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Bond strength between fibre posts and composite resin cores: effect of post surface silanization

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Abstract

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Aim To evaluate the tensile bond strength between two different composite resin cores and (Clearfil™Core, MultiCore® Flow) and fibre posts (DT Light Post®), with and without silanization of the post surface.

Methodology Forty fibre posts were shortened to a length of 15 mm. Specimens were then produced by covering the upper 3 mm of the posts with standardized composite core build-ups. The bonding surfaces of twenty posts were treated with silane coupling agent (Monobond-S). Four experimental groups were formed: G1: Clearfil™Core; G2: Monobond-S + Clearfil™Core; G3: MultiCore® Flow; G4: Monobond-S + MultiCore® Flow. Each post was positioned upright in a post centric device with moulds to ensure standardized shapes of the abutments. After tensile bond strength testing, the type of failure at the interface was determined. The results obtained were compared using an unpaired sample *t*-test.

Results The mean tensile bond strengths and standard deviations were [MPa] 10.08 ± 0.92 for Clearfil™Core, 10.47 ± 1.05 for Clearfil™Core + silane; 6.65 ± 0.79 for MultiCore® Flow and 6.91 ± 0.83 for MultiCore® Flow + silane. Statistical analysis revealed that Clearfil™Core achieved significantly higher bond strengths than MultiCore® Flow ($P < 0.0001$). Post silanization had no significant effect. All tested specimens had an adhesive failure mode.

Conclusion Type of composite had a significant effect on tensile bond strength. Silanization of fibre post surfaces had no effect on core retention.

Keywords: bond strength, composite core build-up, fibre post, silane agent, surface conditioning.

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Introduction

The restoration of root-filled teeth is a topic that has been studied extensively (Schwartz & Robbins 2004). Black coloured carbon-fibre reinforced posts (FRC posts) were introduced in 1990 (Duret *et al.* 1990) and since then they have become an alternative to cast posts for the restoration of root-filled teeth (Monticelli *et al.* 2003). FRC posts are essentially composite materials composed of fibres of silica surrounded by a matrix of polymer resin, usually an epoxy resin. The FRC posts are translucent and have therefore aesthetic advantages. Currently, a wide variety of FRC posts are available with different sizes, tapers and shapes (Bateman *et al.* 2003, Teixeira *et al.* 2006).

Root-filled teeth often have little coronal dentine remaining and as such require a post to retain the core and the future restoration. FRC posts form a bonded unit between root and coronal dentine, adhesive systems, resin cements and composite build-up. Moreover, FRC posts have a modulus of elasticity similar to that of dentine, which may lead to a better distribution of the occlusal loads along the root

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(Lassila *et al.* 2004, Galhano *et al.* 2005, Valandro *et al.* 2006). A variety of composite resin materials with variable viscosities and different modes of polymerization (light-activated, self activated, or dual-activated) can be used for the core build-up (Monticelli *et al.* 2004, 2005). The retention and stability of the core and post systems are important factors for the success of the definitive restoration (Gateau *et al.* 1999). As a consequence, the bonding of the interfaces in the core build-up system should be optimized. Core build-up materials should exhibit good adaptation, and a reliable bond to the post surface (Sadek *et al.* 2007). To improve the bonding of resin cements to FRC posts, several treatments of the surface have been suggested, such as etching with hydrofluoric acid, air abrasion with aluminium oxide or silica particles and application of silane coupling agent (Sahafi *et al.* 2003, 2004, Valandro *et al.* 2006). The adhesion of FRC posts to different composite resin cores has been the subject of previous microtensile investigations, using small units of post and core material (Goracci *et al.* 2005b, Salameh *et al.* 2006). A further and more clinically oriented design of specimens with standardized composite build-ups, covering the upper part of the FRC posts, was demonstrated in a recent tensile bond strength study (Wrbas *et al.* 2006).

The objective of the present study was to evaluate the tensile bond strength between two different types of composite resin cores and FRC posts, with and without silanization of the post surface using a new sample form. The null hypothesis of the study was that neither the type of composite resin core nor the post surface silanization had any significant influence on the tensile bond strength between the composite build-ups and the FRC posts.

Materials and methods

Forty quartz fibre posts DT Light Post® (VDW®, Munich, Germany) size 3 with a length of 20.0 mm and a maximum diameter of 2.20 mm were used for the tensile bond strength testing. The DT Light Posts are FRC posts composed of unidirectional quartz fibres (60% volume) embedded in an epoxy resin matrix, and they have different tapers in the apical third (2%) and the middle third (10%). The coronal third of the post is parallel.

The posts were shortened to a length of 15 mm. On the supposition that posts in clinical practice might be inserted to a maximum length of 12 mm into the root canal, the specimens allowed 3 mm of the upper part to be covered with standardized composite core build-ups. The calculated bonding surface was 23.87 mm^2. After shortening, the post surfaces were cleaned with alcohol, thoroughly rinsed with water and dried. The 3 mm protruding section of half of the posts (20 posts) were treated with silane coupling agent (1% in weight) Monobond-S (IvoclarVivadent, Schaan, Liechtenstein) for 60 s using a disposable brush and dried. Then the composite core build-up procedure followed. Clearfil™Core (Kuraray, Okayama, Japan) and MultiCore® Flow (IvoclarVivadent) were used as core build-up materials. Four experimental groups were formed:

Group 1: DT Light Post® and Clearfil™Core ($n = 10$)

Group 2: DT Light Post®/Monobond-S and Clearfil™Core ($n = 10$)

Group 3: DT Light Post® and MultiCore® Flow ($n = 10$)

Group 4: DT Light Post®/Monobond-S and MultiCore® Flow ($n = 10$)

To make the core build-ups, a special apparatus to centralize the posts in relation to the composite build-ups was constructed. Each post was positioned upright in the post centric device. Then, the upper part of the apparatus, a removable nylon pattern with standardized moulds, was placed on the device. The mould formed core build-ups with a total core height of 9.5 mm, with two different diameters (diameter = 4.5 mm around the post, diameter = 8.7 mm upper part) (Fig. 1). The moulds in the nylon pattern ensured standardized shapes of the composite core build-ups and equal distribution of the core material around the posts. The upper part of the abutment served as a retention site for the tensile device of the universal testing machine (Instron Typ 4204; Instron, Co, Canton, MA, USA).

The composite core build-up materials were used according to the manufacturer's recommendations and applied into the mould and around the upper 3 mm of the quartz fibre posts. The two pastes of the self-activating and self-curing Clearfil™Core were mixed and the material was applied from a syringe. MultiCore® Flow is a dual-activated composite and was applied directly from a syringe in 2 mm thick increments, which were cured for 30 s with a halogen light (Optilux 401; Kerr, Demetron, Orange, CA, USA). The composite was directly irradiated from the upper side of the mould. After removing the cured post-core build-up cylinders from the mould of the nylon pattern, a further irradiation of 60 s of the MultiCore®. Flow specimens was carried out from all sides in order to ensure

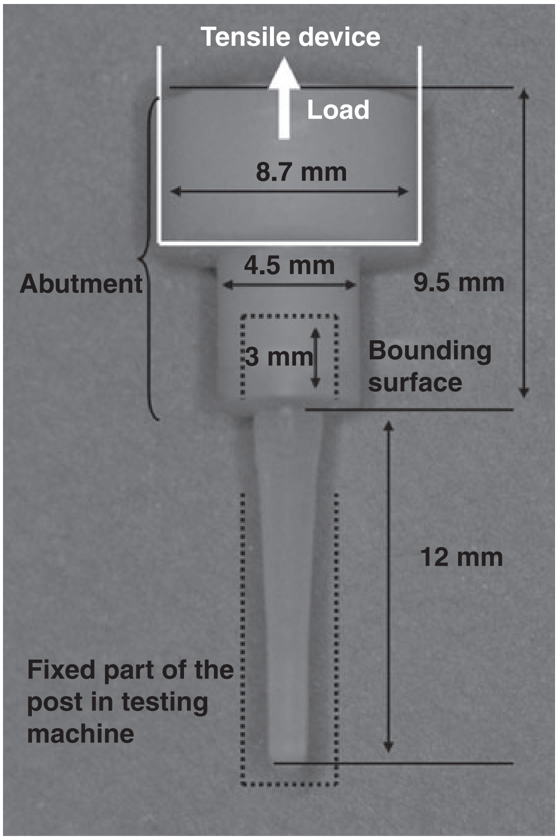

Figure 1 Schematic illustration of a specimen.

complete polymerization of the dual curing composite core build-up material. Then the specimens were mounted in the universal testing machine and the core composite abutments were fixed in the tensile device. The specimens were loaded at a crosshead speed at 1.0 mm per minute until the composite core build-ups separated from the posts. The bond strength was expressed in Megapascals (MPa) by dividing the load (Newton) at failure by the bonding surface (mm^2). After testing, the bonding surfaces were analysed under a light microscope (Axioskop 40; Carl Zeiss, Jena, Germany) at 36× magnification and by evaluation of representative specimens using scanning electron microscopy (SEM; Zeiss, Oberkochen, Germany). The type of failure at the interface was determined as adhesive between post and composite core or cohesive within the composite core.

The results obtained from the assessments were compared using an unpaired sample *t*-test (SPSS 12.0 for Windows, SPSS Inc., Chicago, IL, USA). The level for accepting statistical significance was set at $P < 0.05$.

Results

The bond strength values and standard deviations are shown in Table 1 and Fig. 2. The unpaired sample *t*-test revealed there was a significant difference between the results of Clearfil™Core and MultiCore® Flow. Clearfil™Core achieved significantly higher bond strengths in combination with DT Light Post® than MultiCore® Flow ($P < 0.0001$). Clearfil™Core and the use of Monobond-S resulted in significantly higher bond strengths than MultiCore® Flow and Monobond-S ($P < 0.0001$).

For each core build-up material the use of silane on the bonding surface of the FRC posts did not influence the mean values of tensile bond strength. The unpaired sample *t*-test revealed that the use of Monobond-S did not result in any statistical difference in tensile bond strength ($P > 0.05$).

Light microscopic and SEM analysis of the bonding surfaces after the tensile bond strength tests demonstrated that only adhesive failures between the posts and core build-up materials occurred. None of the tested specimens demonstrated a cohesive (within the

Table 1 Mean tensile bond strength values [MPa] and standard deviation (SD)

Group	*n*	Mean + SD [MPa]
Clearfil™ Core	10	10.08 ± 0,92
Clearfil™ Core + Monobond-S	10	10.47 ± 1.05
Multi Core®Flow	10	6.65 ± 0.79
Multi Core®Flow + Monobond-S	10	6.91 ± 0.83

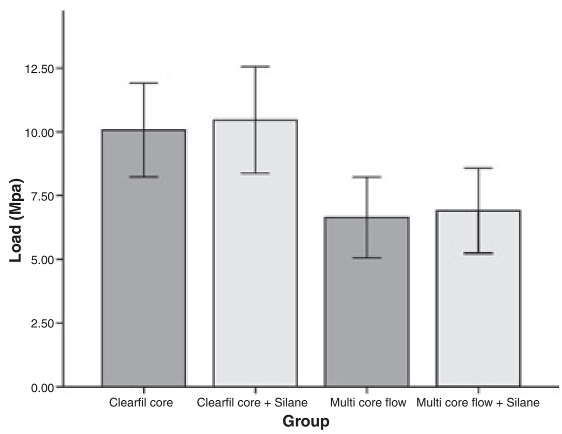

Figure 2 Mean and standard deviations of bond strength values.

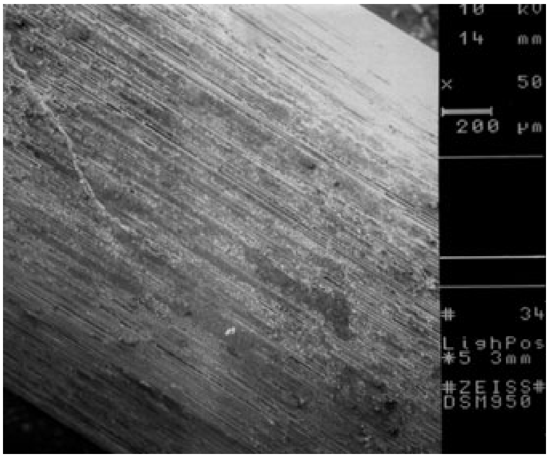

Figure 3 Representative SEM image of the post surface (Group 1: Clearfil Core), no defects are detectable on the surface (50×). Exposed glass fibers, adhesive type of fracture on the bonding surface.

post or the core portion) or a mixed type of fracture (Fig. 3).

Discussion

In the present study, the adhesion of two composite build-up materials to pre-fabricated FRC posts was assessed by a tensile bond strength test. The DT Light Post® was used for testing, because it is a current fibre post with unidirectional glass fibres (60% volume), bound in an epoxy resin matrix. Most fibre posts on the market contain epoxy resin as the matrix connecting the individual fibres (Goracci *et al.* 2005b, Perdigao *et al.* 2006).

The microtensile bond strength test is a conventional method for the evaluation of the interfacial bond strength between prefabricated FRC posts and composite resin cores. For microtensile bond strength testing units of post and core material, serially sectioned 1-mm thick slices with only a small cross-sectional area, are used as specimens (Goracci *et al.* 2005b, Salameh *et al.* 2006, Valandro *et al.* 2006, Sadek *et al.* 2007).

The frequent occurrence of premature failures of the specimens and the high variability of the values are regarded as disadvantage of the microtensile method (Goracci *et al.* 2004, Sadek *et al.* 2007). A further and established method for testing interfacial bond strength is the push-out test, which has been considered more dependable than the microtensile test for bonded posts (Goracci *et al.* 2004, Perdigao *et al.* 2006). The push-out test only reflects the shear strength of a thin slice (1 mm thickness) within the whole specimen and is highly dependent on the position of the punch pin (Bitter *et al.* 2006). Load-displacement curves of push-out tests with thin slices demonstrated that a major part of the fixation strength of FRC posts is contributed by interfacial sliding friction (Goracci *et al.* 2005a). In the present study, the samples were obtained following a new experimental set-up (Wrbas *et al.* 2006). The whole available bonding surfaces of the upper parts of the posts were covered with standardized core build-ups to simulate a clinically oriented situation and to evaluate the total bond strengths between the composite materials and the FRC posts.

Flowable and hybrid composites have been reported to have good adaptation at the post surface of FRC posts (Monticelli *et al.* 2004, 2005). According to the manufacturer's information, MultiCore® Flow has a filler content of 71% by weight and Clearfil™Core a higher filler content of 78% by weight. The mechanical properties of flowable composites are generally inferior compared with conventional composites. Flowable composites have a lower filler-resin ratio than conventional composites (Labella *et al.* 1999). As a consequence of the higher content of resin, an increased contraction during polymerization may occur. Composites with higher filler content have less polymerization shrinkage (Chung & Greener 1990, Davidson & Feilzer 1997, Labella *et al.* 1999, Alvarez-Gayosso *et al.* 2004). Stress from shrinkage strain can weaken the interfacial bond, affecting bond strength to the post surface (Sadek *et al.* 2007). In the present study, the bond strength values of the higher filled Clearfil™Core specimens were significantly higher than these of the lower filled MultiCore® Flow. The explanation for the higher bond strength values of Clearfil™Core might be the better mechanical properties and the lower shrinkage during polymerization because of the higher filler content, compared with MultiCore® Flow. The higher bond strengths and the resulting better resistance to dislocation of Clearfil™Core core build-ups indicate a stronger interfacial bond of the material to the FRC posts.

The light microscopic and SEM analysis of the bond surfaces showed that only adhesive bond failures occurred. This is in accordance with the results of a recent microtensile bond strength study, in which the bond failures of small units of resin composites and fibre posts demonstrated exclusively adhesive failures after testing (Goracci *et al.* 2005b). It was assumed that some free radicals of the matrix of fibre posts allow a chemical bond with BIS-GMA-based resins (Malferrari

& Monaco 2004). The adhesive failures of the specimens in the present study indicate that there was no chemical bond between the composite core materials and the fibre posts. Mannocci *et al.* (2005) proved that monomers of bonding resins were able to penetrate into the interpenetrating polymer network (IPN) polymer structure of the ever Stick Post (Stick Tech Ltd, Turku, Finland), whereas no penetration was observed into the cross-linked matrix of another post. Not all of the monomers used in dental bonding resins are capable of dissolving PMMA-based IPN structures. The matrix of the DT Light Posts used in this study does not consist of IPN structures. Following the assumption that no chemical bonding existed, the resistance to tensile forces of fibre post bonded composites in the present study may be considered to consist only of a combination of micromechanical interlocking and sliding friction.

A further finding of the present study was that with the tested combinations of composite core build-up materials and the FRC posts, the mean tensile bond strengths were not increased significantly after preliminarily treatment of the bonding surfaces with the silane coupling agent Monobond-S. This result can be compared with the findings of a recent study that evaluated the use of a silane agent significantly improved the bond strength between FRC posts and composite core build-up materials (Goracci *et al.* 2005b). In that study, the bond strength at the interface between post and core was measured using the microtensile technique and it can be assumed that the combination of the composite core build-up materials with the different FRC posts or the study design revealed significantly enhanced adhesion by post surface treatment with silane coupling agent.

The chemical reaction and mechanism of action of silanes in the adhesion process is not completely clear (Matinlinna *et al.* 2004). To explain the bonding mechanism of silane coupling in adhesive dentistry, different theories have been considered. With regard to FRC posts, silane agent can only bridge resins and OH-covered inorganic superficially exposed glass fibres of the post. The highly cross-linked polymers of the matrix in FRC posts do not have any functional groups for chemical reaction with silane molecules (Goracci *et al.* 2005b). According to this mechanism, it might be possible that the silane coupling effect of enhancing the post-core bond strength is increased when FRC posts with more superficial parts of fibres are used.

Within the limits of this investigation the null hypothesis, that neither the type of composite resin core nor the post surface silanization had any significant influence on the tensile bond strength between the composite build-ups and the FRC posts requires further comment. The higher filled core material Clearfil™Core had significantly higher bond strengths to the fibre posts compared with the lower filled MultiCore® Flow. The silanization of the bonding surface had no statistically significant effect on the tensile bond strength.

Conclusions

Composite core build-up materials have a significant effect on the tensile bond strength between the core build-up and the FRC posts. The results of the present study indicate no benefit from the preliminarily application of silane coupling agents.

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