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Original Research

Shear Bond Strength of Repaired Composites Using Surface Treatments and Repair Materials: An *In vitro* Study

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Abstract:

Background: Enhancement of bond strength between new and old composite usually requires increased surface roughness of old composite to promote mechanical interlocking and subsequent coating with bonding agents to improve surface wetting and chemical bonding. So this study was carried out to evaluate and compare the effects of different surface treatments and repair materials on the shear bond strength (SBS) of composite repairs The mode of failure of repaired composites whether cohesive or adhesive was also evaluated.

Materials and Methods: The substrates for 60 composite specimens were fabricated and aged with water treatment and subjected to various surface treatments. The surface treatment regimens used in the study were: No surface treatment, abraded with diamond bur, air abraded (sandblasted) with 50 µ aluminum oxide particles. Specimens were then repaired with fresh composite using either Clearfil™ repair or all-bond two adhesive systems. Specimens were water stored, thermocycled and tested for SBS using universal testing machine. Fractured specimens were then examined under stereomicroscope to determine the mode of failure.

Results: It was clearly showed that surface roughening of the aged composite substrate with air abrasion, followed by the application of Clearfil™ repair adhesive system (Group IIIa) yielded the highest repair bond strength (32.3 ± 2.2 MPa).

Conclusion: Surface treatment with air abrasion followed by bonding with Clearfil™ repair adhesive system can be attempted clinically for the repair of composite restorations.

Key Words: Adhesive systems, composite resin repair, surface treatments, shear bond strength

Introduction

With the current trend toward esthetic dentistry, composites have added a whole new dimension. Resin based composites are widely used in restorative dentistry as both direct and indirect restorations in anterior and posterior teeth. The clinical performance of composite materials has improved with the development of more wear-resistant formulations, the newer generation dentin bonding agents and improved light curing and surface-sealing systems. When existing composite resin restoration fails, due to caries, fracture, color change or inadequate contour, the treatment choice consists of either total replacement or repair of an existing restoration. Total replacement is often undesirable as it invariably increases the cavity size and traumatizes the pulp. Hence, repair is more practical than replacing the restoration as it reduces pulpal trauma and is cost-effective. Repair of composite restorations is often accomplished by placing new composite over the old composite. This repair is often challenging as there are few, if any, reactive double bonds in the old composite for bonding to the new composite.[1]

Although the importance of a good bond between the old and new resin material has been accepted, repair bond strengths have been variable and unpredictable, as stated in many studies.[2-4] A variety of chemical, mechanical surface treatments and bonding agents have been evaluated to improve the repair strength of composites. Most studies have indicated that the surface roughness of composite has a great influence on repair strength than using a bonding agent.[5-7] Surface treatment by diamond bur or sandblasting achieved the highest bond strength.[8] Sandblasting[7] and application of multistep adhesive primers[9] greatly improved the bonding.

Until date, there is no consensus exist in the most appropriate way to prepare the surface to obtain maximum bond strength. Hence, the present study has compared the effects of different surface treatments and bonding agents on shear bond strength (SBS) of composite repair, and also evaluated the mode of failure of repaired composites: cohesive or adhesive or both.

Materials and Methods

In this study, two repair adhesive systems namely all-bond 2 adhesive system (Bisco) and Clearfil™ repair adhesive system

(Kurarey) were used to repair the substrate of aged composite with fresh composite after various surface treatments either with Diamond bur or with air abrasion unit. Clearfil™ AP-X microhybrid composite resin was used as to prepare test composite specimens.

The substrates for sixty test specimens were fabricated by placing uncured microhybrid composite into the retentive cavity of the acrylic resin surrounded by stainless steel cylinder. The substrate was cured for 40 s with light intensity of 450 mW/cm^2. Specimens were first stored in 37°C water for 48 h then boiled in water for 8 h and again stored in 37°C water for 3 weeks to again the material. The aged specimens were divided into three groups of 20 each and surface treated as follows.

Group I: No surface treatment, Group II: Abraded with a coarse, tapered, rounded end diamond bur and Group III: Air-abraded with 50 μ aluminum oxide at 80 Psi for 3 s using extra-oral sandblaster unit (APM-Sterengold, USA). The specimens were later rinsed in water and then airdried. The specimens were then subdivided into two sub groups of 10 each and each sub group is subjected to either Clearfil™ repair (sub group A) or all-bond 2 adhesive systems (sub group B) according to manufacturer's recommendations. A hollow translucent polyethylene tube of 6 mm internal diameter was centered on pre-treated surface of each specimen, and the fresh microhybrid composite was then applied in 2 mm increments and light cured for 40 s. The repaired specimens were stored in distilled water at 37°C for 24 h and then additionally thermocycled for 300 cycles between 5°C and 55°C with a dwell time of 30 s and transfer time of 5 s. After 24 h specimens were subjected to shear bond test using Hounsfield Universal testing machine (Instron, USA) at a cross head speed of 1 mm/min. Fractured surfaces of the specimens were examined under stereomicroscope at ×10 magnification to evaluate the mode of failure: Cohesive (Figure 1) or adhesive (Figure 2). The results were analyzed statistically using one-way analysis of variance and for pairwise comparison using Scheffes multiple comparison tests.

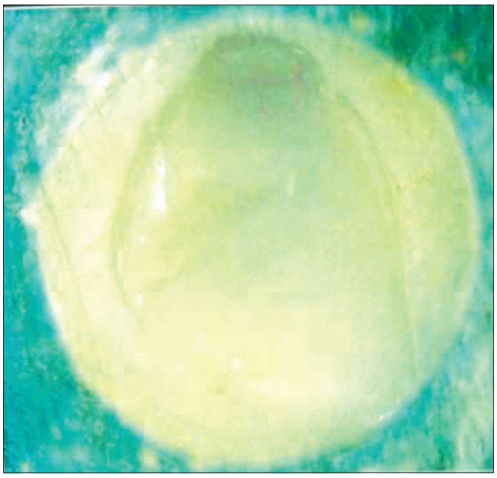


Figure 1: Fractured specimen showing cohesive mode of failure.

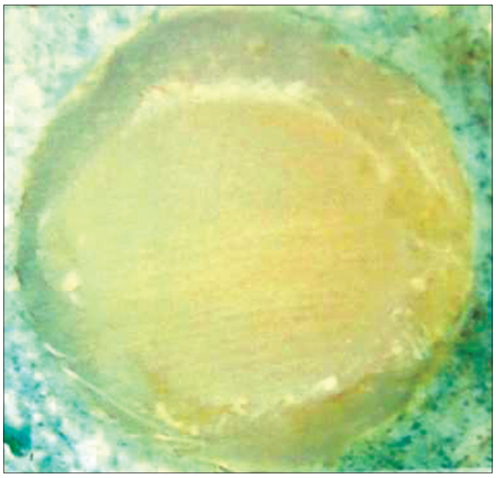
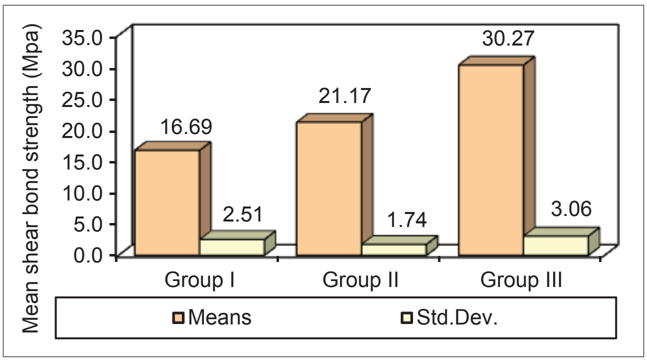


Figure 2: Fractured specimen showing adhesive mode of failure.

Results

The mean SBS (MPa) values with a standard deviation of all the main groups were depicted and compared in the Graph 1. Group III (air-abrasion) has showed the highest SBS values than other groups. The mean SBS values of all sub groups were depicted and compared in the Graph 2 and Table 1. Group IIIa (air-abrasion followed by Clearfil repair) has showed the highest SBS of all groups and in all the main groups, sub groups A (Clearfil repair) showed better results than sub groups B (all-bond 2). The mode of failure of fractured specimens was adhesive for Group I and cohesive in Group II and III specimens (Table 2).



Graph 1: Comparison of three Groups (I, II, III) with respect to shear bond strength.

Discussion

When repairing the old restorations, a frequently asked question is whether the repair material bonds adequately to the existing restorations. Composite repair often presents a different challenge; while there is no oxygen-inhibited layer, if any, few unreacted double bonds remain in the old composites for bonding to the new composite. Thus, the potential for chemical

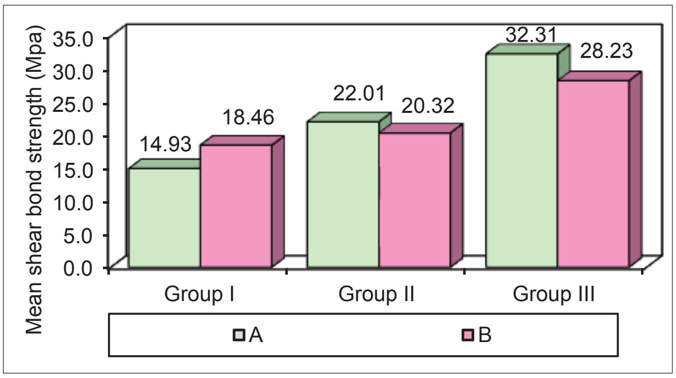
Table 1: Comparison of sub Group A and sub Group B in each main group.

Main group	Sub group	N	Mean	SD	*t* value	*P* value	Significant
I	A	10	14.9260	1.8641	−4.4301	0.0003	HS
	B	10	18.4566	1.6960			
II	A	10	22.0135	1.3615	2.4374	0.0254	S
	B	10	20.3215	1.7219			
III	A	10	32.3055	2.2056	3.9691	0.0009	HS
	B	10	28.2315	2.3813			

SD: Standard deviation, HS: High significant, S: Significant

Table 2: Number of cohesive/adhesive of failure by groups.

Failure	Group I		Group II		Group III	
	A	B	A	B	A	B
Adhesive	10	6	1	2	0	0
Cohesive	0	4	9	8	10	10



Graph 2: Comparison of sub group A and sub group B in each main group.

bonding between old and fresh composite layers decreases over time.[1] Improving the bond strength between new and old composite usually, requires increased surface roughness to promote mechanical interlocking and coating with repair adhesives to advance surface wetting and chemical bonding.

Mechanical and/or chemical treatments to roughen the surface include roughening with diamond bur,[7,10,11] carbide bur,[12] silicon carbide paper,[9,11] green carborundum stone,[8] air abrasion with 50 µ aluminum oxide particles,[5,10,13] etching with 37% phosphoric acid gel,[12,13] hydrofluoric acid[8] and 1.23% acidulated phosphate fluoride gel.[5] Diamond bur is preferred by most clinicians for preparing enamel and composite surface prior to acid etching.[11,12] Air-abrasion or sandblasting is an old technology that is finding a new place in modern science based dentistry. At present, the newer air abrasion unit available is Microetcher II™ intraoral sandblaster (Danville engineering, California). It uses 50 µ aluminum oxide particles at 80 Psi pressure and was found effective to improve the repair bond strength.[5,14,15] Hence in the present study diamond bur and extra-oral sandblaster using same particle and pressure were used for mechanical surface roughening. The use of bonding agents has improved the repair bond strength[16] and most clinicians tend to use the adhesive system that they have already in their practice rather than acquiring a special bonding system for composite repair procedures. Hence, in the present study two different adhesives namely all-bond 2 system (Bisco) and Clearfil™ repair (Kuraray) were tested.

All-bond 2 system is a universal bonding system used to bond composite to enamel, dentin, metal alloy, amalgam, porcelain and composite. It is a fourth generation adhesive system.[17] Clearfil™ repair is a unique adhesive used for intraoral repairs of fractured porcelain or composite restorations. It is a fifth generation adhesive system consisting of self-etch primer, adhesive and porcelain bond activator with silane coupling agent.[9]

To simulate aging of the composite in the oral cavity, short term water storage followed by boiling, then 3 weeks water storage was used in the present study.[9] The shear bond test is considered as an appropriate method for quantifying the adhesion and bonding of repair materials because of its simplicity[18] and hence used in the present study.

The results of the present study showed the least mean SBS value of 16.7 ± 2.5 MPa in Group I when there is no mechanical roughening of substrate subsurface. This bond strength is not clinically acceptable and should be above 18 MPa.[4,19] This is due to decreased surface area for bonding and reduced penetration of new composite to interlock mechanically to the surface of old composite.[7,12,13,20] This was further confirmed with mode of failure being adhesive (Figure 2). When different mechanical surface treatments were compared, air abrasion has improved the repair bond strength resulting in cohesive mode of failure (Figure 1). This could be due to increased surface roughness with large micro-retentive areas which enhances the wettability for adhesive system.[5,6,10,15,21]

Application of Clearfil™ repair adhesive system after any mechanical surface treatment has improved the bond strength values significantly than all-bond 2, especially when applied after air-abrasion. This could be due to deeper penetration of adhesive, in the presence of silane coupling agent, into micro-retentive areas created by air abrasion.[8,15,22] A silane that is used with Clearfil SE primer is 3-methoacryloxy propyl trimethoxy silane. When silane is applied to the exposed filler particles following surface roughening of composite resin, it gets deposited on the filler. In the presence of water, methoxy groups of silane are hydrolyzed to silinol (-Si-OH) groups that can bond to other silinols by the formation of a siloxane bond (-Si-O-Si). Then the methacrylate group of silane form covalent bonds with repair resin when it is polymerized, thereby completing the coupling process.[23] Silane also enhances the wetting ability of the adhesive over the irregularities created by surface roughening.[15,24]

In Group I, application of all-bond 2 adhesive system without any prior mechanical roughening resulted in clinically accepted repair as this system involve the use of 32% phosphoric acid which created interstices resulting in improved mechanical attachment.[12] With Clearfil repair system, its SE primer lacks etching ability when compared to phosphoric acid.

Overall air-abrasion of aged composite substrate followed by application of Clearfil™ repair adhesive system yielded the highest repair bond strength than the any other combinations tested in the present study.

Conclusion

Within the limitation of the study, the following conclusions were drawn:

1. Mechanical surface treatment of the composite substrate significantly improves the repair bond strength especially with air-abrasion
2. Among the repair adhesive systems tested, Clearfil™ repair yielded a higher bond strength.

Hence, surface treatment with air abrasion followed by bonding with Clearfil™ repair adhesive system can be attempted clinically for the repair of composite restorations.

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