compared with the MTA Fillapex group ($P < 0.05$). I Root SP group had significantly higher values than the MTA Fillapex group ($P < 0.05$). There were no significant differences between AH Plus and I Root SP.

In the apical specimens, AH Plus and I Root SP had significantly higher values than MTA Fillapex ($P < 0.05$), but there was no significant difference between AH Plus and I Root SP groups.

Comparisons in terms of root segments revealed that the bond strengths in the middle specimens and the apical specimens were higher than in the coronal specimens. There were no significant differences between the bond strengths in the middle and apical specimens.

According to the results, in terms of the materials used, MTA Fillapex had the lowest bond strength to root dentine (Table 1).

Discussion

Gutta-percha does not bond to root dentine and is used in conjunction with a root canal sealer. In many studies, it is reported that adhesive properties of endodontic sealers are important (Kataoka *et al.* 2000, Lee *et al.* 2002, Gogos *et al.* 2003). It is suggested that, if a material bonds to the root canal walls, it resists dislodgement of the filling (Shipper *et al.* 2004, Ungor *et al.* 2006). It is also believed that chemical bonding to root dentine improves the push-out bond strength of sealers to root canal walls (Onay *et al.* 2009). The present study compared the push-out bond strength of three different root canal sealers to root canal dentine.

Table 1 Mean and standard deviation of the push-out strength values (in MPa) for the displacement of the filling material from the specimens in the coronal, middle and apical thirds of each group. Groups with the same letters (a, b) were not significantly different

	Coronal	Middle	Apical (MPa)
AH Plus	1.9 (0.55)[a]	2.9 (1.1)[a]	2.9 (1)[a]
I Root SP	1.52 (0.53)[a]	2.58 (1.25)[a]	2.6 (2.347)[a]
MTA Fillapex	0.8 (0.55)[a]	1.37 (1)[b]	0.6 (0.38)[b]

I Root SP is a new calcium silicate-based sealer; its principle constituents are calcium phosphate, calcium silicates, zirconium oxide and calcium hydroxide (Zhang *et al.* 2010). Bouillaguet *et al.* (2003) stated that polymerization shrinkage stresses that developed along the root dentine–sealer interface might result in debonding of the sealer. Zhang *et al.* (2009) reported that I Root SP sealer was based on a calcium silicate composition, which does not shrink during setting and hardens in the presence of water. The manufacturers suggest that this sealer has features such as osteoconductivity, hydrophilicity, adhesiveness and chemical bonding to root canal dentinal walls. I Root SP requires no additional curing agent and no mixing and delivers a consistent, homogeneous product for filling root canals with or without gutta-percha points.

MTA Fillapex is another new salicylate resin- and calcium silicate-based sealer. The manufacturer claims that this product provides long-term sealing capacity and high radio-opacity and promotes deposition of hard tissue. It contains calcium silicate, salicylate resin, diluting resins, natural resin, nanoparticulated resin and bismuth trioxide. It is anticipated that release of calcium and hydroxyl ions from the set sealer will result in the formation of apatites when the material comes into contact with phosphate-containing fluids (Sarkar *et al.* 2005).

In the light of the results, the null hypothesis that there was no difference between the groups was rejected. The push-out bond strengths of AH Plus and I Root SP were significantly superior to that of MTA Fillapex, but no significant difference between AH Plus and I Root SP was found. Ersahan & Aydin (2010) also found that there was no significant difference between AH Plus and I Root SP groups in terms of push-out bond strength. Several studies reported significantly higher bond strengths with epoxy resin-based sealers (Lee *et al.* 2002, Saleh *et al.* 2002, Gogos *et al.* 2004). However, others have found that the push-out bond strength of AH Plus was superior to those of other root canal pastes (Jainaen *et al.* 2008, Ureyen Kaya *et al.* 2008, Alfredo *et al.* 2008). In the present study, MTA Fillapex had the lowest bond strength to root dentine. MTA Fillapex also includes MTA as one of its ingredients. Sarkar *et al.* (2005) suggested that release of calcium and hydroxyl ions from the set sealer will result in the formation of apatites as the material comes into contact with phosphate-containing fluids. Reyes-Carmona *et al.* (2009) reported that the apatite formed by MTA and phosphate-buffered saline was deposited within collagen fibrils, promoting controlled mineral nucleation on dentine, seen as the formation of an interfacial layer with tag-like structures. The reason for the low bond strength of MTA Fillapex in the present study could be the low adhesion capacity of these tag-like structures.

Conclusions

The push-out bond strengths in the middle and apical specimens were significantly higher than those of the coronal specimens. There were no significant differences between the push-out bond strengths in the middle and apical specimens. The higher bond strengths in the middle and apical specimens could be related to deeper sealer penetrations because of higher lateral condensation forces or as a result of the dentine structure in these parts of the roots. MTA Fillapex root canal sealer had low adhesion strength to root dentine.

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