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Influence of surface treatments on the bond strength of repaired resin composite restorative materials☆

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ABSTRACT

Objectives. The purpose of this study was to investigate the effect of different surface treatments on the bond strength (σ) of repaired, aged resin composites (ARC).

Methods. Forty blocks of Filtek Z250™ (Z2) and Filtek Supreme™ (SU) were made, stored in deionized water for 9 days, and randomly assigned to different surface treatment groups: hydrofluoric acid etching (HA), abrasion using a coarse diamond bur (AB), sandblasting with alumina particles (AO), and silica coating (SC). The average roughness (Ra) of the treated surfaces was measured with a profilometer. An adhesive system (SB-Adper Single Bond Plus™), a silane (SI) or a combination of both (SI + SB) were applied after each surface treatment. The blocks were restored with the same composite (RC) and cut to produce bars that were turned into dumbbell-shaped specimens (0.5 mm^2) using a precision grinding machine. The specimens ($n = 30$) were tested in tension to fracture and the microtensile bond strength (σ) values were calculated (MPa). Data were analyzed using three-way ANOVA/Tukey test ($\alpha = 0.05$) and Weibull statistics.

Results. AO and SC produced similar Ra values, which were greater than the value produced by HA. The σ values were statistically influenced by the type of RC ($p < 0.0001$), by the surface treatment ($p < 0.0001$) and by the surface coating ($p < 0.0001$). Treating the surface of Z2 with SC + SB produced the greatest m value.

Significance. AO and SC produced the greatest σ values, irrespective of the primer (SI, SB or SI + SB) used. Yet, the RC microstructure influenced the mean σ values, which were greater for Z2 than for SU. The HA should not be used for repairing ARC.

1. Introduction

Adhesive dentistry brought into perspective the possibility of a more conservative approach for tooth restoration, based on the reduction of the cavity preparation size and the bonding of the restorative material (resin-based composite) to tooth structure. It also allowed the repair of pre-existing restorations rather than their complete replacement, preserving sound tooth structure that would be at risk during the removal of the restoration.

Composite restorations are highly challenged in service and may undergo degradation over time. The effects of pH

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changes [1], salivary enzymes [2] and the wet environment [3–5] on the degradation of composites have been extensively reported in the literature. Special att ention has been given to water diffusion through the polymer chains and boundaries with fillers and the hydrolytic deterioration of the polymer chains resulting in elution of components and the plasticization of the composite [6]. Initially, this process would affect surface properties, such as hardness and wear resistance. However, as time goes by, it also interferes with the bulk properties, such as the strength and fracture toughness of the material [6,7], compromising the long-term durability of the restoration.

The extent to which this process affects the performance of the composite restorations also depends upon the microstructural and compositional features of the composites, namely the polymer network characteristics, which are dictated by the varying degrees of mobility and hydrophylicity of the constituent monomers [6,8], and the filler characteristics, such as the composition, packing ratio, surface area and quality of the interfacial boundary [6,9]. These material-related characteristics vary from one commercial composite to another, but they may be important in determining the effectiveness of the surface treatment for repairing aged composite restorations.

Surface treatment of an aged resin composite has two purposes: to remove the superficial layer altered by the saliva exposing a clean, higher energy composite surface, and to increase the surface area through creation of surface irregularities [10]. According to Brosh et al. [11], the union between the old and the new composite in a repair situation may occur by three distinct mechanisms: (1) through a chemical bonding with the organic matrix; (2) through a chemical bonding with the exposed filler particles, and (3) through micromechanical retention to the treated surface. Bonding to the resin matrix relies on the unconverted C=C double bonds remaining in the surface of the aged composite. However, whether they are available to significantly improve the bond strength with an intermediary wetting agent (adhesive system) requires further clarification [12].

Previous studies have shown the efficacy of micromechanical retention in the bond strength of composite–composite repairs [13,14], achieved through the use of diamond burs, sandblasting or acid etching. Other studies, though, obtained the highest bond strength results by using chemical or mechanical roughening of the surface followed by the application of an intermediate material, either a silane and/or an adhesive system [11,15]. Silane has the capacity of chemically bond with the filler particles of the aged composite [16]. In addition, it also improves the wetting ability of the adhesive system to an irregular surface [13].

Several techniques have been suggested to produce adequate micromechanical retention to resin composite [11,14,16]. Sandblasting of the surface with alumina or silica-modified alumina particles have been shown to be promising techniques. Yet, silica coating provides additional mechanisms for retention [17], such as the increase of the surface area for adhesion and the deposition of silica particles on the surface [18]. The use of hydrofluoric acid etching has been proposed as a procedure for repair of composite restorations [19], due to its capacity of promoting surface roughness in the aged resin composite surface through the dissolution of the filler particles [12].

Divergences concerning the best technique for repair of aged resin composite restorations are still found. Therefore, the aims of the present study were: (1) to examine the patterns produced by specific surface conditioning techniques on two different composites; and (2) to evaluate the effect of different surface treatments on the microtensile bond strength (σ) between the aged and the new resin composite. The hypothesis to be tested was that the techniques involving sandblasting of the surface produce greater bond strength values.

2. Materials and methods

Forty blocks of a microhybrid (Filtek Z250™, batch no. 5CB, shade A2, 3 M/ESPE, St Paul, MN, USA) and a nanoparticulate resin composite (Filtek Supreme™, batch no. 6CC5AB, shade A2B, 3 M/ESPE) (Table 1) were fabricated using a silicone mold.

The resin composite blocks (length: 8 mm; width: 8 mm; height: 4 mm) were built in increments of 2 mm, each light cured for 20 s using a halogen light curing unit (Optilux VCL 401, Demetron Research Corporation, Danbury, CT, 06810, USA) with irradiance >450 mW/cm^2 as measured with a hand radiometer (Cure Rite, Efos Inc., Williamsville, NY, USA). The resin composite blocks were finished using 240 through 1200-grit silicon carbide metallographic paper and cleaned in deionized water for 10 min in an ultrasonic device to remove loose particles. The 1200-grit finish produced visually similar surfaces on the two composites when imaged in the SEM.

The resin composite blocks were aged in order to simulate the degradation occurring in the oral environment with time. The aging time was set based on the calculation of the time

Table 1 – Composition of the materials used in the study.

Material	Organic matrix composition	Filler composition
Filtek Z250™ (Z2)	Bis-GMA, UDMA, Bis-EMA and TEGDMA	60% in volume (range of 0.19–3.3 μm)–zirconia and silica
Filtek Supreme™ (SU)	Bis-GMA, Bis-EMA, UDMA and TEGDMA	59.5% in volume (clusters of 0.6–1.4 μm; individual particle size of 5–20 nm)–zirconia and silica
Adper™ Single Bond Plus	Bis-GMA, HEMA, dimethacrylates, ethanol, water, methacrylate functional copolymer of the polyacrylic and polyitaconic acids	10% in weight (5 nm)–silica