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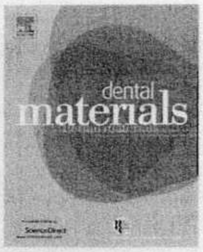

Bond strength performance of different resin composites used as core materials around fiber posts

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ABSTRACT

Objectives. To evaluate the microtensile bond strengths of different resin composites used as core materials around fiber posts.

Methods. Forty DT Light-Posts (RTD) were randomly divided into eight groups, according to the resin composite used. They included two core materials specifically developed for core build-up—Group 1: Core-Flo (Bisco Inc.) and Group 2: UniFil Core (GC Corp.); three hybrid composites—Group 3: Tetric Ceram (Ivoclar-Vivadent), Group 4: Gradia Direct (GC Corp.), Group 5: Bisfil 2B (Bisco, Inc.); and three flowable composites—Group 6: Æliteflo (Bisco, Inc.), Group 7: Filtek Flow (3M ESPE) and Group 8: UniFil Flow (GC Corp). A cylindrical plastic matrix was placed around the silanized post and filled with the respective resin composite. Each bonded post provided five to eight sticks for microtensile testing. Each stick was loaded to failure under tension at a cross-head speed of 0.5 mm/min. One-way ANOVA and Tukey's test were used for statistical analysis. Scanning electron microscopy (SEM) was used to evaluate the interface of the fractured sticks.

Results. Resin composites exhibited a significant influence on microtensile bond strength ($p < 0.05$). Core-Flo showed the highest bond strength (11.00 ± 0.69 MPa) although it was not statistically significantly different from all groups, except from the flowable composites. Under SEM, all the composites adapted well to the fiber post, with a variable extent of voids observed along the fractured composite interfaces.

Significance. Although good adaptation to the post surface was achieved, bond strength to fiber post remains relatively weak. Core build-up and hybrid composites are better alternatives to flowable composites as core build-up materials.

1. Introduction

Endodontically treated teeth are often severely damaged by decay, excessive wear or previous restorations, resulting in a lack of coronal tooth structure. Cast metal posts and cores have traditionally been used in these clinical situations to provide the necessary retention for the subsequent prosthetic rehabilitation [1]. The clinical use of fiber posts has increased tremendously since they were introduced in the 1990s [2]. They are currently perceived as promising alternatives to cast

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metal posts in the restoration of endodontically treated teeth [3].

With a significant loss of coronal tooth structure, abutment build-up around a fiber post is required. Different resin composite materials are available in the market to build up root-filled teeth [4,5]. Although composites that are specifically designed for core build-ups are available [6,7], hybrid and flowable composites have also been employed for the same purpose in recent in vivo and in vitro studies [3,4], even though it would not be the most adequate choice. These non-specific composite materials achieved good results in terms of microscopic structural integrity and surface adaptation around fiber posts [4,5]. When they were used to perform post and core restorations, satisfactory results were also obtained over a follow-up period of 2–3 years [3]. However, flowable resin composites are intrinsically weak, due to their low modulus of elasticity, and are probably unable to offer sufficient resistance against occlusal load. For this reason, their indication should be complemented by bond strength measurements. It is not known whether the bond between fiber posts and flowable or hybrid resin composites are as good as the different core build-up composites that are currently available in the market.

Therefore, the aim of this study was to evaluate the microtensile bond strengths among different resin composites that may be used as core build-up materials. The null hypothesis tested was that there are no differences in the microtensile bond strengths among these composites when they are employed as core materials for coupling to glass fiber posts.

2. Materials and methods

Forty size #3 DT Light-Post RO (RTD, St. Egève, France) were used for testing, each having a maximum diameter of 2.14 mm. All the posts were treated with a silane coupling agent (Monobond-S, Ivoclar-Vivadent, Schaan, Liechtenstein) for 60 s. After silane application, the posts were gently air dried and randomly divided into eight groups of five samples each.

The core portion was built up directly over the post with different resin composites. They included two core materials that are specifically developed for core build-up—Group 1: Core-Flo self-cure (Bisco, Inc., Schaumburg, IL, USA) and Group 2: UniFil Core (GC Corp., Tokyo, Japan); three hybrid composites—Group 3: Tetric Ceram (Ivoclar-Vivadent, Schaan, Liechtenstein), Group 4: Gradia Direct (GC Corp.), Group 5: Bisfil 2B self-cure (Bisco, Inc.); and three flowable materials—Group 6: Æliteflo (Bisco, Inc.), Group 7: Filtek Flow (3M ESPE, Seefeld, Germany) and Group 8: UniFil Flow (GC Corp.).

The core build-up procedure was performed following a technique previously described by Goracci et al. [8]. Light-cured composites were applied to the post in 1–2 mm thick increments. Each increment was carefully adapted to the post surface and light-cured separately according to the manufacturers' instructions, using a halogen light curing unit with an output of 600 mW/cm^2 (VIP, Bisco, Inc.). For the self-cured composites, the plastic matrix was bulk-filled in a single increment.

Sticks of 1-mm thickness were then serially sectioned (Buehler, Lake Bluff, IL, USA) from each cylinder to create specimens for microtensile bond testing. Each stick was secured with cyanoacrylate adhesive (Zapit, Dental Ventures of America, CA, USA) to the two free-sliding components of a jig that was mounted on a universal testing machine (Controls, Milano, Italy). The stick was loaded in tension at a cross-head speed of 0.5 mm/min, until failure occurred at either side of the post–composite interface. Bond strength was expressed in MegaPascals (MPa), by dividing the load at failure by the bonding surface area. As the bonded interface was curved, its area was calculated using a mathematical formula previously applied by Bouillaguet et al. [9] and Goracci et al. [8] for similar purposes.

After microtensile bond strength testing, every fractured stick was examined with a stereomicroscope (Nikon type 102, Tokyo, Japan) at 30× magnification, to determine failure mode, which was recorded as adhesive, mixed or cohesive within the resin composite. Representative fractured sticks from each group were evaluated by scanning electron microscopy (SEM). Each stick was mounted on an aluminum stub, sputter-coated with gold (Polaron Range SC7620, Quorum Technologies, Newhaven, England), and observed under a SEM (JSM 6060 LV, JEOL, Tokyo, Japan). Micrographs were taken at different magnifications in order to provide an overview of each fractured area, to evaluate the type of failure and to note adaptability of the resins to the surface of the fiber posts.

2.1. *Statistical analysis*

As a preliminary linear regression analysis showed that the post–composite core unit had a significant influence on the measured bond strength, this variable was taken into consideration and the statistics were calculated from the five units of each experimental group ($n = 5$). Consequently, the five to eight sticks from one unit were gathered into one mean.

Data distribution was first analyzed for the normal distribution using the Kolmogorov–Smirnov test, and equal variance using the Levene median test. One-way ANOVA was subsequently applied to examine the effects of resin composites used as core materials. Pairwise multiple comparisons were subsequently performed with Tukey's test. The level of significance was set at $\alpha = 0.05$.

3. Results

Microtensile bond strength mean values and standard deviations for the eight experimental groups are reported in Table 1. Statistical analysis revealed that resin composites used as core materials had a significant influence on microtensile bond strength ($p < 0.05$) (Table 1). Core-Flo showed the highest mean bond strength (11.00 ± 0.69 MPa), although it was not statistically significantly different from all groups, except from the flowable composites (Groups 6–8). The results obtained with flowable composites were lower than the other groups. Among them, UniFil Flow showed the lowest mean value (5.18 ± 1.38 MPa). Filtek Flow and Æliteflo were not statistically different from Groups 2–5.

Table 1 – Microtensile bond strength and standard deviation, in MPa, of the coupling of different types of resin composites to fiber posts

Experimental group ($N = 5$)	Microtensile bond strength (MPa)[a]
Core build-up composites	
Core-Flo	11.0 (0.7)a
UniFil Core	9.1 (1.5)a,b
Tetric Ceram	8.7 (1.8)a,b
Hybrid composites	
Gradia Direct	8.7 (2.3)a,b
Bisfil 2B	9.5 (2.0)a,b
Æliteflo	6.6 (0.9)b,c
Flowable composites	
Filtek Flow	6.5 (2.1)b,c
UniFil Flow	4.9 (1.0)c

[a] Values are mean (S.D.). Groups that have the same letters (a–c) are not statistically significant ($p > 0.05$).

SEM and optical observations showed that adhesive failure was the exclusive mode of failure in all the specimens (Figs. 1–3). The resin composites replicated the surface of the fiber posts well, and the flowable composites (Fig. 1) exhibited fewer microbubbles/voids than the hybrid composites (Fig. 2). Post surfaces after fracture always showed no resin composite remnants, confirming the adhesive nature of the failed bonds (Fig. 3).

4. Discussion

Prosthetic restorations of endodontically treated teeth have undergone a paradigm shift, from the traditional use of rigid materials (amalgam, gold alloys, etc.) to the gradual acceptance of materials with mechanical properties closer to dentin (resin composites and fiber posts), in order to reduce stress transmission to the remaining tooth structure [2,10,11]. A core material with a low modulus of elasticity is claimed to partially absorb functional loadings, reducing stress concentration at the interface with dentin [12].

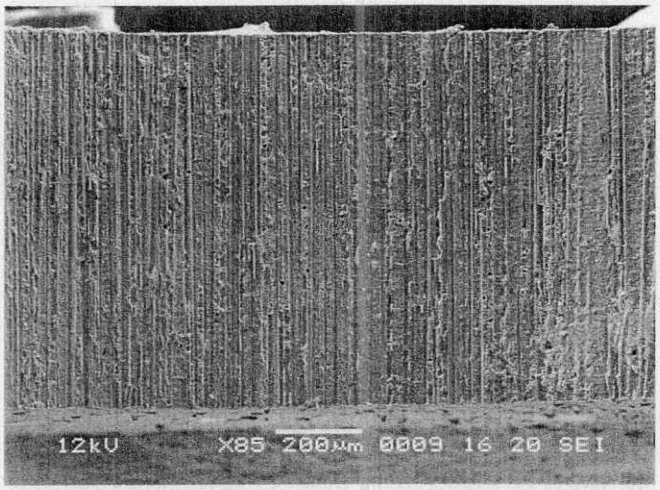

Fig. 1 – SEM image of the flowable composite surface after being tested. The surface shows an adhesive failure and good adaptation of the resin composite to the post surface which is mainly replicated. A few small voids/bubbles are present along the fractured interface (×85).

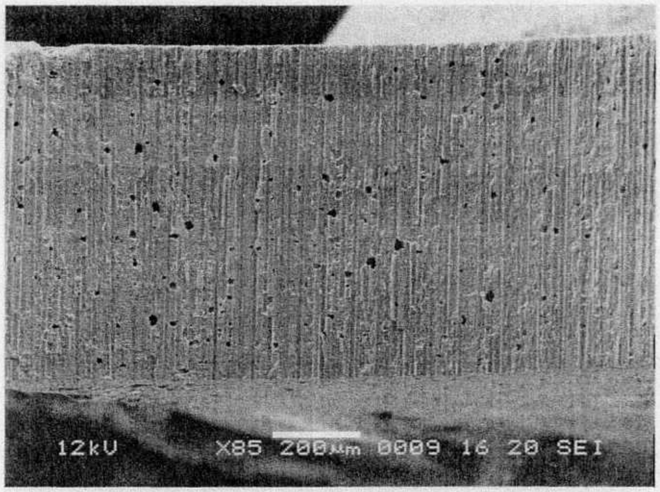

Fig. 2 – SEM image of the hybrid composite surface after being tested. The surface shows an adhesive failure and good adaptation of the resin composite to post surface. Voids/bubbles wider than those observed in flowable composites are present (×85).

With the introduction of glass fiber posts, retention of the core portion around the post could be the contribution of both micromechanical and chemical interaction between post and resin composites, with the latter effected via silanization of the post surface. The role of silane coupling agents on increasing bond strength with resin materials is evident in the literature [8,13,14]. However, Purton and Payne reported that one of the reasons of failure of carbon fiber posts is the lack of adhesion to the core material [15]. They suggested that this occurs since the epoxy resin used for embedding the carbon fibers is highly cross-linked, and does not possess functional groups that can react with the methacrylate groups of the resins usually employed in dental composites. Moreover, the carbon fibers do not permit chemical bonding with the dimethacrylates that are generally employed in dentistry. Thus, adhesion of the carbon fiber posts to resin composites could be attributed solely to mechanical retention and friction [16]. The viscosity/wettability of the composite materials also influences the intimate adaptation, and hence the mechanical and frictional retention with the post surface.

Core build-up materials should exhibit good adaptation, and a reliable bond to the post surface. Ideally, minimal voids should be present along the interface between the post and the composite, as these voids may act as stress raisers and initiate mechanical failure [17]. Flowable composites, because of their low viscosity, exhibited excellent adaptability at the post surface [4,5], making them potential candidates as core build-up materials. In the present study, three flowable composites were compared with hybrid composites for direct restorations and composites that are specifically designed to be used as core build-up materials. The flowable composites have lower filler/resin ratios and, in some instances, modified resin formulations. They were purported to offer high

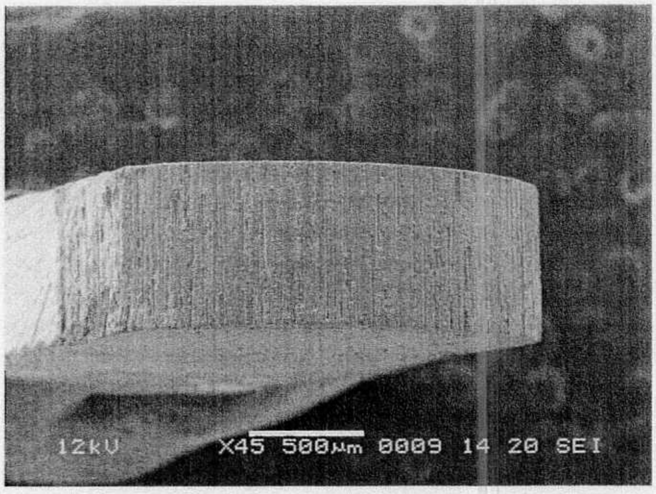

Fig. 3 – SEM image of a post surface after fracture, illustrating the adhesive nature of the failure mode. No resin composite remnants are evident (×60).

flow, better adaptation, easier insertion and great elasticity than previously available products [18] and they have recently been proposed as core materials [4,19]. In terms of adaptability, they compare favorably with the other types of composites examined in this study and resulted in fewer voids along the interface between the flowable composite and the post surface (Fig. 1). However, in terms of bond strength, their performances were inferior to the hybrid composites or core materials (Table 1), although in the case of Æliteflo and Filtek Flow, this difference was not statistically significant. Bayne et al. [20] have shown that the mechanical properties of flowable composites are generally 60–90% of conventional composites; moreover, their high resinous content may induce a significant contraction during polymerization. Stress from shrinkage-strain can weaken the interfacial bond, affecting bond strength to the post surface. Lower shrinkage is expected to occur in composites with a superior filler content [21]. Following this hypothesis, the combination of filler content and flowable consistency allow low-viscosity core materials to perform marginally better than the other materials tested, showing the highest bond strength to fiber post (11.00 ± 0.69 MPa).

The microtensile bond strength test was used in this study, since it is considered to be a suitable test to evaluate the interfacial bond strength of specimens with small cross-sectional areas [22,23]. The non-trimming variant of the technique was chosen in order to reduce the number of premature failures during specimen preparation [24]. Indeed, in this study, the number of premature failures was very low in all the experimental groups, ranging from 0 to 6.17%, and it was included in the statistical analysis as "zero bond" values. Despite the minimal premature failures, bond strengths of all the experimental groups were relatively low when compared with the ultimate tensile strengths of resin composites themselves (Monticelli, unpublished results). Moreover, bond failures were exclusively adhesive in nature. This is comparable to attempts in bonding to heat-treated resin composite inlays [25], in which the heat-treated surface is devoid of the remaining double bonds, which permit coupling of the methacrylate groups from fresh resinous materials. Bonding to these inlays relies predominantly on the chemical bonding to the silanized glass fillers. Similarly, when bonding to glass fiber posts, there is a complete lack of polymerizable groups in the epoxy resin, which permits free radical polymerization, and only the superficial glass fibers are available for silanization [15]. Nevertheless, the step of silanization of the fiber posts prior to composite build-up represents an improvement over the bonding of carbon fiber posts [8].

As it is rare clinically to observe the detachment of glass fiber posts from resin composite cores [4], it is speculated that, similar to the retention of implant attachments in bone [26], the resistance to dislocation of fiber post-bonded composite cores may be considered as a net sum of micromechanical interlocking, chemical bonding and sliding friction [16,27]. Thus, it is worth evaluating the resistance of glass fiber posts to dislodgement from resin composite cores using "thin slice" push-out tests [28,29], from which the role of friction can be readily assessed by examining the load–displacement curves generated during testing [16,30]. Similar to the microtensile bond test, an additional advantage of using the "thin slice" push-out test is that multiple specimens may be retrieved from a single bonded fiber post/composite core.

Within the limits of this study, we have to reject the null hypothesis that there is no difference between the microtensile bond strengths of resin composites that are employed as core materials for coupling to glass fiber posts. Although good adaptation to the post surface is achieved by all the composites tested, bond strengths to fiber posts remain relatively weak and additional treatments should be investigated to enhance the post–core bond. Low-viscosity highly filled core materials and hybrid composites are better alternatives to flowable composites to build-up the core.

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