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Bond strengths of three types of fibre-reinforced post systems in various regions of root canals

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Abstract

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Aim To evaluate the bond strengths of three adhesive/resin cement/fibre post systems to coronal, middle and apical thirds of post space dentine.

Methodology Three types of glass-fibre post systems were selected for the study. Saremco Post Non-stop Fibre (Saremco), FRC Postec Plus (Ivoclar Vivadent) and Anatomical Post (Dentalica) were luted in prepared root canals using adhesive system and resin cement provided by the respective manufacturer. The luting agent was placed into the root canal using a specific syringe with needle. A push-out test was performed on sections from the apical, middle and coronal parts of each specimen to measure bond strength. All fractured specimens were observed using a stereomicroscope to identify the modes of failure.

Results Bond strength values were significantly affected both by the post–adhesive–cement system used and by root region ($P < 0.05$). Additionally, there was no significant interaction between the post system and region of canal factors ($P > 0.05$). The highest bond strength values were found in the coronal third for all experimental groups. The middle and apical thirds exhibited similar bond strengths with no statistically significant differences amongst them. Saremco and Precision post systems had the highest retentive strengths, whilst the Ivoclar post system had the lowest values. Microscopic analysis of the specimens revealed a prevalence of post–cement and mixed failures.

Conclusions Type of post–adhesive–cement system and root position had a significant effect on fibre post retention. The coronal region of the canals was characterized by significantly higher bond strengths.

Keywords : fibre post, luting agent, push-out bond testing, root region, root thirds.

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Introduction

Fibre-reinforced composite (FRC) posts are commonly used for the restoration of root-filled teeth with reduced crown structure (D'Arcangelo *et al.* 2005). Various luting agents and adhesive systems have been proposed for luting fibre posts to root canal dentine and it has been demonstrated that the control of moisture after the application and removal of phosphoric acid as well as incomplete infiltration of the resin into the dentine significantly affect bond strengths (Tay *et al.* 1996). Additionally, the bond strength between resin luting agent and post space dentine is affected by the distribution of resin cement in the coronal, middle and apical thirds of the root during luting procedure, and by the anatomical and histological characteristics of the root canal, including the orientation of dentine tubules (Phrukkanon 1999, Ferrari *et al.* 2000, Mannocci *et al.* 2004). Evaluation of dentine morphology in root canals in terms of tubule orientation and

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density revealed a higher tubule density in the cervical compared with the middle and apical parts of root canal (Ferrari *et al.* 2000). As the number of dentine tubules decreases from the crown to the apical root, the response to acid etching and, consequently, the dentine bonding can vary amongst different regions of the same root canal. Dentine hybridization is not uniform in the apical third and lateral branches of resin tags and the characteristic truncated-cone shape of the neck of the resin tags not observed in the apical part of the interface post–adhesive system (Vichi *et al.* 2002). Various studies reported decreased bond strengths in the apical region of the root canal, in part related to the reduced accessibility of this segment of the canal, making it more difficult to etch and thoroughly apply the adhesive agent and the resin cement (Ngoh *et al.* 2001, Bouillaguet *et al.* 2003, Mallmann *et al.* 2005). Nevertheless, some studies have demonstrated higher bond strengths in the apical third than in the other parts of the root canal (Gaston *et al.* 2001, Muniz & Mathias 2005, Bitter *et al.* 2006), whereas other reports suggested that root canal region does not influence adhesion of post to canal dentine (Foxton *et al.* 2005). The aim of this study was to evaluate the bond strengths of three adhesive/resin cement/fibre post systems to coronal, middle and apical thirds of the post space dentine.

Materials and methods

Tooth preparation

Thirty freshly extracted single-rooted human teeth were selected and external debris was removed (Suprasson P-max; Satelec, Merignac, France). Selected specimens were stored in 0.5% chloramine-T aqueous solution at 4 °C. Crown surfaces of each tooth were sectioned at the buccal cemento–enamel junction using a cylindrical diamond rotary cutting instrument (Intensiv 314, Ø ISO 014, L.8.0 mm; Intensiv, Grancia, Switzerland) mounted on a high-speed handpiece (Bora L; Bien-Air, Bienne, Switzerland) with water-spray cooling.

Root canals were mechanically enlarged to size 25, 0.06 taper (MTwo; VDW GmbH, Munich, Germany). Irrigants used were 5% sodium hypochlorite (Ogna, Muggiò, Milan, Italy) and 17% EDTA (Pulpdent, Watertown, MA, USA). Enlarged canals were rinsed with distilled water, dried with paper points (Roeko, Langenau, Germany) and sealed with gutta-percha (Lexicon Gutta Percha Points; Dentsply Tulsa Dental, Tulsa, OK, USA) using the System-B heat source (Analytic Technology, Redwood City, CA, USA) and endodontic sealer (Pulp Canal Sealer EWT; Kerr, Romulus, MI, USA). Backfilling was performed with the Obtura II system (Spartan, Fenton, MO, USA).

Bonding of fibre posts

After 24 h, gutta-percha was removed with warm endodontic pluggers (Sybron Dental Specialties, Romulus, MI, USA). Teeth were randomly assigned to one of three groups (SAR, IVO or DEN; $n = 10$ each), depending on the types of post/adhesive/resin cement (Table 1). Post spaces were prepared to a depth of 10 mm measured from the sectioned surfaces using the drills from the respective post manufacturers: Post Drill Yellow 2% for SAR, *FRC* Postec reamer No. 3 for IVO and Anatomical Shaper Large for DEN group.

Post space preparations were rinsed with 5% NaOCl. A final irrigation was accomplished with distilled water and post spaces were dried with paper points. Before cementation procedures, each post was marked at a distance of 10 mm from the apical end corresponding to the length of the post space preparation and sectioned horizontally with a water-cooled diamond rotary cutting instrument (R879.014; Diaswiss, Geneva, Switzerland). In this way, the complete seating of the posts was verified.

Every canal was etched for 60 s with phosphoric acid (Table 1). The gel was introduced into the spaces with a needle and after 60 s it was rinsed from the post space walls with distilled water using an endodontic syringe (Monoject endodontic syringe; Tyco, Mansfield, MA, USA). Excess water was removed from the post space with a gentle stream of air and paper points, without allowing the dentine to become dehydrated. Bonding procedures were performed following the instructions provided by the respective manufacturers. A microbrush (Microbrush X; Microbrush Corp., Grafton, WI, USA) was used to introduce the primer and the adhesive into each canal. An equal number of drops of a dentine bonding agents and activators (SAR and DEN groups) were mixed in a mixing well for 2 s. Bonding agents (Table 1) were applied to the root canal for 30 s and then gently air dried for 5 s. The cements (Table 1) were inserted in the canals using tube with needle and the appropriate plug (KerrHawe SA, Bioggio, Switzerland) and injecting the materials into the post spaces with a specific Composite-Gun (KerrHawe SA). The injection technique used for the application of resin cements is reported as an effective technique for

Table 1 Information on the materials tested

Material	Chemical composition	Batch no.	Manufacturer
Fibre post			
Saremco Post Non-stop Fibre Yellow 2% (1.1–1.26)*	Epoxy resin matrix, glass fibres	10.2011-02	Saremco Dental AG, San Gallo, Switzerland
FRC Postec Plus # 3 (1–1.95)*	Solid body of dimethacrylates, inorganic filler, glass fibres	J18974	Ivoclar Vivadent, Schaan, Liechtenstein
Anatomical Post Large (0.7–1.56)*	Epoxy resin matrix, biglass fibres	PR0032ASS	Dentalica, Milano, Italy
Etching agent			
Saremco Microcid	35% phosphoric acid gel	01.2011-44	Saremco Dental
Total Etch	37% phosphoric acid gel	J19987	Ivoclar Vivadent
Axia Etch	37% phosphoric acid gel	41144114QEUF	Dentalica
Adhesive			
Microbond duo Base Microbond duo Catalyst	BisGMA, BisHEMA, TEGDMA, catalysts, inhibitors	11.2006-02 11.2006-04	Saremco Dental
Excite DSC	Phosphonic acid acrylate, hydroxyethyl methacrylate imethacrylates, highly dispersed silicon dioxide, ethanol, catalysts and stabilizers	J19582	Ivoclar Vivadent
One-Q-Bond C.G.T. One-Q-Bond C.G.T. Activator	TEGDMA, aliphatic polyester urethane acrylate, adhesive accelerator, hydroxyethyl, methacrylate, photoinitiators, acetone, ethylalcohol, benzoyl peroxide	4118PQB 4109ACA	Dentalica
Luting agent			
Microcem Duo Base Microcem Duo Catalyst	Barium glass, silanized, Bis-GMA, Bis-EMA, TEGDMA, higly dispersed silicium dioxide, silanized, catalysts, inhibitors, pigments	11.2006-02 01.2008-04	Saremco Dental
Variolink II Base Variolink II Catalyst high viscosity	Bis-GMA, UDMA, TEGDMA, barium glass silica fillers, YbF_3 (ytterbium trifluoride)	J16253 J19103	Ivoclar Vivadent
Nano Core Dual cement	Bis-GMA, 2-hydroxyethylmethacrylate, triethylenglycoldimethacrylate, benzol peroxide, co-initiator, photoinitiators, dendritic polymer, barium alumino borosilicate glass, fluoride releasing filler, fumed silica, nano filler, white pigment, yellow pigment shade A3, alkyl quaternary ammonium bentonite	4124QCLVA3	Dentalica

Information provided by manufacturers.
*Minimum/maximum cross-section post diameter in mm.

reducing voids and bubbles within the luting agent (Boschian Pest *et al.* 2002). All the posts were then seated to full depth in the prepared spaces using finger pressure. Excess of luting agent was immediately removed with a small brush. A constant axial load of 5 kg was applied for 60 s to stabilize the fibre posts in position. After initial set, the resin luting cement was polymerized with a curing light (with 1200 mW cm^{-2} output; LE Demetron I, Sybron/Kerr, Orange, CA, USA) for 40 s. Thirty minutes after the cementation procedures, all root specimens were stored in distilled water for 24 h. Then, specimens underwent 10 000 thermal cycles between 5 and 55 °C, with a 30-s dwell time and a 5-s transfer between temperature baths. Specimens were also subjected to 300 000 cycles of mechanical loading parallel to the long axis of the post with a masticatory simulator (Willytec, Munich, Germany) at 30 N force and 1.6 Hz. The mechanical loading pattern was equivalent to 1 year of clinical function (Stegaroiu *et al.* 1996, D'Arcangelo *et al.* 2007a). The specimens were then preserved in a saline solution at room temperature for 1 week.

Push-out testing

Specimens were then fixed to phenolic ring forms filled with an autopolymerizing acrylic resin (Technovit 4000; Heraeus Kulzer, Wehrheim, Germany).

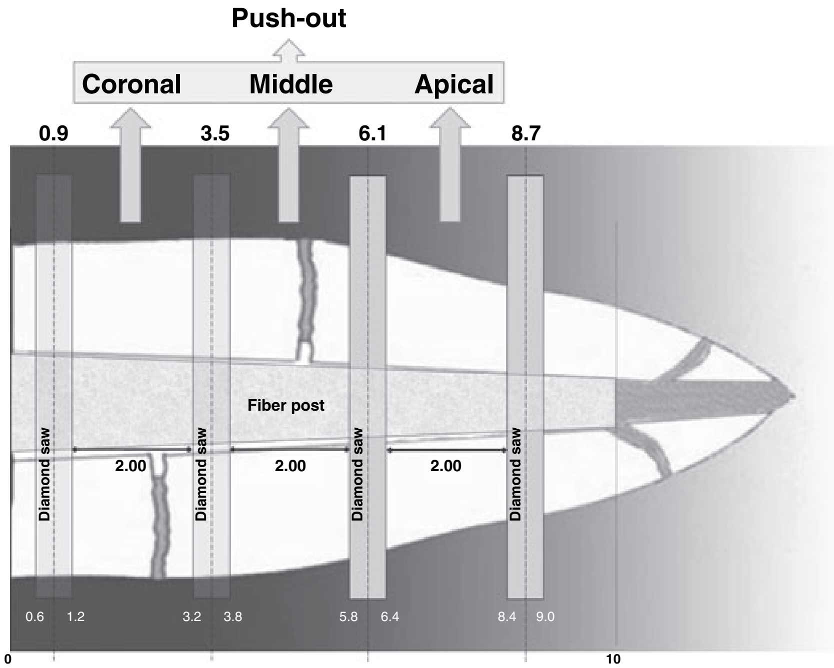

Figure 1 Root sections performed by the Micromet M machine. The numbers express, in millimetres, the distance from the arm of the machine and, thus, from the cervical end of the root. The diamond saw was 0.6 mm thick. The sections directed to the push-out test were 2 mm thick.

Specimens were attached to the arm of a low-speed saw (Micromet M; Remet S.p.A., Casalecchio di Reno, Italy) and sectioned normal to the long axis under water cooling. Three slices per each root (Fig. 1), representing cross-sections of coronal, middle and apical parts of the bonded post, were obtained. The sections were 2.0 ± 0.1 mm thick. Each slice was marked on its apical side with an indelible marker. The thickness of each specimen was measured and recorded by a digital caliper (series 500 Caliper; Mitutoyo America Corp., Aurora, IL, USA) with an accuracy of 0.01 mm. The sections were stored individually in black film canisters with sterile water.

Push-out tests were performed by applying a compressive load to the apical aspect of each slice via a cylindrical plunger mounted on a Universal Testing Machine (Lloyd LR 30K; Lloyd Instruments Ltd, Fareham, UK) managed by PC software (Nexygen-Ondio Version 4.0; Lloyd Instruments Ltd). Because of the tapered design of the post, three different sizes of punch pin: 1.1 mm diameter for the coronal, 0.9 mm for the middle and 0.7 for the apical slices, were used for the push-out testing. The punch pin was positioned to contact only the post, without stressing the surrounding root canal walls (Goracci *et al.* 2004). Care was also taken to ensure that the contact between the punch tip and the post section occurred over the most extended area, to avoid notching of the punch tip into the post surface. The load was applied to the apical aspect of the root slice and in an apical–coronal direction, so as to push the post towards the larger part of the root slice, thus avoiding any limitation to the post movement. Loading was performed at a crosshead speed of 0.5 mm min^{-1} until the post segment was dislodged from the root slice (Vano *et al.* 2006). A maximum failure load value was recorded (N) and converted into MPa, considering the bonding area (mm^2) of the post segments. Post diameters were measured on each surface of the post/dentine sections using the digital caliper and the total bonding area for each post segment was calculated using the formula: $\pi(R + r)[h^2 + (R - r)^2]^{0.5}$, where R represents the coronal post radius, r is the apical post radius and h is the thickness of the slice.

All fractured specimens were carefully removed and observed under stereomicroscope (Zeiss MC 80 DX; Zeiss, Jena, Germany) at 20× and 50× magnification from the cervical as well as from the apical direction to determine, for each root third, the mode of failure, which were classified into five types (Perdigao *et al.*

2006): (i) adhesive between post and resin cement (no cement visible around the post), (ii) mixed, with resin cement covering 0–50% of the post diameter, (iii) mixed, with resin cement covering 50–100% of post surface, (iv) adhesive between resin cement and root canal (post enveloped by resin cement) and (v) cohesive in dentine.

Data were analysed using a two-way repeated-measures analysis of variance and Tukey's multiple comparison tests with 'post–adhesive–cement system' and 'section level (root thirds)' as factors with $\alpha = 0.05$.

Results

Push-out test results are shown in Table 2. Statistical analysis displayed that both the type of post–adhesive–cement system used and the section level (root thirds) significantly affected the bond strength values ($P < 0.05$). The interaction between these two factors was not significant ($P > 0.05$). For the factor post–adhesive–cement system, the SAR and PRE groups had the highest bond strengths, with no statistically significant differences amongst them (Table 2). The IVO group had significantly lower bond strength values. For the section level factor, there were differences in bond strength amongst root thirds, with a reduction in values from the coronal to middle and apical thirds for all experimental groups (Table 2). The middle and the apical thirds exhibited similar bond strengths with no statistically significant differences ($P > 0.05$). Analysis of the specimens under optical microscope revealed that there were no cohesive failures in dentine (Table 3). A prevalence of post–cement and mixed failures was found. The fracture pattern observed was similar amongst the specimens of the tested groups.

Table 2 Mean push-out bond strengths (MPa) ± SD for experimental groups according to the root thirds

Push-out (MPa) ± SD	Post–adhesive–cement system		
	SAR[1]	IVO[2]	DEN[1]
Section level			
Coronal third[a]	13.61 ± 4.87	8.63 ± 4.12	10.89 ± 3.51
Middle third[b]	10.77 ± 3.03	4.47 ± 3.13	9.63 ± 3.59
Apical third[b]	8.91 ± 3.65	4.19 ± 3.80	7.71 ± 3.06

Different superscripted numbers indicate significant differences amongst the levels of the factor post–adhesive–cement system. Different lowercase letters represent significant differences with regard to the factor section level.

Table 3 Failure modes for experimental groups

Groups	(i) Adhesive: post–cement	(ii) Mixed: 0–50%	(iii) Mixed: 50–100%	(iv) Adhesive: cement–dentine	(v) Cohesive in dentine
SAR					
Coronal	3	4	2	1	0
Middle	3	3	3	1	0
Apical	4	2	3	1	0
IVO					
Coronal	4	2	3	1	0
Middle	3	3	4	0	0
Apical	2	3	4	1	0
DEN					
Coronal	2	5	3	0	0
Middle	4	1	4	2	0
Apical	4	2	3	1	0

Discussion

The objective of this investigation was to evaluate the bond strengths of three adhesive/resin cement/fibre post systems to coronal, middle and apical thirds of canal dentine using a push-out model. Push-out tests result in a shear stress at the interface between dentine and cement as well as between post and cement (Van Meerbeek *et al.* 2003) and is comparable with the stress under clinical conditions. The push-out design is characterized by polymerization stresses that would happen in the clinical situation (Frankenberger *et al.* 1999). It has been suggested that, because of the small size of specimens, microtensile testing permits a uniform stress distribution along the bonded interface (Cardoso *et al.* 2002). Nevertheless, as observed previously (Goracci *et al.* 2004), the push-out test is a more reliable method for determining bond strengths between fibre posts and post space dentine because of the high number of premature failures occurring during specimen preparation and large data distribution spread associated with microtensile testing.

Several laboratory studies reported controversial results regarding bond strengths of different luting agents to endodontic posts and root canal dentine (O'Keefe *et al.* 2000, Goracci *et al.* 2004, Perdigao *et al.* 2004). The present study revealed that a significantly higher resistance to post dislodgement for SAR and DEN post system groups was found, whilst the IVO group had significantly lower bond strength value. All tested groups achieved high bond strength values in all thirds. Irrespective of post system, the interfacial strength is also significantly affected by the region of the root canal with the highest values for the coronal third and lowest for the middle and apical thirds, as previously reported (Ngoh *et al.* 2001, Bouillaguet *et al.* 2003, Perdigao *et al.* 2004, Mallmann *et al.* 2005). This is to be expected because of more difficult access to this third and the possible limitations of cement flow, although some authors (Gaston *et al.* 2001, Muniz & Mathias 2005, Bitter *et al.* 2006) obtained the best results in the apical third. Gaston *et al.* (2001) evaluated the microtensile bond strength of an autopolymerized resin luting agent used in combination with a self-etching primer and found no statistically significant bond strength differences between the cervical and middle post space dentine, but the bond strength values were significantly higher in the apical region. The bond strength in different post space dentine regions seems to be influenced by tubule density and the area of a tubular dentine, as well as the type and chemical composition of the dentine bonding agents (Akgungor & Akkayan 2006). According to a previous study (Ferrari *et al.* 2000), as the number of dentine tubules decreases, moving from the cervical to the apical third of the post space dentine, the difference in the tubule density may explain why the strongest adhesion occurred in the most coronal sections. In the present study, analyses of failure mode indicated that most failures occurred at the cement–post interface or in a mixed mode. This finding suggested that the nature of the dentine surface of the canal wall or the tubule density might not be the basis for the difference in bond strengths between the coronal and middle/apical regions, a finding that lends support to those investigations aimed at improving the retention through various surface pre-treatment procedures for posts (Sahafi *et al.* 2004, Balbosh & Kern 2006, D'Arcangelo *et al.* 2007a,b). The most likely explanation for the higher resistance to post dislodgement in the coronal region of the root canal could be the decreasing effectiveness of light curing at greater distances from the light source. Moreover, the coronal portion of the canal is the most accessible part of the canal space, making it easier to etch and more thoroughly apply the adhesive agents. Rinsing with water during the etching procedure, the difficulties of moisture control in the apical third of the post space probably result in the retention of remnant water within the dentine tubules, causing an incomplete infiltration of the resin agent. A reduction of strength in middle and apical thirds may also be related to the more difficult distribution of resin cement with void formation (Bouillaguet *et al.* 2003, Mallmann *et al.* 2005) or to traces of gutta-percha and endodontic sealer that may remain in these thirds after post space preparation (Bolhuis *et al.* 2005). These findings seem to suggest that lack of direct viewing and luting agent application techniques may affect the bond strength in the apical region of the post space which will be inevitably lower. In contrast, previous studies (Gaston *et al.* 2001, Bitter *et al.* 2006) concluded that the bond strength to post space dentine is related more to the surface area of a tubular dentine than to tubule density. Recently, Kalkan *et al.* (2006), comparing bond strength between root dentine and glass-fibre post systems in three different thirds of prepared post spaces, have concluded that push-out bond strength values of the cervical root segments were significantly higher than the middle and apical segments in translucent glass-fibre post groups, whilst in opaque glass-fibre post group there was no significant difference between the cervical and middle segments. In agreement, the present study showed that the highest bond strength values were found in the coronal third for the three translucent glass-fibre-reinforced posts tested.

Conclusions

The present study revealed that bond strengths to root canal dentine did vary with type of post–adhesive–cement system used and region of root canal. Highest bond strength values were obtained in the coronal thirds and with Saremco and Dentalica post systems.

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