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Original Article

Comparison the Effect of Different Surface Treatments on Shear Bond Strength of Repaired Composite

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Abstract

Background: Repairing aged composite resin is a challenging process. Many surface treatment options have been proposed to this end. This study evaluated the effect of different surface treatments on the shear bond strength (SBS) of microhybrid composite resin repairs.

Methods: Sixty-four cylindrical specimens of a Filtek Z2503M composite resin were fabricated and stored in 37°C distilled water for two weeks. The specimens were divided into 8 groups according to the following surface treatments: composite primer (group 1); composite primer + G-premio (group 2); composite primer + SE bond (group 3); roughening with coarse-grit diamond bur + composite primer + G-premio (group 4); roughening with coarse-grit diamond bur + composite primer + SE bond (group 5); Er,Cr:YSG + G premio (group 6) Er,Cr:YSG + Se bond (group 7); bulk composite (positive control group). Then the same composite resins were packed on specimens into layers. After being stored in distilled water for 24 hours, specimens were thermocycled. The SBS of the resin composites were tested with a universal test machine. Data was analyzed using one-way ANOVA and Tukey test ($P < 0.05$).

Results: One-way ANOVA indicated no significant differences between groups 2, 3, 4, 5, 7 and control group. SBS of group 1 and 6 was significantly lower than control group. Surface treatment with diamond bur + composite primer + SE bond resulted in the highest bond strength.

Conclusions: Surface roughening with bur and using sixth generation adhesives (SE bond) and eighth generation bonding agents (G-premio) and laser with sixth generation indicated similar result to intact composite, although use of composite primer did not lead to acceptable bond strength for repairing composite. However Clearfil SE bond show highest bond strength.

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Background

With the increased demand for aesthetic procedures as well as the development of bonding systems, the applied composites are routinely and widely used for direct restorations (1-3).

In recent years, in spite of the considerable advances in resin composite components, marginal failures have occurred due to abrasion, discoloration, secondary decay, polymerization contraction, microleakage, poor anatomical form, pain and tenderness, which limit the composites' lifetime (3-8). In these cases, selected treatments include repair or replacement of the entire restoration. The repair is a conservative process, so that there is no need for removing entire restoration and the minimum cavity preparation is only required (9). Repairing old composite restorations is considered as a challenge due to the reduction of its free radicals after the initial steps of polymerization (10,11).

Highlights

- Surface roughening with bur and using sixth and eighth generation bonding agents are valuable way for composite repair

During less than 24 hours since the curing of the bonding composite, it does not cause any problem due to the unreacted remaining free monomers. Nevertheless, after a longer time after the composite curing, these free monomer groups tend to leave the composite and the water absorption by resin over time makes it difficult to replace the old bonding composite with the new one (1,4,5,7,12,13). A variety of methods has been proposed to obtain the bond strength between the old and new composite interface. These techniques (including rinsing,

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roughening surface with bur or disc, sandblasting, etching, use of silane and different bonding) are used to change the surface topography (14-18).

The surface preparation refers to mechanical and chemical methods such as chemical bonding with organic matrix and exposed filler particles (1,8,12,19). Studies have concluded that the bond strength will significantly increase if air abrasion or drilling is used as a composite roughening technique (17,20-25)

Universal bonding used as etch and rins, self-etching and selective etching protocol in direct and indirect restorations and capable of bonding with all substrates, including enamel, dentin, non-precious alloys, Nobel and zirconia without any need for primer. They have a film thickness less than 10 microns and are compatible with different types of composites and light-cure, self-cure and dual-cure resin cements. 10-MDP and 4-META provide acceptable bonds in this bonding. The use of these agents usually saves time and decreases the errors of multiple stages of applying it (26,27). Laser applications in dentistry include surgery, diagnosis, decay prevention, decay removal, tooth preparation, root curing, orthodontics, gum diseases treatment, implants, pediatric dentistry and so on (28,29). In recent years, the effect of laser on the bond strength of composites has been significantly drawn attentions. It has been reported that Er,Cr:YSGG laser is able to produce a considerable surface roughness than that produced by acid etching of enamel and dentin surfaces (30).

There is still no agreed protocol on bonding the old composite to the new one, and the variable bond strengths have been obtained by different methods, which can be due to the difference in the composition of the used composites and various methods of applying them (1, 13).

This study aimed to assess the effect of various surface preparation methods and Er,Cr:YSGG laser, composite primer and different bonding systems on the repaired composites' shear bond strength (SBS).

Materials and Methods

A total of 64 cylindrical shape samples were prepared with a height of 6 mm and a diameter of 4.5 mm from a light-cure microhybrid composite (Z250XT, 3M, ESPE, USA) with A3 color (Table 1). A transparent plastic mold with a height of 4 mm and a diameter of 4.5 mm was used in order to prepare the samples. The composite was packed in a cylindrical mold in two 2-mm layers using a plastic instrument. 2-mm height was considered for acrylic mounting. The first layer was cured using a light-cure LED device (Guilin Woodpecker Medical Instrument Co., Ltd., China) with an intensity of 1200 mW/cm^2 at a distance of 1 mm for 40 seconds and the light cure device was fully perpendicular to the mold. Then, the second composite layer was placed and a Mylar matrix strip and a glass slide were placed on it to make a smooth surface and remove additions as well as to prevent the formation of oxygen inhibited layer. The intensity of the light cure device was regularly measured by a radiometer (LM-100, Monitex, Xianyang, China). The composite samples were kept in distilled water in a dark environment at 37°C for 2 weeks (7). During this time, the samples were controlled to add water if necessary (6,8); they were then thermocycled (Mashhadnomvo, Mashhad, Iran) for 5000 rpm for aging in the range of 5-55°C with an interval of 30 seconds (2, 4-15). After preparing of all groups, the surface used to restore the composite was polished with silicon carbide paper 800 grit (Sof-Lex, 3M, ESPE , USA) under a water stream as a lubricant.

The samples were randomly divided into 8 groups of 8 each:

Group 1: surface of the sample was rinsed with water for 20 seconds and air-dried for 10 seconds, and a thin layer of primer composite (GC, Tokyo, Japan) was placed on it and cured with LED for 20 seconds;

Group 2: the procedure was similar to that performed in group 1 except that after placing a thin layer of primer composite and curing it for 20 second, the universal G-Premio Bond (GC, Tokyo, Japan) was used, and after 10 seconds it was completely dried with maximum air pressure for 5 seconds, and cured for 10 seconds;

Group 3: the procedure was similar to that performed in group 1 except that after curing the primer composite,

Table 1. Materials

Materials	Type of Material	Main Components	Manufacturer
Composite Primer	Primer	Monofunctional methacrylate, urethane dimethacrylate (UDMA), camphorquinone	GC; Tokyo, Japan
Clearfil SE bond	Two step self-etch adhesive	Primer: MDP, HEMA, hydrophilic dimethacrylate, photo-initiator, water Bond: MDP, HEMA, Bis-GMA, hydrophobic dimethacrylate, photo-initiator, silanated colloidal silica	Kuraray; Tokyo, Japan
G-Premio Bond	Universal adhesive	MDP, 4-MET, MEPS, methacrylate monomer, acetone, water, initiator, silica	GC; Tokyo, Japan
Filtek Z250	Resin composite	Bis-GMA, UDMA, Bis-EMA Zirconia/silica Fillers (without silane treatment)	3M ESPE, St. Paul, MN, USA

UDMA, urethanedimethacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate; Bis-GMA, bisphenol A diglycidylmethacrylate; HEMA, 2hydroxyethyl methacrylate; BHT, butylated hydroxytoluene; MDTP, methacryloyloxydecyl dihydrogen thiophosphate; Bis-MEPP, bisphenol-Aethoxylatdimethacrylat; TEGDMA, triethylene glycol dimethacrylate

the SE bond was applied for 20 seconds and dried with gentle air pressure; then it was bonded and dried with gentle air pressure, and cured for 10 seconds;

Group 4: the samples were roughed with a tough cylindrical diamond bur (Tizkavan, Tehran, Iran), which was gently pulled over the surface (all 5 diamond bur samples were replaced after preparation). Then the primer composite and then the G-Premio Bond were used according to the manufacturer's instructions;

Group 5: the samples were roughed by the method applied in group 4; then the primer composite and then the SE bond (Noritake Dental, Kuraray, Tokyo, Japan) were used according to the manufacturer's instructions;

Group 6: the procedure was similar to that performed in group 1 except that the surface preparation of the composite was performed with Er,Cr:YSGG Laser (Bio Lase, ER, USA) and MZ6 type gold handpiece, with a diameter of 600 micron, power of 3 watts, frequency of 20 Hz, energy of 150 mJ and density energy of 41.66 J/cm^2 with air percentage of 60% and water percentage of 30% from the distance of 1 mm perpendicular to the surface on a composite disk of 6 mm diameter for 10 seconds. Then, the G-Premio Bond was used according to the manufacturer's instructions;

Group 7: the procedure was similar to that performed in group 6 except that the SE bond was used according to the manufacturer's instructions; and

Group 8: Group 8 was the control group and composite samples were prepared in a mold with a height of 6 mm and a diameter of 4.5 mm.

For making shear tests easy, 2 mm of the end of each composite sample was mounted in an acrylic mold (Acroparse, Tehran, Iran). Then a plastic mold was placed and 2 mm Z250XT microhybrid composite with A1 color was packed in 2 layers. The composite samples were then kept in distilled water at 37 °C for 24 hours and thermocycled for 5000 times in the range of 5-55 °C with an interval of 30 seconds (8).

For making experiments and microshear tests easy, 2 mm of the end of each composite sample was mounted in an acrylic mold (acroparse, Tehran, Iran) (5) because the composite samples were small and bright; hence, they were temporarily turned into a heavy and bulky sample and placed on the universal testing machine (STM-50, Santam, Tehran, Iran). The microshear force was applied and measured at a speed of 0.5 mm/min through a chisel with a straight edge of thickness of 1 mm to the old and new composites' interface until the samples were burst.

Results

The mean and standard deviation of SBS of the studied groups are presented in Table 2.

According to the results, the highest SBS was obtained for B & CP & SE (group 5) and CP and SE (group 3) and the lowest SBS was obtained for Laser & Gprimio (group 6). Based on the one-way ANOVA results, the mean difference between the groups was significant ($P < 0.05$) (Figure 1). According to the Tukey's post hoc test results, there was a significant difference in mean SBS between group 1 (CP) and the control group ($P = 0.006$). Furthermore, a statistically significant difference was observed between the mean SBS of the group 6 (ER & G-premio) and group 8 (control) ($P < 0.001$)

Discussion

The composite restorations have been widely used owing to their esthetic, mechanical bonding to dental tissue, conservative tooth preparation, and the higher acceptance by patients. In many countries, the composite restorations have been taken into account due to reduced risk of decay. A variety of surface preparation methods has been employed to increase the repaired composite restorations' bond strength (7,20). Surface preparation is required to remove the surface layer and obtain a clean surface with high superficial energy level and to achieve a higher cross-sectional surface through porosity for more access of bonding agents.

Although surface preparation methods have been applied in order to achieve the highest bond strength in repaired composites, no specific strategy yet has been reported. Laser is one of the newest methods. Er,Cr:YSGG laser can be highly absorbed by hydroxyapatite and water. The absorption of photon energy results in evaporation, leading to the macroscopic and microscopic irregularities

Table 2. The Means and Standard Deviations of Shear Bond Strength

Groups	Number	Maximum	Minimum	Mean±SD
CP	8	27.60	5.43	15.10 ± 6.31
CP & G-Premio	8	28.38	4.78	17.22 ± 7.02
CP & SE	8	38.92	12.07	23.28 ± 8.33
B & CP & G-Premio	8	29.73	11.54	18.02 ± 6.29
B & CP & SE	8	29.75	15.11	24.33 ± 5.42
Laser & Gprimio	8	19.52	4.9	11.92 ± 4.25
Laser & SE	8	27.20	13.10	19.58 ± 5.35
Control	8	40.43	8.21	26.89 ± 10.70

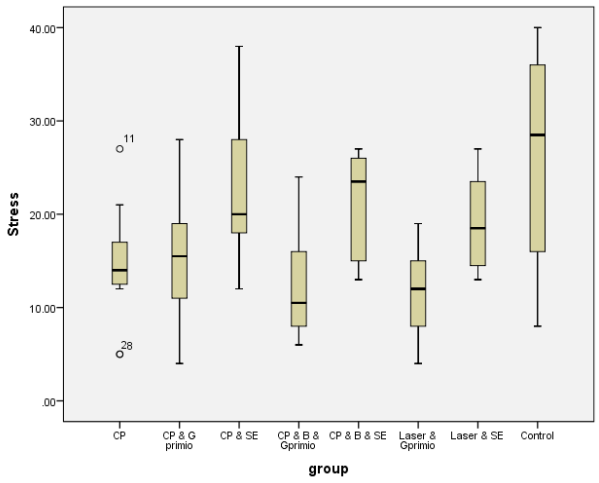

Figure 1. Medium, Minimum and Maximum Shear Bond Strength (MPa) and Data Distribution.

at the material's surface. The goal of using laser in composite restoration is 1) increasing roughness and superficial energy and 2) mechanically preparing the surface conservatively (21,26).

Different methods of aging materials in the studies on composite restoration are significant factors. Samples were kept in distilled water for 2 weeks, since the water absorption controlled by the dissemination process leads to the rinsed monomers not involved in the reaction and contraction of the matrix. The water weakens the polymeric structure of the composite resin as a plasticizer that can also degrade the matrix-filler bonding surface by the hydrolytic degradation of the silane surface and the filler particles' surface. Given that in various studies, 5000 rpm thermocycles showed the lowest repair bond strength compared to citric acid or boiled water, we also used 5000 rpm (in the range of 5-55°C with the interval of 30 seconds) to simulate the oral environment (27,30). The repaired composites' bond strength should be similar to the cohesive strength of the intact composite. Therefore, we considered the control group as homogenous composite samples.

According to the results of this study, there was no significant statistical difference in mean SBS between group 2 (CP & G-premio), group 3 (CP & SE), group 4 (B & CP & G-premio), group 5 (B & CP & SE), and group 7 (Er & Se) and group 8 (control), i.e., these seven groups showed significantly different mean SBS compared to that of the control group. There was a statistically significant difference in the mean SBS of the repaired composites between group 1 (CP), group 8 (control), and group 6 (Er & G-premio) and the control group (bulk composite) , showing no acceptable bond strength for composite restoration. The maximum mean SBS was observed in group 5 (B & CP & SE) and group 3 (CP & SE), and the minimum mean SBS was observed in group 6 (Er & G-premio).

Primer composite is one of the materials recently introduced for composite restoration. It is a light-cure primer. Its advantages include easy use by a brush, easy use, reconstruction of the oxygen-inhibited layer, decreased number of the required steps, as well as increased speed of work in the clinic; nevertheless, few studies have been carried out to evaluate the efficacy of this material. In the study of Çelik et al, there was a statistically significant difference in mean tensile bond strength between a group of composites repaired with composite primer and the intact composite (control) group, which is in line with the results of the present study. This may be attributed to the novelty of this material and the low level of information about it (30).

Since universal bonding benefits from a new technology, its applying process is facilitated, which leads to time saving and reduction in errors associated with the multiple stages of using it.

Universal bonds designed to connect to the dental structure with total-, self- or selective-etch techniques can bond various non-dental structures, such as composite resins, zirconia, and metal alloys without the need for additional primers (28). In this generation, the addition of nanofillers to particles with a mean of 12 nm enhanced the penetration of resin monomers and the thickness of the hybrid layer, strengthening the mechanical properties of this generation of bonding. Nano-bonding agents are solutions of nanofillers leading to the increased strength of enamel and dentin bond. Few studies have been conducted on their efficacy. In this study, the universal bonding (G-premio) was used (29).

In the study of Joseph et al, the highest mean bond strength was obtained for the Futura bond DC bonding group (the 8th generation) than Clearfil SE bond (the sixth generation) and Adper™ Easy One (the seventh generation) groups; these results are not consistent with the results of the current study. This inconsistency can be due to insufficient drying time or methods of applying the bonding that affect the bond strength obtained with the G-Premio Bond. Other variables like functional monomers, cross-linking monomers, solvents, inhibitors and activators can have various bonding that can influence the bond strength. Furthermore, the substrate (composite, dentin, enamel, etc), type of the performed test for bond strength, storage duration and aging conditions of the substrate affect the results, as well (31).

In contrast to the present study, Nalcaci and Cokakoglu reported that applying bonding did not significantly enhance the repaired composites' bond strength, which may be attributed to the high degree of conversion of the new composite (32). In a study by Poggio et al on the effect of dentin preparation on universal bonding strength, the results revealed that universal adhesive type did not have any significant effect on the composite's SBS. The interesting finding in this study was that when the surface preparation was performed with glycine, only

G-premio universal bonding could significantly enhance the SBS; perhaps, the significant effect of G-premio universal bonding on the increase of the bond strength in the presence of glycine is due to the lower pH of this bonding (33).

Consistent with the results of the present study, it has been observed that G-Premio Bonding with surface roughness enhances the bond strength. In line with the present study, Hannig et al found increased bond strength seems to be due to the capability of adherence of the new composite to the old one by increasing the available surface to penetrate bonding agents because of porosity (34).

Papacchini et al reported lower bond strength in the milling roughness group compared to other available methods. These results are not in accordance with the present study, which can be attributed to the exposed filler after using bur and interfering with bonding agents (10). In the current study, the groups that used the SE bond indicated the maximum bond strength, which is similar to the findings of Cavalcanti et al in which the bond strengths were higher in the Clearfil SE bond repaired composites than other bonding systems (3).

In the study of Irmak et al, the highest mean SBS was obtained for the Clearfil SE bond repaired composite group, which is in line with the current study. Composite restorations are continuously exposed to the saliva and therefore can absorb water and become swollen, leading to resin degradation and filler particles rinse. Since self-etching adhesives are hydrophilic, they can effectively bond to old composites in interacting with the phosphate group of adhesive systems (35).

10-MDP in universal bonding makes chemical bond with with hydroxyapatite crystals. Moreover, similar functional chemical monomers bond oxides by hydrophilic phosphate terminals and copolymerized with resin monomers through the hydrophobic methacrylate terminal (31,36).

In line with our study, in the study by Ahmadizenouz et al on the SBS of the nanofilled composites repaired after different surface preparation and Er:YAG laser methods, the samples were assigned to 5 groups with different surface preparation methods, including air abrasion, Er:YAG laser, rough diamond burr and then etching with 35% phosphoric acid, etching with 9% hydrofluoric acid and control group. It was observed that in surface preparation with all methods, the SBS was significantly higher than control group; nevertheless, in the studied groups, only the rough diamond burr with 35% phosphoric acid group indicated significantly higher SBS. The use of burr leads to macromechanical bonding; and with the removal of the debris layer and exposure to the lower surfaces, phosphoric acid increases the surface and spreads stress in the interface (1).

Furthermore, Barcellos et al studied the tensile strength of composites repaired after various surface preparation and laser methods, and found that the use of diamond burr and ordinary adhesives and sandblasts for repair are simple and cost-effective. However, the use of laser and silane alone, hydrofluoric acid and silane, or a self-etch adhesive are methods producing less bond strength (2). Another finding in our study was that the laser in combination with G-Premio Bond did not increase the bond strength. By converting light to heat energy and increasing the pressure inside the resin, the Nd:YAG applied to the composite surface causes explosion and ablation. In indirect restoration composite by ultrasonic washing, the particles of the explosion interfering with bonding may be removed. However, washing is not possible in direct restoration, and the presence of loose particles and microcracks can damage the bond strength. The Er,Cr:YSGG waterlase laser abrades the hard tissue by its high-energy particles; the created surface temperature and subsurface microcracks that are the starting point for stress are lower. In addition, the high-energy water molecules provide a cleaner surface by removing resin matrix during ablation process (37,38).

In line with our study, Alizadeh Oskoee et al (14) concluded that there was a significant difference between the increased shear bond after applying Er,Cr:YSGG laser and those in other groups.

Cho et al observed that air abrasion with 50-micron aluminum oxide showed significant SBS compared to the laser method, but no significant difference was observed compared to silica coating. Lasers did not produce any significant effect on bond strength. The highest SBS was provided by air abrasion with 50-micron aluminum oxide and silica coating, followed by bonding agents recommended as satisfactory methods to enhance the quality of the repaired composites (4). The surface roughness created using laser was the highest roughness and was associated with the highest degree of irregularity compared to other methods; and cracks were only observed on the surfaces under the laser irradiation (4).

Conclusions

The findings of the present study show that the use of burr increases the SBS of repaired composites. Both Clearfil SE bond and G-Premio Bond have acceptable bond strengths of repaired composites compared to the intact composites. Nevertheless, Clearfil SE bond shows higher bond strength. In addition, primer composite alone has lower bond strength. Hence, the use of primer composite alone is not suggested for this purpose. In the case of laser method, its combination with Clearfil SE bond shows higher bond strength, while it leads to no acceptable outcome with G-Premio Bond.

Authors' Contribution

MS, design and conception of the study as well as the revision of the prepared manuscript; LR, supervisor; BA, literature search and data collection, analysis of the data and preparation of the primary draft. EN literature search; MA, literature search and data collection. All

the authors have read and approved the final manuscript.

Ethical Statement

The procedure of the study was approved by the Ethics Committee of the Hamadan University of Medical Sciences.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

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