Original Article *International Journal of Dental Materials 2021; 3(2)* **ISSN:2582-2209**

Repair bond strength of aged resin composite using different surface treatments and bonding protocols

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INFORMATION

Article History

Received 23rd *February 2021*

Received revised
12th April 2021

Accepted *16th April 2021*

Available online
15th May 2021

KEYWORDS

Resin Composite

Surface treatment

Bonding

Ageing

Thermocycling

Bond strength

ABSTRACT

Background: Repair of direct composites are less invasive than replacement, diminishing the risk of iatrogenic exposure of the pulp and the risk of detrimental to adjacent teeth, all in all, reducing the procession of the "restoration death spiral".

Aim: This study aimed to evaluate the repair bond strength of aged resin composites using different surface treatments and bonding protocols.

Materials and methods: A total of 45 discs (n=45) were fabricated of Nano-hybrid composite measuring about 2.5 mm in height and 3.5 mm in diameter and were mounted in acrylic resin and subjected to 10,000 thermal cycles between 5-55° C with 30 seconds of dwell time in a thermocycler in order to simulate artificial ageing. All these samples were assigned into three groups (n=15) based on the surface treatment protocol. According to the bonding protocol, the samples in each group are further divided into three subgroups (n=5). After surface treatments of the aged composites, the application of bonding agent followed by new composite material was performed. All the samples were stored in distilled water at 37° C for 24 hours. The shear bond strength of the samples was measured using a universal testing machine at a crosshead speed of 1mm/min.

Results: Among the groups, the mean bond strength in medium grain diamond bur and 37% phosphoric acid etchant with the universal bonding agent subgroup was higher 852.56±27.71 than the remaining groups. The lowest mean bond strength of 200.9±10.62 was observed in 37% Etchant with direct composite subgroup.

Conclusion: Different combinations of surface treatments and bonding protocols affect shear bond strength differently. The highest shear bond strength values were achieved for the group where surface treatment was done with the combination of blue diamond bur and 37% phosphoric acid along with a universal bonding agent.

1. Introduction

Resin composites are commonly used as direct restorative materials for the esthetic restoration of both anterior and posterior teeth in dental practice [1]. They have critical applications in contemporary restorative dentistry, including but not limited to restorative materials, cavity liners, pit and fissure sealants, core buildup, luting of indirect restorations, provisional restorations, cements for single or multiple tooth prostheses and orthodontic devices, endodontic sealers

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How to cite this article: Bandaru P, Bolla N, Garlapati R, Vemuri S, Bandaru Y. Repair bond strength of aged resin composite using different surface treatments and bonding protocols. Int J Dent Mater 2021;3(2): 51-57.
DOI: http://dx.doi.org/10.37983/IJDM.2021.3203

and post bonding [2]. They have considered as the ‘material of choice’ for use in direct, minimal intervention approaches with adhesive techniques due to their aesthetic and physical properties [3,4].

Composites present various advantages, such as ease of handling, satisfactory physical and mechanical properties and the most excellent esthetic appearance [5]. They also have several disadvantages like secondary caries, marginal staining, marginal defects, marginal or body fracture, discoloration, degradation and loss of anatomical form, unsatisfactory shade, and painful symptoms [6].

Although composite materials are adhesively bonded to the tooth structure, they are subjected to different degenerative changes [7]. The degradation of resin composites is complex and includes intraoral degradation (mechanical, physical, or chemical) and extraoral degradation (storage and shelf life of the material) [8]. Composites are less stable in fluids and have a higher degradation rate in saliva simulating conditions. The enzymes present in the saliva of the oral cavity degrade the composite matrix. All these factors affect the clinical longevity and success of composite restorations [9,10].

Therefore, to effectively improve the longevity of composite restorations, they need to be either refurbished, repaired or replaced [11]. Refurbishment refers to the addition of restorative material without removing material or dental structure [12]. Repair refers to removing defective parts and adding new composite resin to remaining aged resin composite restorations and/or adjacent tissues, leaving the intact part in place [13]. Replacement refers to the complete removal of restorative material for the placement of new material [14].

Replacement was used to treat defective composite restorations traditionally. But repairing serviceable composite restorations have gained wider acceptance regarding the modern concept of minimally invasive dentistry [15].

The success of the repair is dependent on the magnitude of the bond strength obtained at the interface of old and new restoration [16]. The bonding and shear bond strength are improved due to the presence of Camphoroquinone in the new composite layer, which is essential for complete polymerization of the oxygen inhibited layer at the inter-phase [17]. Therefore, adequate surface treatment of the old resin, section of an adhesive system, and the appropriate restorative material are required to repair an existing restoration successfully [18,19].

Numerous surface treatments promote mechanical interlocking, surface wetting, and chemical bonding during composite repair [12]. The surface treatments include surface roughening with diamond burs [20], silicon papers, carborundum stones [21], finishing discs [22], sandblasting [21,23], airborne particle abrasion with aluminium oxide particles with or without silanated silica coating [24], acid etching with phosphoric or hydrofluoric acid [25], silane coupling agent application [22,26], and resin-based adhesive systems application.

These surface treatments and bonding protocols showed variable results on the composite repair bond strength. Therefore, this study was designed to evaluate composite restorations’ repair bond strength through different surface treatments and bonding protocols. The null hypothesis was that there were no differences between the bond strength values of repairs performed on composites, and the surface treatment protocols applied have no influence on these repairs’ bond strength.

2. Materials and methods

The armamentarium of the present study was presented in Figure 1. In this in vitro study, 45 discs (n=45) were fabricated of composite (Herculite Ultra, Kerr, United States) measuring about 2.5 mm in height and 3.5 mm in diameter. All the samples were mounted in acrylic resin. they were subjected to 10,000 thermal cycles between 5-55° C with 30 seconds of dwell time in a thermocycler (Model TS130, Weiss Umwelttechnik Gmbh, Germany) in order to simulate artificial ageing.

The samples were assigned into three groups based on the surface treatment protocol, with fifteen samples (n=15) (Figure 2) in each group. In Group I, the samples (n=15) were surface treated with the application of 37% phosphoric acid (d-tech, India) for 20 seconds (Figure 3). In Group II, the samples (n=15) were surface treated with the use of medium grain diamond bur driven in a high-speed airrotor handpiece (NSK, Japan) (Figure 4). In Group III, the samples (n=15) were surface treated with the combination of medium grain diamond bur driven in a high-speed airrotor handpiece (NSK) followed by the application of 37% phosphoric acid (d-tech, India) for 20 seconds.

The samples (n=15) of each group were further divided into three subgroups with five specimens in each (n=5) for repairing. In the group I, all the three subgroups were treated with 37% phosphoric acid (d-tech). Then, the first subgroup was restored with direct composite (Beautifil-II composite, SHOFU Dental ASIA-Pacific P. Ltd., Singapore) with a Teflon coated composite instrument and light-cured for 30 seconds. The second subgroup specimens were applied with a universal bonding agent for 10 seconds with an applicator tip. The specimens in the third subgroup were restored with flowable composite (Flow plus composite, SHOFU Dental ASIA-Pacific P. Ltd, Singapore) and light-cured for 30 seconds.

In the group II, all the three subgroups were surface treated with medium grain diamond bur driven in a high-speed airrotor handpiece (NSK Japan). Then the specimens were restored with direct composite and a universal bonding agent and flowable composite as disrobed in the group I. In group III, all the specimens in the subgroups were surface treated with medium grain diamond bur driven in a high-speed airrotor handpiece (NSK), followed by treating with 37% phosphoric acid (d-tech). Then, the specimens were restored as described in the group I and II.

Various surface treatments of the aged composite were performed prior to the application of the bonding agent and then followed by the addition of new composite material. All the samples were stored in distilled water at 37°C for 24 hours. Shear bond testing for the samples was measured using a universal testing machine (Instron, UK) at a crosshead speed of 1mm/minute. Statistical analysis was done by using Kruskal-Wallis and Analysis of Variance (ANOVA) tests.

3. Results

Results of Kruskal-Wallis and Analysis of Variance tests showed a statistically significant difference between the groups. Mean shear bond strength (kN/m2) and standard deviation of all the combinations of surface treatment and bonding protocol and flowable composite application were presented in table 1. The highest shear bond strength values were observed in Group III (surface treatment with medium grain blue diamond bur and 37% phosphoric acid) (Table 1 and figure 5).

In the subgroups, placement of new composite material over the aged composite in situ with the application of bonding agent showed higher shear bond strength values than other subgroups (Table 1 and figure 5). The least mean shear bond strength was observed in the direct composite specimens etched with 37% etchant. Significant differences in the shear bond strength were observed among the groups (Table 1).

4. Discussion

Composite resins are tooth-coloured materials commonly used for aesthetic restorations of anterior and posterior teeth. Composites are polymer matrix filled materials, which derives their physical properties and handling characteristics from loading with reinforcing filler particles and the viscosity of the resin matrix [27-29]. They need the application of adhesive systems for adequate bonding and sealing of the restorations [30]. The primary aim of dental adhesives is to provide retention to composite restorations, withstand mechanical forces and prevent leakage along the restorative margins [31]. Bonding to the enamel can be achieved effectively due to its uniform composition of hydroxyapatite. In contrast, adhesion to dentin has several challenges due to the presence of water, smear layer, smear plugs and heterogeneous nature [32, 33].

Table 1. Shear bond strength in kN/m2 (Mean ± standard deviation) of all combinations of surface treatments and restored with direct composite, bonding agent and flowable composite.

Groups	37% Etchant	Medium grain diamond bur	Medium grain diamond bur and 37% Etchant	Significance (p-Value)
Direct Composite	200.9±10.62	368.84±46.4	417.12±38.77	0.004
Universal Bonding Agent	400.82±70.4	576.52±105.4	852.56±27.71	0.002
Flowable Composite	524.3±28.4	557.8±28.4	660.4±34.3	0.008
Significance (p-Value)	0.002	0.008	0.002	

Figure 1. Materials used in the study.

Figure 2. Groups based on surface treatment.

Figure 3. Surface treatment with 37% phosphoric acid.

Figure 4. Surface treatment with medium grain diamond bur.

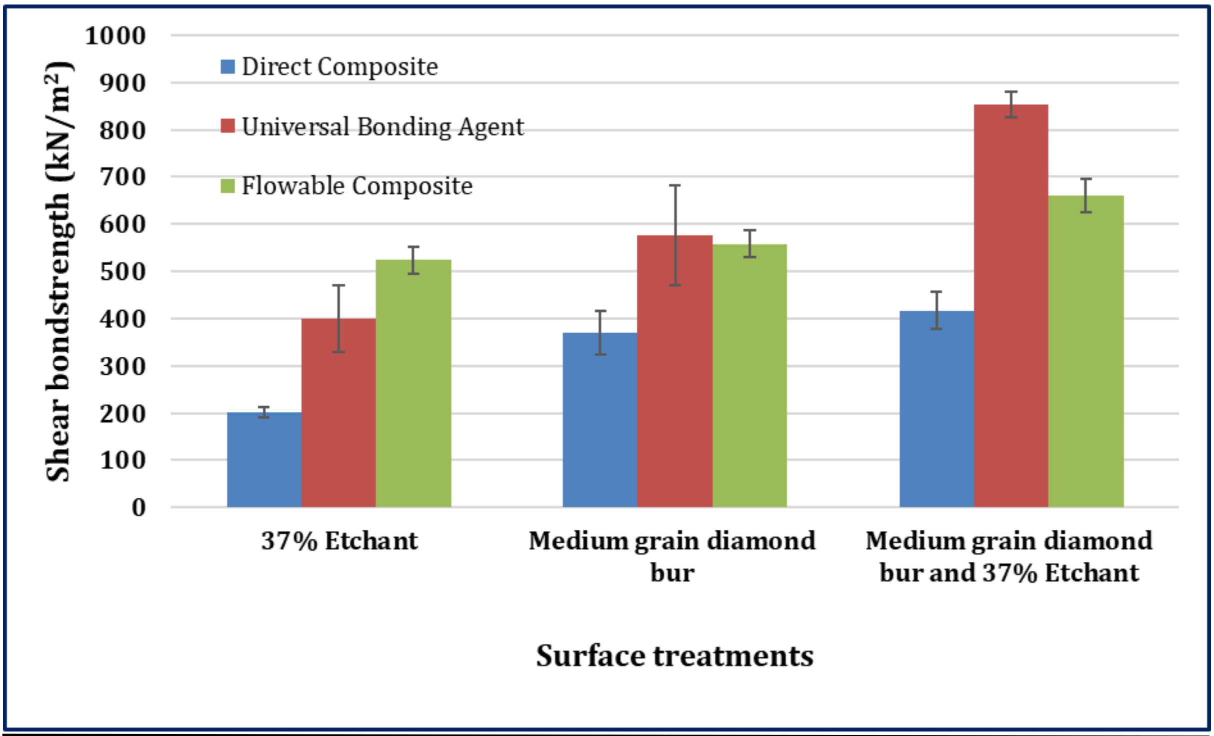

Figure 5. Comparison of shear bond strength of samples within the groups

Composite restorations are prone to ageing or failure in the long term. Artificial ageing of composite resins can be done through thermal cycling, boiling, and storage of the dry material at 37° C in acids, immersion in water, sodium chloride, artificial saliva or hot water [34-36]. In the present study, thermocycling of the samples was done to simulate hydrothermal ageing. Thermal temperatures between 5° C and 55° C coupled with water contributed to ageing in this study.

Repairing of aged composite restoration was considered as the treatment of choice rather than replacement [37]. Since the repair process results in weaker restorations, successful repair requires the development of an adequate interfacial bond between aged and new resin composites [23]. Repair bond strength can be influenced by several factors such as organic matrix composition, filler load, filler size, surface treatment for repair, conditioning prior bonding, application of silane coupling agent and adhesive system [13,38].

The interface between aged and new composite is the weakest link of the restoration [39]. Therefore, several ways have been proposed to improve the interfacial bond between aged and new composite, including surface treatments, either physical or chemical, to improve mechanical keying and chemical coupling at the adhesive interface [20,25,40]. In the present study, surface treatments were carried out using 37% phosphoric acid, medium grain diamond bur and a combination of both for the samples, respectively.

The phosphoric acid acts by the infiltration of resin monomers into the microporosities created by the dissolution of enamel and subsequent dissociation of the exposed hydroxyapatite crystals with polymerized monomers within the pores on the enamel surface, thereby accomplishing micromechanical retention [41]. Surface treatment with diamond bur resulted in creating macro irregularities. The conditioning of the aged composite surface aimed to obtain a cleansing effect, removal of debris and particles that have remained after treatment [42].

The present study showed the highest shear bond strength among the samples treated with medium grain diamond bur and 37% phosphoric acid (Table 1). This can be supported by the fact that prior surface treatment with diamond bur removed the superficial layer of the old composite. Later etching resulted in more penetration of composite into the microporosities, thus, enhancing the shear bond strength. The results of this study were consistent with the study done by Eliguzeloglu E *et al*. (2008) [43] reported that high surface roughness created with bur might have increased the dentin surface, promoting for better contact between the dental substrate and adhesive [43].

Lower shear bond strength values were observed in samples treated with 37% phosphoric acid and diamond bur, respectively (Table 1). Lower shear bond strength values with the treatment of 37% phosphoric acid were due to the collapse of resin matrix of composite in situ, creating improper bonding, which was in accordance with the study done by Sabatini C. (2013) [44] stated that surface treatment with acid etching might lead to incomplete adhesive infiltration into the denuded collagen network and also residual hydroxyapatites removal from collagen mesh due to sub-optimal removal of the phosphoric acid all together compromises the potential for chemical adhesion.

The results of the present study also presented higher shear bond strength values in subgroups characterized by the placement of new composite material over the old composite with the application of universal bonding agent, i.e., water/ethanol-based and both self-etch one-step adhesives when compared to other subgroups (Table 1), that was in accordance with the study done by Eliasson ST *et al*. (2017) [45] stated that the Scotchbond Universal promotes adhesion as it contains small amounts of silane or increases wettability as a coupling agent, thus enhancing bond strength.

Long-term water storage affects the mechanical properties of composite materials. For this reason, the samples in the present study were stored in distilled water only for 24 hours that was in accordance with study b Ferracane JL *et al*. (1998) [46] stated that water storage shows less significant effect on mechanical properties and indicates limited decomposition of composites in water.

In the present study, shear bond strength testing was done using a universal testing machine consisting of a notched cross-head designed to match the bonded specimen's diameter and apply a specific testing load in concurrence with the study done by Sabatini C. (2013) [44].

5. Conclusion

Different combinations of surface treatments and bonding protocols affect shear bond strength differently. The highest shear bond strength values were achieved for the group where surface treatment was done with the combination of blue diamond bur and 37% phosphoric acid along with a universal bonding agent. In contrast, the lowest values were observed with 37% phosphoric acid as the surface treatment agent and placement of direct composite.

Conflicts of interest: Authors declared no conflicts of interest.
Financial support: None

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