Original Article

An in vitro study to compare shear bond strength of aged composite to two single-shade composites

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Abstract

Aim: (a) To evaluate and compare the repair bond strength of aged composite to two single-shade composites. (b) To determine the prominent mode of failure.

Materials and Methods: Thirty composite discs of Filtek 250 (micro hybrid, 3M ESPE, USA) were aged in artificial saliva for 4 weeks and thermocycled for 5000 cycles. The samples were roughened with diamond points (TF12, Mani, Japan) and etched with 37% phosphoric acid. The composite discs were then divided into 3 groups of ten each and the surface was treated with silane coupling agent, followed by bonding agent application. The three groups were restored with one layer of 2-mm thickness of Filtek 250 (Group 1), Omnichroma (Group 2), and Topaz ONE (Group 3) composites, respectively. The samples were subjected to universal testing machine to evaluate the shear bond stress. The detached samples were assessed under 20X stereomicroscope to determine the mode of failure.

Results and Conclusions: Multiple comparisons between the three groups demonstrated significantly higher mean repair bond strength when the same composite was used for repair and between the two single-shade composites, Omnichroma demonstrated significantly higher repair bond strength ($P = 0.002$). Within the limitation of this study, it was concluded that repair with the same composite resulted highest repair bond strength, while the single-shade composites provided acceptable repair bond strengths.

Keywords: Microhybrid composite; omnichroma; repair bond strength; single-shade composite; topaz one

INTRODUCTION

Aged composite restorations may fracture or discolor due to the loss of fillers, hydrolyzation of the polymer matrix, and separation of silane from the composite.[1] Old esthetic restorations that have been compromised can either be repaired or replaced completely.[2,3] Complete removal of older restoration leads to loss of intact dental structures including enamel and endangers the tooth structure, therefore, repair of the composite is a more conservative and modern approach according to studies by Nassoohi *et al.*,[3] Rinastiti *et al.*,[4] and Mjör *et al.*[5]

Commercially available composites are copolymers of methacrylate-based monomers (Bis GMA and TEGDMA) which harden after a free radical-induced polymerization reaction. This reaction is strongly inhibited by free radical scavengers such as oxygen. The oxygen diffusing from the atmosphere into the curing resins results in the formation of a soft, sticky, superficial layer on the freshly polymerized resins and is known as the oxygen inhibition layer which improves interfacial bonding. This layer adapts the overlying new material and increases the contact area between the two layers and allows the materials on both sides to cross the interface and blend together to form an interdiffusion zone, where

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copolymerization can take place to produce a chemical bond.[6]

In aged composites, due to water sorption, there will be a deficiency of freely available monomer and carbon double bonds in the matrix, which reduces the availability of nonpolymerized oxygen inhibition layer which is essential for bonding of new layers of the composite during the repair process.[2,3,7,8] Studies have been done where various surface treatments of aged composite have been used to overcome the challenge of bonding new composite to them.[9]

Repair of aged restorations requires knowledge of the type of composite used, its composition, and shade, which at times is close to impossible. Shade matching between old restoration and new repair composite is important as the optical properties of aged composites change and complicate the shade selection. In this respect, new single-shade resin composites have been introduced that claim to match the 16 VITA shades and simplify the restorative process.[10,11]

Shear bond strength and mode of failure are the essential tests that are employed *in vitro* to assess the bond strength of new composite to aged composite. Failure modes can be interpreted in a way that materials with high shear bond stress will demonstrate cohesive failure through the composite. Whereas adhesive failures are more common than cohesive failures in materials that have low bond strength.[2,3,12,13]

In our literature search, there were no studies evaluating the shear bond strength of aged composite to single-shade composites when used in the process of repair. This study aims to evaluate the shear bond strength of aged composite using single-shade composites and to determine the prominent mode of failure.

MATERIALS AND METHODS

Institutional ethical clearance was obtained for the protocol of this *in vitro* study (VIDS-IEC/PG/APP/2023/47). The sample size was estimated using the GPower software v. 3.1.9.7 (Franz Faul, Universität Kiel, Germany), the total sample size was 30. Each study group comprised 10 samples (10 samples × 3 groups = 30 samples).

The study was done using three composites-a microhybrid universal composite (Filtek z 250, 3M ESPE, USA), a nanofilled single-shade composite (Ominichroma Tokuyama Dental, Japan), and a nanohybrid composite single-shade composite (Topaz ONE, Kulzer, Germany). The study consisted of thirty samples of composite discs which were divided into three groups.

Thirty composite discs were made using microhybrid composite (Filtek z 250, 3M ESPE, USA) which were divided into 3 groups. To make the composite discs, a silicone putty impression of a disc with dimensions 3 mm (height) ×5 mm (radius) was used, and the composite was compacted into the mold, leveled out with a Mylar strip, and cured for 20s using a LED-curing light (Woodpecker, China). Samples were finished and polished using abrasive discs (medium fine and superfine) (Sof-Lex/3M/USA).[14] Samples were washed with water to remove surface debris and then stored in distilled water at 25°C for 24 h to complete the polymerization process [Figure 1].

These discs were stored and aged in artificial saliva prepared according to a study by Gupta *et al.*,[15] and incubated at 37°C for 4 weeks to simulate the oral temperature. To thermally age the specimens, they were placed in a thermocycling device for 5000 cycles at a temperature of 5°C–55°C.[16]

The surface of the composite discs was roughened with a tapered diamond bur (TF12, Mani-Japan) and etched with 37% phosphoric acid (3M ESPE, Scotchbond, Etchant) for 20, washed for 15 s, and then dried for 10 s.

Silane coupling agent was applied on the surface of the aged composite (Silano, Angelus) and waited for 4 min for the solvent to evaporate after which using a microtip-brush, two layers of dentin bonding agent (3M ESPE, Adper Single Bond 2, USA) was applied on the surface and dried for 5 s by air spray and light cured for 20 s with the curing tip placed at a distance of 1 mm.

The specimens were divided into 3 groups:

- Group 1 (control group): One layer of microhybrid multishade composite (Filtek 250, 3M ESPE, USA) of 2-mm thickness was placed on the surface and cured for 20 s (n = 10)
- Group 2: One layer of nanofilled single-shade composite (OmnichromaTokuyama Dental, Japan) of 2-mm thickness was placed on the surface and cured for 20 s (n = 10).
- Group 3: One layer of nanohybrid single-shade composite (Charisma Topaz ONE, Kulzer, Germany) of 2-mm thickness was placed on the surface and cured for 20 s (n = 10).

The samples were then subjected to shear bond strength test using a universal testing machine, set at 500 kg of force, and a crosshead speed of 1 mm/min. The breakage force (KiloNewton) was divided by the surface area (78.53 mm^2) to calculate SBS in mega Pascal (MPa). The dismounted specimens were examined under × 20 stereomicroscope to determine the mode of failure.

Statistical analysis

Statistical Package for Social Sciences (SPSS) for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses. Descriptive analysis of shear bond strength was done using mean and standard deviation. The test results were subjected to one-way ANOVA test followed by Tukey's *Post hoc* test to compare the mean shear bond strength between three study groups. Chi-square test was used to compare the mode of failure (adhesive, cohesive, or hybrid) between the three groups.

RESULTS

The level of significance (*P* value) was set at $P < 0.05$ and confidence interval was set at 95%.

Table 1 and Graph 1 explain the comparison of mean and standard deviation of shear bond strength values between the three groups using one-way ANOVA-test. There was a significant difference in the mean shear bond strength between the three groups was significant with $P < 0.001$.

Table 2 and Graphs 1-3 explain the pair-wise comparison between the three groups in shear bond strength using Tukey's *post-hoc* test (pair-wise test). Group 1, that is repair with the same composite (Z250), showed

Table 1: Comparison of mean shear bond strength (Mpa) between 3 groups using one-way ANOVA test

Groups	*n*	Mean±SD	Minimum	Maximum	*P*
Group 1	10	39.427±1.434	36.78	41.46	<0.001*
Group 2	10	36.726±2.026	34.39	40.74	
Group 3	10	34.011±1.100	32.09	35.80	

*$P < 0.05$. SD: standard Deviation

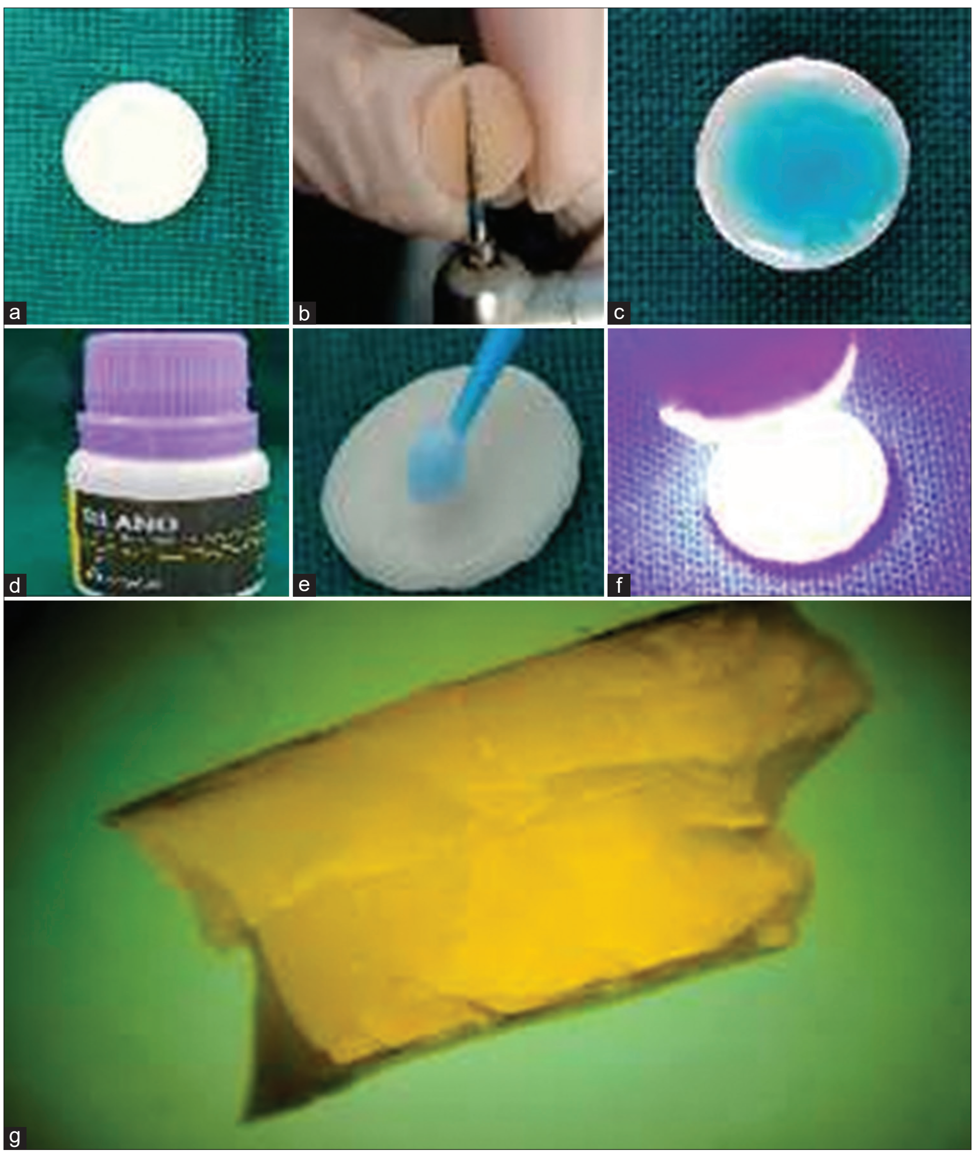


Figure 1: (a) Composite disc fabrication, (b) Abrasion of surface with diamond bur, (c) Etching with 37% phosphoric acid, (d and e) Silane coupling agent and adhesive application, (f) Curing the treated surface, (g) Examination of the samples under stereomicroscope after subjecting to Shear bond stress test

significantly higher mean shear bond strength when compared to repair with Group 2 (Omnichroma) and Group 3 (Charisma Topaz ONE) with $P = 0.002$ and < 0.001, respectively. Between Group 2 (repair with Omnichroma) and Group 3 (repair with Charisma Topaz ONE), the mean shear bond strength of Group 2 was significantly higher with $P = 0.002$.

A comparison of the mode of failure between the three groups was done using Chi-square test [Table 3 and Graph 4]. The control group showed 60% cohesive failure followed by 20% adhesive and 20% hybrid failures. Both Omnichroma and Charisma Topaz ONE groups showed 40% cohesive, 40% hybrid failures, and 20% adhesive failure. The difference in mode of failure between the groups was not significant-$P = 0.85$.

DISCUSSION

Repair of old or aged restoration can be considered when there is premature fracture of the recent restoration, color mismatch, and deficient contact points. Replacement of restoration is indicated when caries have undermined the pre-existing restoration or when there is a history of failure of previous repair.

Recently, a study has been done to calculate color difference when single-shade composites are used to

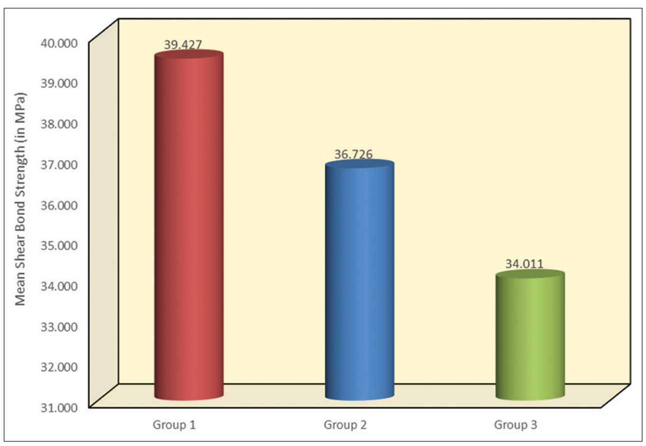
Table 2: Multiple comparison of mean different in shear bond strength between 3 groups using Tukey's *post hoc* test

(I) Groups	(J) Groups	Mean different (I−J)	95% CI for the different		*P*
			Lower	Upper	
Group 1	Group 2	2.701	0.963	4.439	0.002*
	Group 3	5.416	3.678	7.154	<0.001*
Group 2	Group 3	2.715	0.977	4.452	0.002*

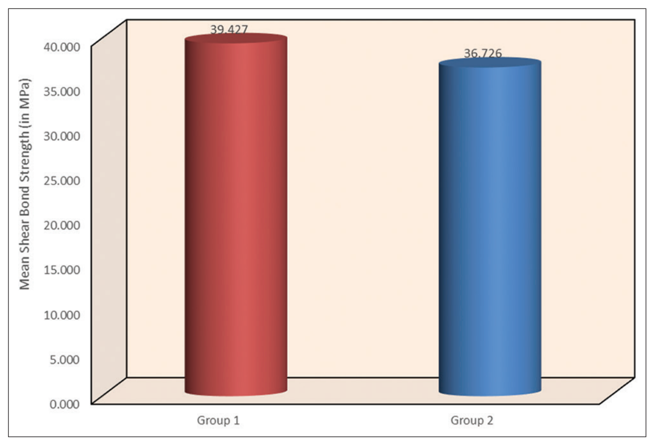
*$P< 0.05$. CI: Confidence interval

Table 3: Comparison of modes of failure between 3 groups using Chi-square test

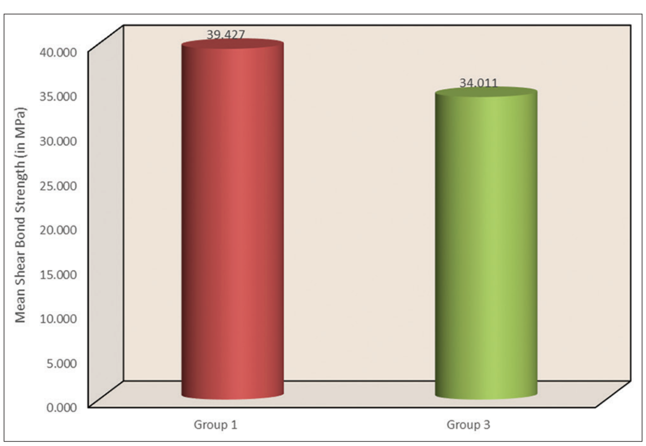
Modes of failure	Group 1, *n* (%)	Group 2, *n* (%)	Group 3, *n* (%)	*P*
Cohesive	6 (60)	4 (40)	4 (40)	0.85
Hybrid	2 (20)	4 (40)	4 (40)	
Adhesive	2 (20)	2 (20)	2 (20)	



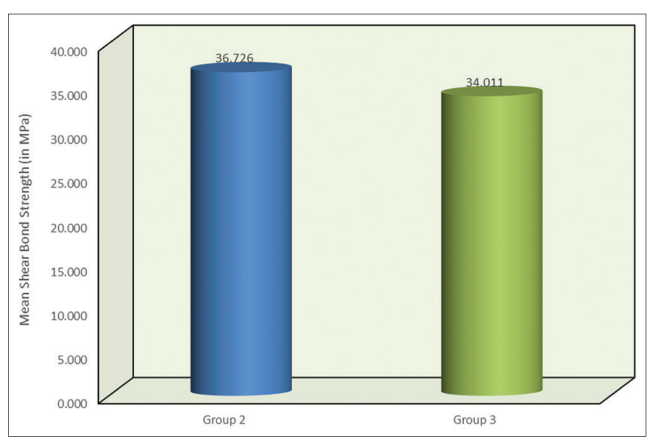
Graph 1: Demonstrates mean shear bond strength between three groups



Graph 2: Demonstrates mean shear bond strength between Group 1 and Group 2



Graph 3: Demonstrates mean shear bond strength between Group 1 and Group 3



Graph 4: Demonstrates mean shear bond strength between Group 2 and Group 3

repair aged composites, satisfactory results in shade match between aged composite and single-shade composites were observed.[17]

The interface at the repair composite and the aged composite is considered a fragile link. Therefore, adequate surface treatment of old composite resin, selection of appropriate adhesive system, and restorative material are considered essentials for successful repair.[3,4] In this *in vitro* study, the samples were thermocycled for 5000 cycles to mimic 6 months of clinical service.[18,19]

In our study, microhybrid composite provided higher repair bond strength in comparison to nanofilled and nanohybrid composites, this is similar to the finding by Nassoohi *et al.,*[3] but contradicting results were shown in the study by Rinastiti *et al.,* which showed nanohybrid and nanofilled composites provided higher shear bond strength.[4]

The properties and performance of adhesively bonded structures are dictated by the interfacial adhesion.[20] One of the primary requirements for good adhesion in dentistry is the adequate surface wetting of substrate with adhesive.[21] Low contact angle between the adhesive and the substrate increases wettability and enhances the adhesive bond.[22] Studies have found that the wettability of the substrate is influenced by its chemistry and surface roughness to an extent.[22-24] The repair bond strength of new composites to aged composites (similar or dissimilar) is influenced by their resin matrix content and filler particles. Application of silane coupling agent helps to establish new covalent bonds with the inorganic filler particles in the composite which increases its wettability and enhances the infiltration of the bonding agent.[25,26]

In their study, Gregory *et al.* found that there are more carbon bonds available for polymerization resin matrix made of Bis-GMA that is microfilled.[27] This explains the probable reason why microhybrid composite (control group) showed better repair bond strength compared to nanohybrid and nanofilled composites.

Difference in the wettability and surface profile of microhybrid, nanohybrid, and nanofilled resin-based composites needs to be studied to find how they affect mechanical properties when used to repair aged composites.

In a recent study, aged nanohybrid composites received surface treatment with silicon carbide grinding and air particle abrasion followed by repair with Omnichroma and Charisma Diamond One. Omnichroma single-shade composite showed better repair bond strength when the surface of substrate was treated with silicon carbide grinding and Charisma Diamond One performed better when the substrate composite was treated with air particle abrasion.[28] In our study, the aged composite substrates were surface treated with silane coupling agent followed by repair with Omnichroma and Charisma Diamond One, where Omnichroma showed better repair bond strength.

Some studies have suggested that repair bond strength above 18 MPa or at least between 20 and 25 MPa is clinically satisfactory.[2,3] In the present study, mean shear bond strength values were 39.427 ± 1.434 for Group 1, 36.726 ± 2.026 for Group 2, and 34.011 ± 1.100 for Group 3.

This could be influenced by the composition of the composites, the surface treatment, or the method of aging.

Until 2015, there were no studies explaining clinically acceptable composite repair bond strength. Nassoohi *et al.*[3] suggested that repair bond strength similar to enamel–resin bond strengths (range between 15MPa to 30MPa) were suitable in clinical conditions.

Tezvergil *et al.*[29] conducted a study to compare composite–composite repair bond strength. The repair bond strength values in this study were similar to those achieved in our study and ranged between 34MPa to 39MPa. Thus, the available literature supports the findings in our study and suggests that microhybrid composites provide superior repair bond strengths. Single-shade composites used in this study (nanofilled and nanohybrid) provided clinically acceptable repair bond strengths.

In our study, when the mode of failure was evaluated, the control group (repair with microhybrid composite) showed predominantly cohesive fracture with 60% of samples. In the experimental groups, repair with single-shade nanofilled and nanohybrid composites showed an equal percentage of cohesive (40%) and hybrid mode (40%) of failure. Pure adhesive failures were the least common mode of failure seen in 20% of samples.

When there is cohesive failure, the fracture is within either of the two composite matrices involved. This type of cohesive failure occurs when the adhesive strength between the two composites is greater than the cohesive bond within the composite matrix. It is desirable for the adhesive bond to be superior in strength while considering repair. In contrast, when the samples detach at the junction of the two composite layers, it suggests an adhesive failure. Adhesive failure is undesirable during repair, as it indicates poor bond strength between the composite layers.[3]

Repair is minimally invasive but clinicians choose replacement over repair in esthetic restorations as they face a challenge in achieving accurate shade match and good bond to the older restoration.[30]

This study is clinically significant as we have found that single-shade composites have clinically acceptable repair bond strengths to aged resin composites when surface treatment with silane coupling agent is done. Therefore, they can be used to repair defects or refurbish restorations superficially, while also achieving an acceptable shade match to the older restoration.[17] Further studies with air particle abrasion of the substrate can be used to evaluate repair bond strengths with single-shade composites.

CONCLUSIONS

Within the limitations of this study, it can be concluded that the best repair bond strength considering various studies on scientifically accepted values is produced by the same composite as the restoration, both the single-shade composites used in this study provided clinically acceptable repair bond strengths, with Omnichroma (nanofilled composite) providing higher strength compared to Charisma Topaz ONE (nanohybrid composite). The modes of failure in all three groups were predominantly cohesive, suggesting a good repair bond strength.

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Conflicts of interest
There are no conflicts of interest.

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