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Research Paper

Effect of components and surface treatments of fiber-reinforced composite posts on bond strength to composite resin

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ARTICLE INFO

Article history:
Received 22 March 2013
Received in revised form
14 May 2013
Accepted 19 May 2013
Available online 30 May 2013

Keywords:
Fiber-reinforced composite
Matrix resin
Fiberglass
Composite resin
Bond strength

ABSTRACT

The aim of this study was to clarify the effect of the components and surface treatments of fiber-reinforced composite (FRC) posts on the durable bonding to core build-up resin evaluated using the pull-out and microtensile tests. Four types of experimental FRC posts, combinations of two types of matrix resins (polymethyl methacrylate and urethane dimethacrylate) and two types of fiberglass (E-glass and zirconia-containing glass) were examined. The FRC posts were subjected to one of three surface treatments (cleaned with ethanol, dichloromethane, or sandblasting). The bond strength between the FRC posts and core build-up resin were measured using the pull-out and microtensile tests before and after thermal cycling. The bond strengths obtained by each test before and after thermal cycling were statistically analyzed by three-way ANOVA and Tukey's multiple comparisons test ($p<0.05$). The bond strengths except for UDMA by the pull-out test decreased after thermal cycling. Regardless the test method and thermal cycling, matrix resins, the surface treatment and their interaction were statistically significant, but fiberglass did not. Dichloromethane treatment was effective for the PMMA-based FRC posts by the pull-out test, but not by the microtensile test. Sandblasting was effective for both PMMA- and UDMA-based FRC posts, regardless of the test method. The bond strengths were influenced by the matrix resin of the FRC post and the surface treatment. The bond strengths of the pull-out test showed a similar tendency of those of the microtensile test, but the value obtained by these test were different.

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http://dx.doi.org/10.1016/j.jmbbm.2013.05.022

1. Introduction

Fiber-reinforced composite posts (FRC posts) have the potential to reduce the risk of vertical root fracture due to their elasticity, which is similar to dentin (Lassila et al., 2004; Plotino et al., 2007). Moreover, FRC posts are currently used often because of their favorable esthetics. The failure rates of FRC post restoration were reported 7–11% after 7–11 years (Ferrari et al., 2007) and 4.6% after 120 months (Naumann et al., 2012) observation. Most frequently observed reasons for failure were endodontic problem, post fracture, and loss of post retention. The remaining cavity wall is suggested the most relevant factor which indicates usage of the FRC post in combination with bonding/luting materials. Moreover, the manufacturers recommend to use composite resin core build-up with the respective adhesive systems to obtain suitable retention to the remaining dentin (Wrbas et Al., 2007a). Therefore, retention and stability of the FRC post and composite resin for luting and core buid-up are considered an important factor to obtain a good clinical success.

A wide variety of materials makes up the components of commercial FRC posts. Thermosetting polymers, such as epoxy resin and urethane dimethacrylate (UDMA) resin, and thermoplastic polymers, such as polymethyl methacrylate (PMMA), are often employed for the matrix resin of the FRC posts. Studies of the effects of matrix resins on the FRC posts have reported that the flexural strength of FRC posts made of PMMA was greater than those containing UDMA, although the flexural strength of the PMMA was lower than that of the UDMA (Asakawa et al., 2010). The thermoplastic polymer like PMMA, could create interdiffusion bonding, or inter penetrating polymer network (IPN) bonding with composite resins (Bell et al., 2005; Mannocci et al., 2005; Vallittu, 2009). However, thermosetting polymers are not easily dissolved or swelled by the matrix resin of core build-up materials; therefore, it is difficult to obtain sufficient bonding of these FRC posts to core build-up resins without surface treatment.

Several surface treatments have been suggested to improve the retention of FRC posts and composite resins. Such as sandblasting using Al_2O_3 particles (Choi et al., 2010; Radovic et al., 2007; Soares et al., 2008), etching treatment with organic solvent using dichloromethane (Cheleux et al., 2007; Kulunk et al., 2012), etching treatment with acid solution using hydrogen fluoride (Costa Dantas et al., 2012; Yenisey and Kulunk, 2008), silane coupling treatment (Choi et al., 2010; Goracci et al., 2005), plasma treatment (Costa Dantas et al., 2012; Yavirach et al., 2009), and ultraviolet light (UV) irradiation treatment (Zhong et al., 2011). Sandblasting and etching treatments increase surface microroughness to create mechanical interlockings (Choi et al., 2010; Yenisey and Kulunk, 2008). Silane coupling treatment is possible to establish chemical bonding between fiberglass surface of FRC post and core build-up materials (Choi et al., 2010; Goracci et al., 2005). Plasma and UV treatments have surface cleaning effect due to removal of organic contamination, and change the molecule structure of surface area (Costa Dantas et al., 2012; Yavirach et al., 2009; Zhong et al., 2011). Moreover, the surfaces of commercial FRC posts are usually grooved or primed; thus, it was difficult to characterize the simple effect of surface treatments on the bonding of commercial FRC posts. Therefore, a smooth surface of FRC posts without priming is desirable to elucidate effects of surface treatments on the bonding of FRC posts. In addition, the matrix resins of several commercial FRC posts are thermosetting polymers which is not easy to be etched with organic solvents. As a result, effects of surface treatment were considered to vary due to the components of FRC posts.

Several test methods have been employed to evaluate the bonding effectiveness between commercial FRC posts and core build-up resins; these methods include the pull-out test (Castellan et al.,2010; Sahafi and Peutzfeldt, 2009; Wrbas et al., 2007a; Yavirach et al., 2009), push-out test (Castellan et al., 2010; Kulunk et al., 2012), shear bond testing (Choi et al., 2010; Yenisey and Kulunk, 2008), and microtensile testing using dumbbell-shaped and bar-shaped specimens (Castellan et al., 2010; Mallmann et al., 2007; Soares et al., 2008). There are several variables influencing the bonding effectiveness such as type of stress (shear, compressive, tensile), removal direction to the unilateral fiberglass (vertical, horizontal), effects of polymerization shrinkage of core buid-up resin, etc. Pull-out and microtensile tests have often been used for evaluating the bond strengths between FRC posts and resins. The fracture caused by the pull-out test occurs due to shear stress parallel to the bonding interface along the long axis of the post, while that caused by the microtensile test occurrs due to tensile stress perpendicular to the bonding interface. Therefore, the results of these tests varied according to the test method; for example, the bond strengths of one FRC post using the push-out and pull-out tests were 7.3 ± 1.6 MPa and 4.8 ± 0.6 MPa, respectively (Kececi et al., 2008; Wrbas et al., 2007b). Moreover, one study reported slightly small or equal shear bond strength comparing microtensile bond strength (Valandro et al., 2008), while the other study reported that the microshear bond strength was one-third of the microtensile bond strength (Yildirim et al., 2008). The relationship of bond strengths of FRC post and core build-up resins using different test methods has not clearly confirmed.

Durable bonding between the FRC post and core build-up resin in the oral environmental is essential for clinical success. In attempts to evaluate durable bonding, thermal cycling is often used as clinical aging (Bitter et al., 2007; Sahafi and Peutzfeldt, 2009).

The purpose of the present study was to clarify the effects of the components, surface treatments of experimental FRC posts on the bond strength to core build-up resin using pull-out and microtensile testing. The null hypotheses of this in vitro study were that the components and surface treatments of the FRC posts did not influence the durable bonding to the core build-up resin, and the bonding strengths obtained by pull-out test and those by microtensile test were identical.

2. Materials and methods

2.1. FRC post preparation

The materials used to fabricate the specimens are listed in Table 1. Four experimental FRC posts with two types of