Effect of Various Surface Treatment on Repair Strength of Composite Resin

M. Hasani Tabatabaei,[1] Y. Alizade,[2] S. Taalim[3]

[1] Assistant Professor, Department of Operative Dentistry, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[2] Assistant Professor, Faculty of Mechanic, Amirkabir Industrial University, Tehran, Iran
[3] Postgraduate Student, Department of Operative Dentistry, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

Statement of Problem: In some clinical situations, repair of composite restorations is treatment of choice. Improving the bond strength between one new and old composite usually requires increased surface roughness to promote mechanical interlocking since chemical bonding might not be adequate. Similarly, the treatment of a laboratory fabricated resin composite restoration involves the same procedures, and there is a need to create the strongest possible bond of a resin cement to a previously polymerized composite.

Purpose: The aim of this study was to evaluate the effect of various surface treatments on the shear bond strength of repaired to aged composite resin.

Materials and Methods: Eighty four cylindrical specimens of a composite resin were fabricated and stored in distilled water for 100 days prior to surface treatment. Surface treatment of old composite was done in 6 groups as follow:

1- Air abrasion with CoJet sand particles with micoretcher + silane + dentin bonding agent
2- Air abrasion with 50µm Al_2O_3 particles+ phosphoric acid+ silane+ dentin bonding agent
3- Air abrasion with 50µm Al_2O_3 particles + phosphoric acid + dentin bonding agent
4- Diamond bur + phosphoric acid + silane + dentin bonding agent
5- Diamond bur + phosphoric acid + dentin bonding agent
6- Diamond bur + phosphoric acid + composite activator + dentin bonding agent

Then fresh composite resin was bonded to treated surfaces. Twelve specimens were also fabricated as control group with the same diameter but with the height twice as much as other specimens. All of the specimens were thermocycled prior to testing for shear bond strength. The bond strength data were analyzed statistically using one way ANOVA test, t test and Duncan's grouping test.

Results*:* One-way ANOVA indicated no significant difference between 7 groups (P=0.059). One-way ANOVA indicated significant difference between the three diamond bur groups (P=0.036). Silane had a significant effect on the repair bond strength of diamond bur/silane group. There was no significant difference in the bond strength diamond bur/composite activator group and diamond bur/no silane group. Silane had no significant effect on the repair bond strength of air abrasion group. The lowest bond strength was for diamond bur/ composite activator group.

Conclusion*:* The best surface treatment for repair of an aged composite restoration could be used of diamond bur with silane, air abrasion with or without silane or ceramic deposition with CoJet Sand system.

Silanation is a necessary step in the repair of composite resin with the use of diamond bur but not with the use of air abrasion.

Key Words*:* Composite resin; Repair; Surface treatment; Bond strength

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Bonding fresh resin composite to previously cured composite restorations is a fairly common occurrence in clinical practice. Composite restoration repairs may be considered the treatment of choice for surface discoloration of existing restorations, small areas of recurrent caries along the margin of an otherwise sound composite restoration, or when complete removal of a very large composite restoration would unnecessarily jeopardize the health of a tooth. Similarly the treatment of a laboratory fabricated (indirect) resin composite repair, because there is a need to create the strongest possible bond of resin cement to a previously polymerized composite. [1,2]

Occasionally there is need for cementing a porcelain veneer on a previously cured composite restoration, so bond strength of resin cement to previously cured composite is a significant matter. [2]

Unfortunately, complete removal of a failed composite restoration would generally entail removal of previously etched enamel and subsequent etching of more enamel in order to optimize the enamel bond. [3]

Complete removal will therefore inevitably lead to larger cavities with further loss of tooth substance. So based on tooth saving principles, repair is an appropriate alternative to replacement of failed restorations and possibly increases the longevity of restorations at low cost. [4]

However some other factors like clinical situations, cost, esthetic, extent and mode of failure, failure site, quality of existing restoration, cause of failure and expected age of the existing restoration affect the treatment plan.[4]

Bond strength of incrementally built composite up on fresh, uncontaminated or unprepared composite resin, is similar to cohesive strength of the material.[5] There is, however, the possibility that repair may lead to an unacceptably weak restoration. This potential problem has been investigated in several composite resin repair studies that have shown a wide variation in interfacial repair bond strengths equal 25-80% of the cohesive strength of the composite.[6-9]

It seems because of lack of air-inhibited layer on surface, the degree of unreacted carbon double bond is lower and chemical bonding between fresh and aged composite is not a reliable bond.[10,11]

For this reason, some methods such as hydrofluoric acid etching, micro etching with air abrasion, use of coarse burs, silicon paper and green carburandum stone; acetone application and silane have been suggested. [12-15]

Recent studies have found air abrasion techniques quite effective in roughening the aged composite surface prior to bonding.[14,16]

In addition, several studies have shown that the use of an intermediate bonding agent enhances the repair bond significantly.[6,17,18]

Recently a new system has been introduced and qualified as CoJet-sand system (3M ESPE, USA), which uses 30 micron silanated silica coated aluminum oxide particles with high pressure air abrasion unit to create a ceramic like layer on the surface of old composite.

There is an expectance that this layer can bond chemically and mechanically to fresh composite, thus can enhance the repair bond strength. [1]

One the other hand, composite activators are introduced to convert the unsuitable bonding surface of aged composite to an active one. These materials increase surface energy and wetting ability of composite surface. One of these products (composite activator, Bisco, Inc) is a methacrylate surfactant, and has been suggested for this mean.[10]

The purpose of this study was to evaluate in-vitro effectiveness of various surface treatments on the shear bond strength of repaired to aged composite resin.

Materials and Methods

The materials used in this study are listed in table I and were used strictly according to the manufacturer's recommendations.

Seventy-two composite samples were prepared, 12 in each group. All composite specimens were made in a cylindrical mold was inserted on a glass slide and filled with 1.5mm layers of Tetric ceram composite and covered with Mylar strip and glass slide. Each group was light polymerized with an Astralis 7 curing unite (Ivoclar Vivadent AG, Liechtenstein) for 60 seconds with 450 mw/cm^2.

The light out put was checked regularly during the study and the light curing tube was kept in contact with the glass slide to ensure adequate curing.

After curing of top surface, the mold was turned up side down and the lower surface was similarly cured, for 60s.

The control group was made in two 3mm of increments of composite, with 5mm diameter, to make the unprepared test samples.

These specimens were carefully removed from the mold and another exposure of 40s to light was done at the center of cylinder in each side.

All samples were stored in distilled water at 37ºC for 24 hours, and then test samples were hand polished by fine grit sand paper disk for 5 strokes with a low speed handpiece. (a 2-second movement of disk across the diameter of sample surface constitutes a stroke.)

After polishing, each sample was rinsed for 15s and all samples (control and test) were stored in distilled water at 37ºC for 100 days.

Test samples were randomly distributed into 6 groups (n=12) for repair using the following methods:

Table I- Materials used in this study

Material	Manufactured by
Tetric cream	Ivoclar Vivadent
Excite	Ivoclar Vivadent
Total etch	Ivoclar Vivadent
Al_2O_3	Bisco, Inc
CoJet-Sand	3M ESPE,
Composite Activator	Bisco, Inc
Monobond S	Ivoclar Vivadent

Group 1: Air abrasion with CoJet- sand using a microetcher operating at 3 bars pressure at a 5mm distance and 90ºC to the composite surface for 7 seconds. Silane was applied to composite surface and allowed to dry for one minute. Any residual solvent was evaporated with compressed air and finally a dentin bonding agent (Excite) was used according to manufacturer's instruction.

Group 2: Air-abrasion with 50µm aluminum oxide particles using a microetcher operating at 3 bars pressure at a 5mm distance and 90° to composite surface for 7s. Then 37% phosphoric acid (H_3P0_4) was applied for 15s, rinsed and dried. Silane was applied to composite surface and allowed to dry for one minute. Any residual solvent was evaporated with compressed air and finally dentin-bonding agent was used.

Group 3: Like group 2 without silane application.

Group 4: In this group composite surfaces were roughened in 5 strokes with coarse diamond bur (No: 8811 012 Diatech AG). A new diamond bur was used for each 4 samples. Then 37% phosphoric acid, silane and bonding agent was applied as for group 2.

Group 5: Like group 4 without silane applying.

Group 6: Composite surface was roughened in 5 strokes with coarse diamond bur. After cleaning with phosphoric acid and acid washing, a surface surfactant (composite activator) was applied in layers according to manufacturer's instruction, and finally dentin bonding was used. (4)

The specimens were inserted in split mould and fresh composite was condensed over prepared surface in 1.5m layers. Each layer was cured 60s. Samples were removed from mold and additional curing was done at center of sample in each 4 sides for 40s. All specimens were stored in distilled water at 37ºC for a week and then thermocycled for 500 cycles between 5 and 55ºC with a interval time of 30s. the specimens were loaded in a Zwick material testing machine (model=1494, Germany) with a straight-edge chisel of 1mm thickness attached to the cross head, shearing force of 0.5mm/min at failure was recorded by a person blind to the samples according to ISO/TR 11405.[19]

Shear bond strength was calculated by dividing the failure force by the cross sectional area of samples.

Data was analyzed using one way analysis of variance (ANOVA), Post hoc Duncan's multiple range test and T student using SPSS statistical software. A confidence level of 95% was selected to determine statistical significance.

Results

The mean and standard deviation of shear bond strength data for various surface treatments are illustrated in table II. The highest bond strength was found for Group 4 (diamond bur with silane) followed by control group.

Surface treatment with diamond bur and composite activator group (group 6) had the lowest bond strength. One-way ANOVA indicated significant differences between diamond bur/silane group (group 4), diamond bur/no silane group (group 5) and diamond bur/ composite activator group (group 6) ($P<0.05$).

Consequently the mean bond strength of this 3 group was compared with Duncan's test that showed silane effect was significant.

T students test showed no significant difference between air abrasion/silane group (group 2) and air abrasion/no silane group (group 3) ($P>0.05$).

T student test indicated no significant differences between air abrasion/silane and diamond bur/ silane group. ($P>0.05$)

T student test also showed statistically significant difference between air abrasion/no silane and diamond bur/no silane groups ($P<0.05$). Since many clinicians use similar method to the one used in group 6, to repair composite restorations, the bond strength for diamond bur/no silane (group 6) was compared with that of control group statistically significant difference in the bond strength was found between the two groups ($P<0.05$).

Discussion

There are many problems in repair of aged composite resin restorations. Because there is no air-inhibited layer and degree of conversion is high[11,20] and because of leaching of non reacted monomers even though in minor amounts,[21] there is a reduction in number of unsaturated double bonds for producing the initial and secondary bonds between the new and old composite. Meanwhile with increasing polymerization, there is decreasing in solubility and permeability of polymer,[22] therefore, a roughened surface and micro mechanical bonding is needed for composite repair.

Increasing the surface roughness provides better mechanical interlocking and increases the probability of finding residual free carbon bonds through the layer surface area. [23] In the present study six different surface treatment methods were evaluated to achieve optimum repair bond strength and results were compared with the cohesive strength in control group.

Table II- Shear bond strength (MPa) of study groups

Groups	N	Mean	SD*	SE**	95% confidence interval for mean	
					Lower bound	Upper bound
Control	12	23.7133	5.31407	1.53404	20.3369	27.0897
Group 1 (CoJet)	12	21.9267	4.51461	1.30326	19.0582	24.7951
Group 2 (AA+S)	12	22.5792	5.37616	1.55196	19.1633	25.9950
Group 3 (AA-S)	12	23.3925	3.39111	0.97893	21.2379	25.5471
Group 4 (DB+S)	12	23.7600	3.16935	1.49226	20.4755	27.0445
Group 5 (DB-S)	12	19.2967	2.90993	0.84003	17.4478	21.1456
Group 6 (DB+CA)	12	19.1342	5.65593	1.63273	15.5406	22.7278
Total	84	21.9718	4.91393	0.53615	20.9054	23.0382

*SD: Standard deviation** SE: Standard error

The results of this study revealed that with various methods of surface treatment, the bond strength close to the cohesive strength could be achieved; it means that most of those methods were effective in bonding the aged composite to fresh one.

The repair strength required for a satisfactory composite repair in vivo has been thoroughly investigated and there are few published reports on this subject. In contrast, the bond strength of composite to etched enamel has been extensively investigated and is reported to be about 15-30 MPa. [6,10,11]

It is well known that composites seldom fail mechanically at the junction with etched enamel and it can therefore be surmised that a repair bond strength that is similar to that of composite to etched enamel would be clinically adequate.[18] One the basis of this fact the results of this study would suggest that any of the repair methods would produce adequate repair bond strength.

Analysis with one-way ANOVA didn't indicate significant differences between groups. This result is supported by the study of Kupiec who didn't find significant differences in surface treatment with diamond bur and abrasion with 50m aluminum oxide particles after 24 hours aging.[24]

The repair bond strength in CoJet (CJ-S) system group was 21.92 MPa, that when compared to the cohesive strength of control group (23.71 MPa), was in acceptable average bond strength value.

CJ-S particles roughen and increase the surface energy of aged composite and produce a proprietary (silicate ceramic layer) of sub micron particles, which can be treated with a silane-coupling agent that chemically bonds to bonding resin and resin composite of the repair.[1] The advantages of the CJ-S are: smaller size of particles when compared with 50µm air abrasion particles that makes it safe in intra-oral using and facilitated applying because of eliminating phosphoric acid surface cleaning.

This study showed CJ-S didn't increase the composite repair bond strength significantly. This finding agrees with the report of Bouschlicher that showed CJ-S didn't improved bond strength of indirect composite restorations[25], but Bouschlicher et al reported an increase in the repair bond strength for hybrid and microfilled composite resins with CJ-S. [1]

1- Air-abrasion groups:

T-test didn't indicate any significant difference between the two groups. Air abrasion removes some resin matrix and exposes the surface filler and results in surface roughness of composite resin. [26]

The finding of this study is not in agreement with many of the reports. [3,6]

However, Lloyd et al [27] found no difference between the repair strength of five chemically cured composite when the surface was ground or not. Besides, investigators have noted a reduction in repair strength after surface abrasion.[22,28,29] They have generally attributed this reduction in strength to the exposure of filler particles following abrasion, and hence reduced availability for primary bonding to the resin.

Other possibilities are that surface debris interfered with the repair or that inclusion of air at the interface reduced the surface area available for bonding.

2- Diamond bur groups:

One-way ANOVA showed significant difference between these groups (P=0.036), the highest mean value for bur and silane and the lowest for composite activator.

Diamond bur roughening may create microretentive features as well as microretention and this may have differentially exposed more filler particles than air abrasion methods. Silane treatment of the exposed filler particles in the composite matrix results in the formation of siloxane bonds when the silanol groups condense with similar groups on glass or other silicon surfaces. At the same time the methacrylate groups of the organosilane compound form covalent bonds with use the resin when it is polymerized. Some studies have failed to establish that the use of silane reliably enhance the strength of composite repairs (30.15 MPa). The finding of this study agrees with Bouschlicher et al that revealed silanation increases the bond strength of composite repair. They supposed if clinicians are unsure of the nature of prudent to utilize silane because all groups had statistically equivalent or higher bond strength with silane application. [1]

Use of a diamond bur for surface roughening may differentially expose more filler particle than the air abrasion methods. The smear layer created by a rotary instrument may also be more effectively penetrated or wetted if silane is applied.

Composite activator used in this study was a surfactant methacrylate that was recommended by producers for aged composite repairs. The treatment protocol was surface roughening with diamond bur, cleaning with phosphoric acid+ composite activator + D.B. + new composite. It was supposed that these agents increase the surface energy and decrease the contact angle, penetrate into old matrix and produce a good bonding.[10,15] But in this study C.A. did not have any significantly effect on repair bond strength. The subtle mechanism of this material is unknown. Because the manufacturer recommends that immediately after applying two layer of C.A., the dentin bonding should be utilized. Cesar compared the effect of a surface-softening agent (art glass liquid), when mainly consist of dimethacrylate, in air abrasion and diamond burs groups and didn't find any statistically difference. [31] It is noticeable that most of clinicians roughen the surface of old restoration and used dentin bonding to repair the old composite. The result of this study indicated the bond strength in this method was significantly less than control group and couldn't achieve the cohesive strength; thus there is a need to use silane.

Conclusion

-CJ-S with silane is recommended for composite repairs. This system is less time consuming and less harming than air abrasion intraorally, and creates acceptable repair bond strength.

-Air-abrasion+ silane produced acceptable repair bond strength.

- Diamond bur should be used with silane.

-Composite activator produced the lowest repair bond strength of all groups.

-The durability of repair bond strength should be evaluated in further studies.

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