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Shear Bond Strength of Bulk-fill Resin Composite after Bur and Air Abrasion Surface Treatments

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Abstract

Objectives: To investigate the shear bond strength of aged bulk-fill resin composite after being repaired using different surface treatments and types of resin composite.

Methods: Sixty cylindrical specimens of bulk-fill resin composite (X-tra fill®) 6 mm in diameter and 4 mm thick were prepared using an acrylic mold. They were aged using thermocycling at 5ºC and 55ºC for 5,000 cycles then mounted with self-cured resin acrylic in PVC tubes. The specimens were divided into 3 groups using surface treatments, including (a) abraded with a diamond bur, (b) air-abraded (sandblasted), and (c) no surface treatment. The specimens were then divided into 2 subgroups according to the resin composites used (viz., Filtek Z350XT®or X-tra fill®). All of the samples were divided into 6 groups (n=10): Group 1 (Bur + Filtek Z350XT®); Group 2 (Bur + X-tra fill®); Group 3 (Sandblast + Filtek Z350XT®); Group 4 (Sandblast + X-tra fill®); Group 5 (No surface treatment + Filtek Z350XT®); and, Group 6 (No surface treatment + X-tra fill®). The specimens were then tested for shear bond strength using a universal testing machine (0.5 mm/min). Fractured samples were examined under a stereomicroscope to determine the mode of failure. The results were analyzed using Friedman's Two-way Analysis of Variance by rank with a significance level of 0.05.

Results: The respective median sorted from highest to lowest values for Group 4, 2, 3, 1, 5, and 6 was 25.8, 25.5, 22.1, 21.8, 14.0, and 13.2 MPa. Differences between values were statistically significant ($p<0.001$). All surface treatments demonstrated significantly greater shear bond strength than not having any surface treatment. Groups 1, 2, 3, and 4 were statistically significant different from group 5 and 6 ($p<0.001$), but there was no respective statistically significant difference between Groups 1 and 3 ($p>0.99$), and Groups 2 and 4 ($p=0.94$). Repairing with X-tra fill® had higher shear bond strength than Filtek Z350XT®. A statistically significant difference was found between Groups 1 and 2 ($p=0.001$), Groups 3 and 4 ($p=0.019$), but not between Groups 5 and 6 ($p=0.762$). All specimens in Groups 2 and 4 had cohesive failure, while Groups 5 and 6 demonstrated adhesive failure, and Groups 1 and 3 exhibited both types of failure.

Conclusions: Shear bond strength of aged bulk-fill resin composite after being repaired using bur and air abrasion surface treatments were no different, but greater than no surface treatment.

Keywords: bulk-fill resin composite, resin composite repair, shear bond strength, surface treatment, thermocycling

Introduction

Many options are available for tooth restorative material.[1] Tooth restoration with resin composites is favored[2] because of their esthetic quality, natural color, good adhesion, and adequate strength. Conventional tooth restoration with resin composites is generally done with layering or an incremental technique. Each layer should be about 2 mm thick in order to achieve complete polymerization.[3] New improved resin composite properties ex Bulk-fill resin composite have been developed. Bulk-fill resin composite is often used due to its increased depth of cure from 2 to 4 mm and less polymerization shrinkage. These features can save time and provide adequate strength for usage[4]; however, it is transparent, so cannot conceal dentin color anomalies. In addition, some products add large-size filler, which makes polishing difficult. In sum, bulk-fill resin composite is mainly used for teeth restoration that does not need high esthetic quality, such as posterior teeth.

When resin composites are used in the oral cavity, wearing or failure may occur. Replacement of material can be done under specific criteria: defect of material quality, large secondary caries, very damaged of unrepairable fractured material, or patient allergy to restorative material.[5] In some cases, a replacement may be inappropriate because the loss of tooth structure will cost more than repairing the restoration.[6] Replacement will make the treatment more complicated, time-consuming, and possibly harmful to the dental pulp.[7] Thus, repairing the resin composite is an option to preserve tooth structure and minimize intervention.[8] Criteria for repairing include: (a) correcting marginal ditching or specific areas of color discoloration, (b) restoring small-sized secondary caries, or (c) restoring a cavity that will not affect retention between the cavity and repair material.[5] The success of resin composite repair depends upon adequate bond strength between the old and fresh resin composites,[9] and the teeth must be able to resist occlusal loading, especially in posterior area restoration. Good preparation or surface treatment of material and proper material selection are factors promoting adhesion between the old and fresh resin composites. Surface treatment of restorative materials consists of physical and chemical methods that help to create physical adhesion. Macro-mechanical retention includes preparing, undercutting, hole retention, and burring, while micro-mechanical retention includes airborne particle abrasion, laser, and etching agents. In addition to the physical method, chemical methods include adhesive resin and silane coupling agents.[5]

The purpose of this study was to investigate the repair of bulk-fill resin composite after bur or airborne particle abrasion surface treatment of old resin composite (X-tra fill®) and the effects of types of resin composite (Filtek Z350XT or X-tra fill®) on shear bond strength.

Materials and Methods

The study was done in the laboratory, and different conditions were simulated to mimic the oral cavity environment. Two types of resin composites were used for the repair: X-tra fill® – a bulk-fill resin composite with a 4-mm depth of cure; and, Filtek Z350XT® – a conventional resin composite with a 2-mm depth of cure. X-tra fill® bulk-fill resin composite was used to fill a single 4-mm layer in the mold. The environment of the oral cavity was simulated using thermocycling. The surface of the bottom lowest layer of the specimen was treated with a bur or airborne particle abrasion. Both techniques are simple and convenient.

Specimen preparation: Sixty specimens of bulk-fill resin composite (X-tra fill®) were prepared (Table 1). Specimens were prepared using a cylindrical acrylic resin mold (external diameter 22 mm, internal diameter 6 mm, height 4 mm) with the same shape and size. Bulk-fill (X-tra fill®) resin composite was added by a single bulk placement into the mold using a plastic instrument. The top composite resin surface was closed using a mylar strip covered with a glass slide. The specimens were cured for 40 sec with an LED blue light (400-500 nm) (Euro LED light gun IV, Eurodent Part and Tool, U.S.A.), keeping the edge of the gun at a right angle by attaching it to the glass slide. A symbol was marked using a round diamond bur 014 (round diamonds 801, Hager& Meisinger GmbH, Neuss, German) on the bottom of the specimen. The specimens were then immersed in distilled water at 37±2ºC for 24 h.

Accelerated aging: The specimens were subjected to thermocycling to accelerate aging, simulating a lifetime of usage. Each specimen was immersed in water for 30 sec alternately between 5 and 55ºC at each temperature for 5000 cycles.[10-11]

Mounting specimen with PVC tube: Plaster of Paris was mixed and poured into a PVC tube (external

diameter 22 mm; internal diameter 17 mm; height 40 mm). The plaster was poured into the tube to about three-quarters full and left for one hour to set. Acrylic resin powder and monomer were mixed until viscous and poured over the hardened plaster in the PVC tube. The mixture of acrylic slightly overflowed the rim of the PVC tube. The specimen was placed leaving the marked side down: 1 mm of material emerged from the acrylic (Figure 1) at the center of the PVC tube (Figure 2). When the acrylic was hardened, the specimen was rinsed with water from 5 cm away using a triple syringe for 30 seconds. Finally, the specimen was blow-dried.

Surface treatment: The 60 specimens were randomly divided into three groups, with 20 in each. In Group A, the surface was treated with a tapered round-ended diamond bur (Robot FG medium grit diamond 223/018, Shofu Inc., Kyoto, Japan). The preparation process took three cycles (back and forth), and the bur was changed after every four specimens were completed. In Group B, the surface treatment was done using a 5-μm aluminum oxide intraoral air abrasion device (Intraoral Air Abrasion Device, Microetcher IIA, Danville, CA) with a working pressure of 3 bars and 5 mm of blowing distance from the specimen for 7 sec.[12] For group C, no surface treatment was done in this group.

Repair process: Concentrated phosphoric acid (37%) was applied to the surface-treated resin composite for 15 seconds. It was then washed with water for 10 sec and slightly blown for 10 sec 5 mm distant from the material surface. Adhesive (Adper single bond plus adhesive 3M ESPE, Minnesota, U.S.A.) was applied (compositions shown in Table 1) and slightly blown for 5 sec. The specimen was exposed to curing light for 20 sec. Split molds of cylindrical specimens were placed on the semicircle (exterior diameter 22 mm, interior diameter 3 mm, and height 3 mm (Figure 3). The specimens after

Figure 1: Side view of a specimen showing 1 mm of the top surface with emerging resin composite.

Figure 2: Top view of cylindrical specimens fabricated with acrylic resin at the center of PVC tube.

Table 1: Products and composition of resin composite and adhesive.

Material	Product	Manufacture	Shade	Composition	
				Organic polymer matrix	Filler
Bulk-fill resin composite	X-tra fil®	VOCO, Cuxhaven, Germany	A3	Bis-GMA, UDMA, TEGDMA	Bariumboroaluminium-silicate 70.1 vol% (86 wt%)
Conventional resin composite	Filtex Z350 XT®	3M/ESPE, Minnesota, U.S.A.	A3	Bis-GMA, Bis-EMA, UDMA, TEGDMA	Zirconia/Silica 59.5 vol% (78.5 wt%)
Adhesive (Total etch system)	Adper® Single bond plus adhesive	3M/ESPE, Minnesota, U.S.A.	-	Bis-GMA, HEMA, Dimethacrylates	Silica 10 vol%

Abbreviation: Bis-GMA = bisphenol A glycidyldimethacrylate, Bis-EMA = ethoxylated bisphenol A dimethacrylate, UDMA = urethane dimethacrylate, TEGDMA = triethylene glycol dimethacrylate

being repaired with resin composite are 3 mm of repaired resin composite. The specimens in Groups A, B, and C were randomly divided into two subgroups. Each subgroup had ten specimens—all specimens were divided into six groups (Figure 5).

The followings are the details of the six groups of repaired resin composites.

Groups 1, 3, and 5 were repaired with Filtex Z350 XT® (Table 1). The material had a depth of cure of 2 mm. The height of the mold was 3 mm, and the filling was divided into two layers. The first layer was 2 mm thick, and the curing light time was 20 sec. The second layer was 1 mm thick, and the curing light time took 20 sec to produce a complete depth of cure.

Groups 2, 4, and 6 were repaired with X-tra fill® 3 mm thick with 40 sec curing light time.

Shear Bond Strength Testing: All six groups repaired with resin composite were mounted on a universal testing machine (Universal Testing Machine. LLOYD model LR 30 K. Lloyd Instruments Ltd., Hants, England) by setting the test speed at 0.5 mm/sec and the tip of the wedge at the interface between the old and repaired resin composite (Figure 6). We recorded the moment (shear bond strength in MPa) when adhesive strength failed[7,13,14]. The tested

Figure 3: Acrylic split mold show interior diameter 3 mm and height 3 mm.

Figure 4: Top view of specimens after repair with resin composite height 3 mm.

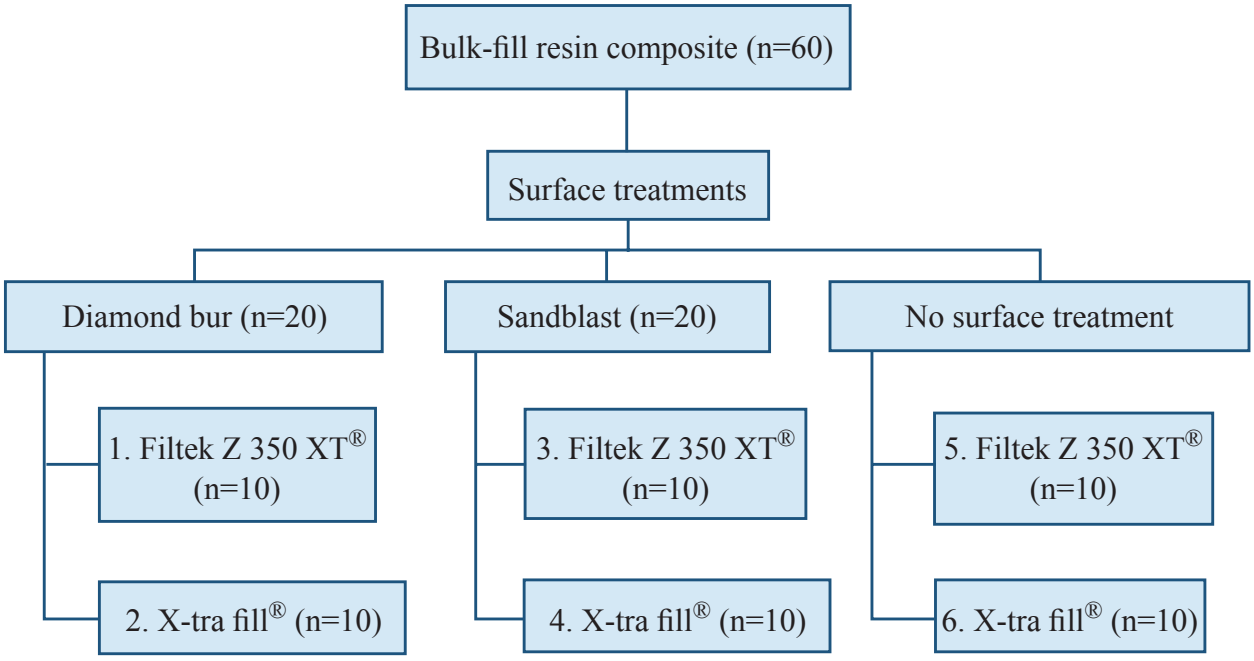

Figure 5: Diagram of groups of different surface treatments and resin composite type

products were examined under a stereomicroscope (Stereomicroscope, Nikon Measurescope 20, Japan) at 20x magnification to determine the mode of failure: cohesive, adhesive, or mixed.

Measurements and Assessment: The number of specimens needed for the study was calculated using the STATA® (StataCorp LP., College Station, TX, USA) Two-way ANOVA analysis and selecting the average values from similar studies[12,15] (n=60). The number was divided into six groups. Each group had ten specimens. The statistical analysis demonstrated that equal variances could not be assumed, so the results cannot be used in a Two-way ANOVA analysis. The analysis was thus done using a non-parametric test, the Friedman's instead. Shear bond strength values were statistically analyzed with three methods: 1) a comparison of shear bond strength acquired from the surface treatment and the type of restorative material, using Friedman's Two-way Analysis of Variance by Ranks; 2) a comparison of shear bond strength acquired from surface treatments, using the Kruskal Wallis Test; and, 3) a comparison of shear bond strength acquired from the types of repaired resin composite, using the Mann Whitney test.

Results

The respective shear bond strength of X-tra fill® of the six groups after repairing with resin composite, sorted from the highest to lowest median values, for group 4, 2, 3, 1, 5, and 6 are 25.8, 25.5, 22.1, 21.8, 14.0, and 13.2 MPa (Table 2). The statistical analyses on shear bond strength by method of surface treatment and type of repair material using Friedman's analysis revealed significant differences (p<0.001).

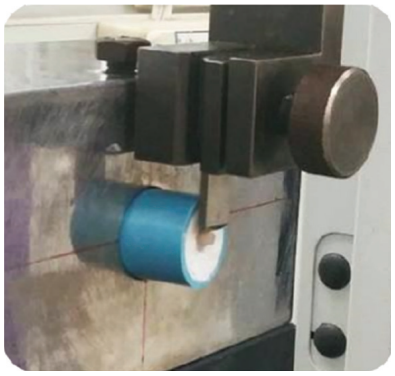

Figure 6: Side view of specimen on the Universal Testing Machine. The tip of the wedge is set at the interface between the old and repaired resin composite.

Comparison of shear bond strength with surface treatment analyzed using the Kruskal Wallis Test at 0.05 significance indicated that at least one pairing exhibited differences. The couples that showed statistically significant differences (p<0.001) were groups 1 and 5, 3 and 5, 2 and 6, and 4 and 6. There was no significant difference between groups 2 and 4 (p=0.94). Comparison of shear bond strength on different types of restorative material analyzed using the Mann Whitney test at 0.05 significance indicated a significant difference between groups 1 and 2 (p=0.001) and 3 and 4 (p=0.019). There was no significant difference between groups 5 and 6 (p =0.762). The study of fracture failure by investigating in stereomicroscope found crack depth within resin composite or cohesive failure (Figure 7). Adhesive de-bonds from the interface of resin composite or adhesive failure

Table 2: Median, minimum, and maximum shear bond strength of aged bulk resin composite after being repaired using different surface treatments and types of resin composite (MPa)

Group	Surface treatment	Type of resin composite	Median	Min	Max
1	Diamond bur	Filtex Z350 XT®	21.8^{1A}	20.4	23.1
2	Diamond bur	X-tra fil®	25.5^{2B}	22.6	28.0
3	Sandblast	Filtex Z350 XT®	22.1^{1C}	16.4	27.9
4	Sandblast	X-tra fil®	25.8^{2D}	21.5	29.9
5	No surface treatment	Filtex Z350 XT®	14.0^{3E}	8.6	16.7
6	No surface treatment	X-tra fil®	13.2^{3E}	11.7	16.2

Differences in superscript numbers show statistically significant different surface treatments (p<0.01). Differences in superscript letters show statistically significant different types of resin composite (p<0.05).

(Figure 8). The results of fracture failure are presented in Table 3. All specimens in groups 2 and 4 had cohesive failure, while all specimens in groups 5 and 6 had adhesive failure. In groups 1 and 3, both cohesive and adhesive failure occurred.

Table 3: Failure modes of specimens in each group

Group	Failure		
	Adhesive	Cohesive	Mixed
1	2	8	0
2	0	10	0
3	1	9	0
4	0	10	0
5	10	0	0
6	10	0	0

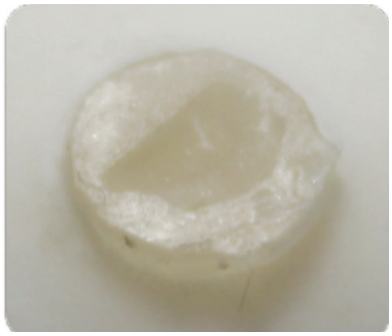

Figure 7: Top view of specimen cohesive failure shows crack depth within resin composite.

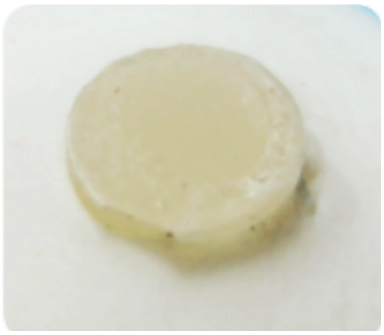

Figure 8: Top view of specimen adhesive failure shows adhesive de-bonds from the interface of resin composite.

Discussion

We investigated the impact of repair on shear bond strength of bulk-fill resin composite after bur and airborne particle abrasion surface treatment of old resin composite. The study was done in the laboratory, but so as to simulate conditions in the oral cavity over six months, the specimens were alternately soaked in water at 5 and 55ºC for 5000 cycles.[10,11,16,17]

The bulk-fill resin composite or aging resin composite specimens were 4 mm high. According to the literature, the optimum depth of cure for bulk-fill resin composites was 4 mm.[3] The piece of resin composite was to be used for repair, which this study use height mold was 3 mm. If we provided a height mold of only 2 mm, the repaired resin composite would perform a complete depth of cure of 2 mm, which was not in conformity with bulk-fill resin composite. On the contrary, if we provided a mold height of 4 mm for the repair. They could become replacements instead of repairs.

The test of shear-bond strength of the bulk-fill resin composite was determined. The specimens received macro-surface treatment using a medium diamond bur or micro-surface treatment with airborne particle abrasion. According to the literature, these two methods provide relatively high shear bond strength compared to other methods. The current study indicated that groups undergoing two surface treatment methods had higher shear bond strength than groups without any surface treatment. This finding corresponds to a study on the effects of nanohybrid resin composite by Perriard *et al.*[18] They found that creating roughness before using acid and adhesive agents helped increase the repair strength. When this approach was compared to treatment with a bur or airborne particle abrasion, Marco *et al.* found no statistically significant differences.[19] By contrast, Reham *et al.* found that the strength after airborne particle abrasion was greater than that after using a bur;[20] possibly because they used a finishing carbide bur to create surface roughness instead of a diamond bur. In the present study, the adhesive agent system—a total-etch system—used 37% phosphoric acid to treat the material surface before the repair, promoting adhesion.[18]

Another key factor was the type of restorative material. If the restorative material used to repair is the same type, shear bond strength is higher than when using a different type, possibly because of differences in the size and shape of the filler particles and polymerization.[21,22] X-tra fill® is a hybrid resin composite and Filtex Z350 XT® is a nanofill resin composite. The groups repaired with X-tra fill® of the same type had higher shear bond strength than the groups repaired with Filtex Z350 XT®.

The material composition (Table 1) and monomers in the resin matrix of both types of components were comparable. The difference was in the proportion of nanofiller in X-tra fill® which was 70.1% by volume, compared to 59.% in Filtex Z350 XT®. When the amount of filler particle is increased, the mechanical properties increase accordingly.[23,24]

Other researchers[12,15] reported shear bond strength between the old and repaired resin composite was between 17-33 MPa. The current study results demonstrated that when surface treatment was done with a medium diamond bur or airborne particle abrasion and repaired with X-tra fill® or Filtex Z350 XT®, shear bond strength was between 20-30 MPa. In the present study, bur and airborne particle abrasion were used for mechanical surface treatment only. If the study were to be revised with chemical methods (i.e., with silane coupling agent), those factors should help to increase shear bond strength further.[25]

Concerning fracture failures, the study found that in groups 5 and 6, which did not receive surface treatments, all specimens in these groups had adhesive failure occurring only at the interface of the resin composite. Fractures occurring inside the resin composite were not found (Figure 8); this was possibly due to decreased surface adhesion and reduced penetration of repaired resin composite into the old composite.[26] Fractures within resin composite were found in groups 1, 2, 3, and 4, which did receive surface treatment. Most of the fractures were cohesive failure (Figure 7), which possibly resulted from the use of a diamond bur or airborne particle abrasion for surface treatment, increasing roughness and the area available for adhesion.[27] Mixed failure was a combination of adhesive and cohesive failures which were not found in the current study. Fracture failure modes were examined with a stereomicroscope which was possibly inadequate for such a detailed study, and the use of a scanning electron microscope might have discovered mixed failure, so it should be considered in further confirming research.

A problem discovered during the study was that sometimes when parts of the restorative materials were being treated, the two parts did not always adhere to each other. This observation was probably due to the acrylic split mold, which would cause adhesion failure during movement. The problem can be prevented by fixing the mold tightly to restrict movement during the treatment, and the acrylic split mold design needs to be improved to provide better stability.

The present study was a laboratory experiment, and the materials used were X-tra fill® or Filtex Z350 XT®, so the results cannot be generalized to other conditions and materials. Further studies should be conducted to consider the adhesive agent system and light treatment machine and the selection of restorative materials vis-à-vis their mechanical properties (e.g., durability, microleakage, and shrinkage after polymerization). The study results can be used in clinical practice as a guideline for surface treatment and choice of resin composite suited to repair bulk-fill resin composite.

Conclusions

Shear bond strength of X-tra fill® after repair with either a bur or airborne particle abrasion was comparable and greater than not having any surface treatment. Repairing X-tra fill® with the same type of resin composite provided higher shear bond strength than repairing with Filtex Z350 XT.

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