Shear Bond Strength of Repaired Composite Using Single Bond Adhesive

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Abstract

Objectives: The aim of this study was to evaluate the shear bond strength of repaired composite resin restorations using one-step Single Bond Universal adhesive.

Materials and Methods: Sixty cylindrical composite samples (8 x 9 mm each) were prepared from Filtek Z350 XT, light-cured and stored for 6 weeks. The surface of each sample was bur-roughened and acid-etched with 37% phosphoric acid. Samples (N = 60) were randomly assigned into 2 groups. For group 1 (the control group), silane coupling agent and bonding agent were applied in two separate steps. For group 2 (the test group), Single Bond Universal adhesive containing both silane and bonding agents was applied to the surface of the samples. Fresh composite resin was bonded to treated surfaces, and samples were cured and stored for another 6 weeks. The shear bond strength (SBS) was measured and analyzed using an independent samples t-test and descriptive statistics. Stereomicroscope examination of the samples was done to assess the mode of failure between the original and the repaired composite layers for the control and test groups.

Results: The mean initial failure SBS for the test group was significantly higher than that of the control group ($p < 0.001$). Of the control group samples, 80% failed adhesively, while 100% of the test group samples showed cohesive failure and a mixed mode of failure when observed under the stereomicroscope.

Conclusion: Single Bond Universal adhesive provides more reliable bond strength for repaired composite resin restorations compared with two-step silane and bonding agent application.

Keywords: Composite, Repair, Silane, Shear, Single bond universal adhesive.

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Introduction

Composite resin restorations are currently the most widely used dental filling material for the restoration of teeth in dental practice. However, these restorations are subject to different degenerative changes during their use intra-orally as they undergo deterioration and wear.[1] Approximately 50% of resin-based composite restorations are replaced after five years of service. The main reasons for this are the development of secondary caries, marginal staining, marginal defects, marginal or body fractures, discoloration, degradation and loss of

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anatomic form, unsatisfactory shades, and/or painful symptoms.[2-5]

Traditionally, replacement is the ideal approach to treat defective composite restorations; however, repairing composites offers an alternative and more conservative approach when restorations are still partly serviceable.[6] The repairing of composite restorations may be considered the treatment of choice for surface discoloration, small areas of recurrent caries along the margin of otherwise sound composite restorations, when complete removal of a very large composite restoration would unnecessarily jeopardize the health of a tooth, and laboratory-fabricated (indirect) resin composite repair.[7] A recent clinical study involving composite resin repairs showed that, when properly planned, repairs may increase the clinical longevity of restorations.[8] The efficiency of the repair is related to the magnitude of the bond strength obtained at that interface.[9] The bond strength between increments of composite should be equal to the cohesive strength of the material. If the composite has been contaminated, polished, processed in a laboratory (i.e., indirect composite restorations), or aged, adhesion to a new composite is reduced up to 25% from the original cohesive strength.[10-12]

When placing composite restoration using a layering technique, the unreacted molecules, present in the air-inhibited layer, allow the materials on both sides to cross the interface and blend together to form an inter-diffused zone, where copolymerization can take place to produce a covalent bond.[13] The presence of camphorquinone in the new composite layer results in complete polymerization of the oxygen-inhibited layer at the interphase.[13] Thus, bonding is improved and shear bond strength is enhanced. However, in repairing aged composite, the air-inhibited layer is not present, and the amount of unreacted carbon double bond is low, therefore the chemical bonding between fresh and aged composite is not reliable.[7]

To address this issue, surface treatment has been used successfully in promoting the mechanical interlocking, surface wetting, and chemical bonding during composite repair.[14-16] Several single-surface treatments or combinations of treatments have been used to improve the bond strength of composite repair, including the following: surface roughening with burs or airborne particles (i.e. aluminum oxide particles), acid-etching, application of silane coupling agents, and application of resin-based adhesive systems.[7,10,11,14,15,17-19]

Silane treatment of exposed filler particles in the composite matrix results in the formation of siloxane bonds when the silanol groups condense with similar groups. At the same time, methacrylate groups of the organosilane compound form covalent bonds with the resin when it is polymerized.[7,20] Silanization has proven to give better bonding results when bonds chemically the aged post-cured composite with fresh composite.[7,15,21-23]

Moreover, intermediate adhesives and bonding agents improve the strength of repaired composite and significantly enhance bonding between aged composites and fresh composite layers.[14,16,18,19,24,25] Recent advancements in bonding systems have made it possible to combine the silane agent with the bonding agent in a single-bottle system (single bond adhesive), which makes it more user-friendly for the dentist. To the best of our knowledge, no previous study has evaluated the shear bond strength of repaired composite using silane and bonding agents in two separate steps or in one step, which was the aim of this study.

Materials and Methods

Sample preparation

In this descriptive analytical study, a cylindrical mold made of vinyl polysiloxane duplicating material (elite double, Zhermack, Ohlmuhle, Germany) was used to prepare 60 cylindrical samples (8-mm height and 9-mm diameter) of Filtek Z350 XT composite (3M ESPE, St. Paul, MN, USA). Two increments (2 mm each) of A2 dentin shade were packed inside the mold to yield a cylindrical sample with a height of 4 mm. Each increment was initially light-polymerized (starlight pro, mectron, Carasco, Italy) for 40 s. The light intensity was 800 mW/cm^2, verified by a radiometer (Demetron LC, Kerr). The sample was removed from the mold, and an additional 40 s of light curing was achieved on each side of the sample. Light curing tube was kept in contact with the composite surface to ensure adequate curing at a 90-degree angle to the top surface. The light output was calibrated according to the manufacturer's instructions. All samples were stored in a dry environment for 24 hours.

After 24 hours, samples were finished under water with high-speed fine diamond finishing burs (Dia-Tessin, Vanetti SA, Gordevio, Switzerland) and polished with low-speed green and pink Sof-Lex finishing discs (3M ESPE, St. Paul, MN, USA). Each sample was rinsed for 15 s with tap water and stored in distilled water for six weeks at 37℃.

The samples were randomly assigned to either the control group or the test group (n = 30). In group 1 (the control), the composite surfaces were roughened using high-speed rough diamond burs (Dia-Tessin, Vanetti SA, Gordevio, Switzerland) under water (5 strokes over 5 seconds). Then, 37% phosphoric acid gel (Scotchbond Universal etchant, 3M ESPE, St, Paul, MN, USA) was brushed on the composite surface for 30 s using a micro brush (3M ESPE, St. Paul, MN, USA). The acid was rinsed for 15s and dried for 15s. Silane coupling agent (RelyX, 3M ESPE, St. Paul, MN, USA) was applied to the etched composite surface and allowed to dry for 60 s. Finally, two coats of the bonding agent (Adper Single Bond 2, 3M ESPE, St. Paul, MN, USA) was applied to the composite surface with 5 s of waiting time, and then light-cured for 20 s.

In group 2 (the test group), the composite surfaces were roughened and etched in the same manner as in the control group. Single Bond Universal (SBU) adhesive (3M ESPE, St Paul, MN, USA) was applied to the etched composite surface with a disposable applicator and rubbed in for 20 s. Subsequently, a gentle stream of air was directed over the liquid for 5 s, and then light-cured for 10 s.

All treated samples were reinserted into their molds, and a fresh Filtek Z350 XT composite layer of 2-mm thickness was condensed over each prepared surface and light-cured for 40 s. A different shade (A2 enamel shade) was chosen for the repairing composite in order to enable visual identification and orientation of the repair interface during shear bond strength (SBS) testing. Another 2-mm layer of composite was applied and cured for another 40 s. Each sample was then light-cured from all sides for an additional 40 s after removing it from the mold. All samples were kept dry for two weeks before testing the shear bond strength.

Shear bond strength test

The samples were mounted in the jig of a universal shear-testing machine with a semicircular loading surface (JINAN material testing machine, Jinan, China) at the Jordan University of Science and Technology University in Irbid, Jordan, as shown in Figure 1. The shear bond strength was determined at a crosshead speed of 0.5mm/min for more precise results. The shear bond strength was calculated by dividing the failure force by the cross-sectional area of the samples according to the following equation:

SBS = Load/Area,

where SBS is in units of MPa, load in N, and area in mm^2.

Stereomicroscope examination

A stereomicroscope examination was performed to assess the mode of failure between the original and the repaired composite layers for both control and test groups. A stereomicroscope (Leica, EZ40 Leica Microsystems Limited, Switzerland) was used to evaluate the samples at the Dental Anatomy and Histology Department at the University of Jordan in Amman, Jordan.

Statistical analysis

Statistical analyses were performed using SPSS Statistics 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics were generated. An independent samples t-test was used to examine difference in the means of SBS between both groups. Results were considered significant if *p*-values were less than 0.05.

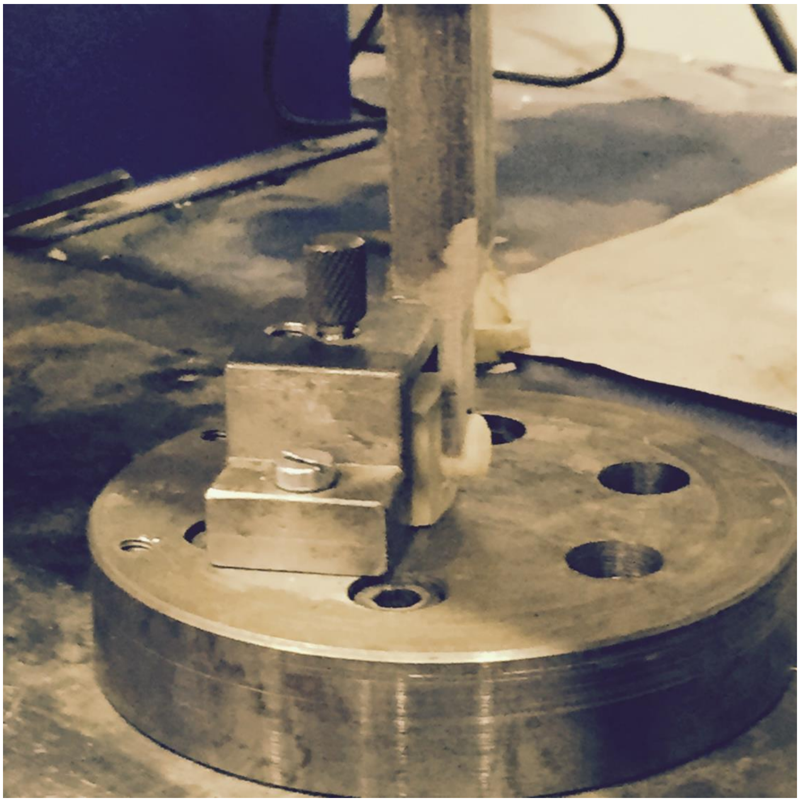

Figure 1: A dental composite sample loaded in the jig of the shear bond strength (SBS) testing machine

Results

The mean SBS for the test group was 16.27 MPa (SD = 5.37), which was significantly higher than that of the control group, which was 11.78 MPa (SD = 2.63) ($p < 0.001$). The SBS results for both the control and test groups are presented in Figure 2.

Under the stereomicroscope with a magnification of 8X, 80% of the control group samples failed adhesively, while all of the test group samples showed cohesive failure and a mixed mode of failure as shown in Figures 3a and 3b.

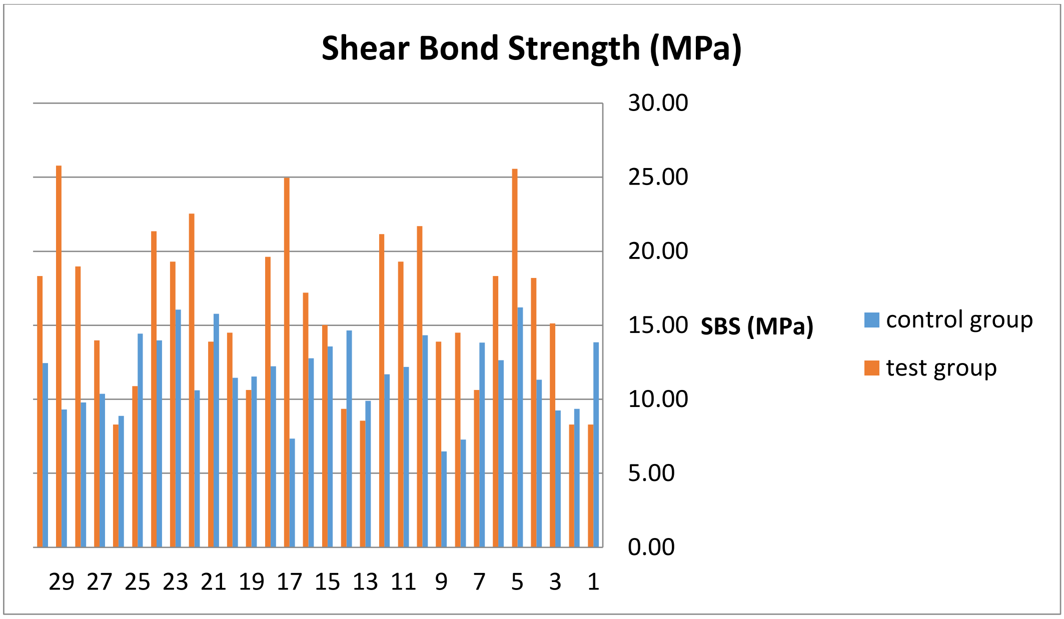

Figure 2: Shear bond strength (SBS) values at initial failure for both the control and test groups of dental composites

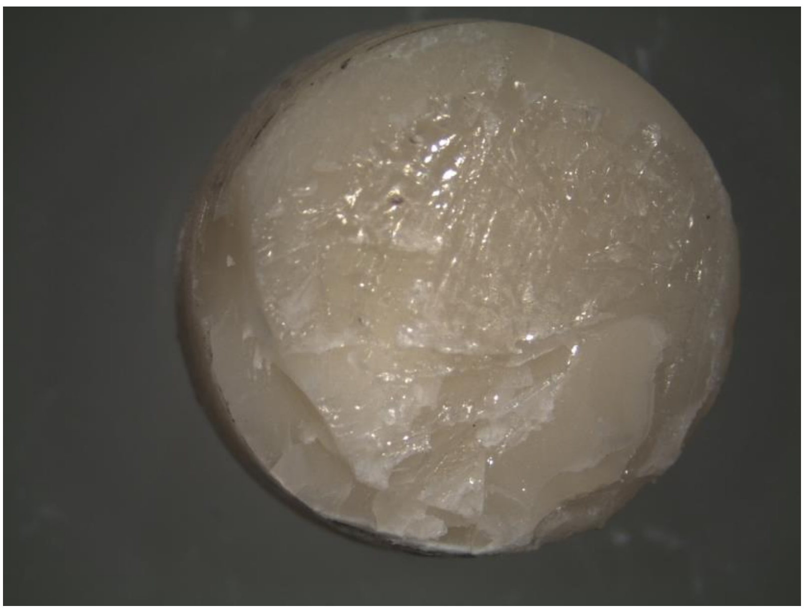

Figure 3a: Sample from the control group with adhesive failure in the composite substrate (image under 8X magnification by stereomicroscope)

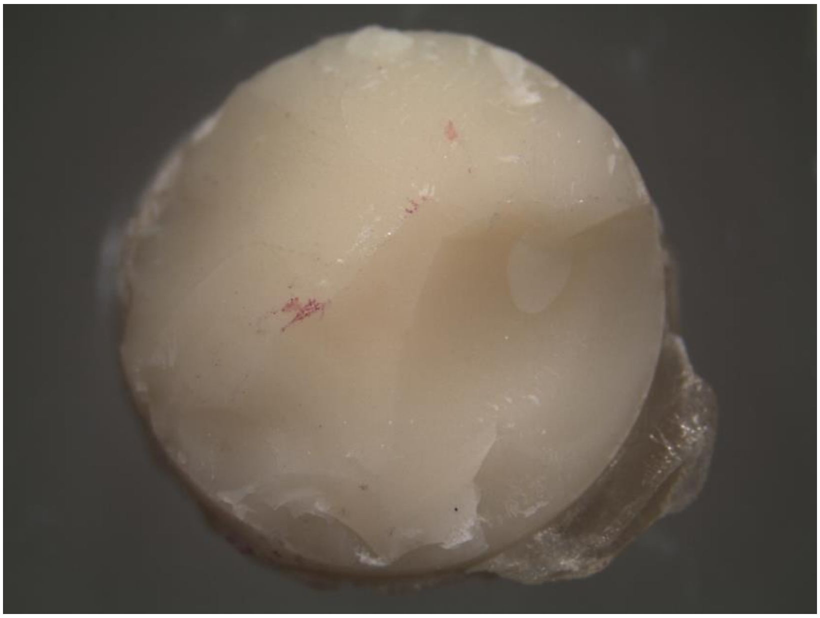

Figure 3b: Sample from the test group with cohesive failure in the composite substrate (image under 8X magnification by stereomicroscope)

Discussion

In this study, we evaluated the strength of the SBU adhesive. The SBS of repaired composite resin restorations with the application of SBU adhesive should at least be as strong as the SBS of composite resin restorations repaired with a silane coupling agent and a bonding adhesive applied separately. The results of this study demonstrated that the mean initial failure SBS for the test group was significantly higher than that of the control group.

When repairing old composite restorations, surface pretreatment of the old composite has two purposes: to remove the superficial layer altered by the saliva, exposing a clean, higher energy composite surface; and to increase the surface area through the creation of surface irregularities.[26] Bonding between old and new composite may occur by three distinct mechanisms: (1) chemical bonding with the organic matrix; (2) chemical bonding with the exposed filler particles, and (3) micromechanical retention to the treated surface.[14]

In the present study, we used bur roughening with rough diamond burs to provide micromechanical retention.[16,27] An etching procedure was used to facilitate bonding, because it creates a porous surface in which the porosity leads to an increase in the retentive bond.[28,29]

Bonding composite to enamel and dentin has been thoroughly investigated in the literature, and the SBSs for enamel and dentin have been reported to be about 15 to 30 MPa for enamel and 17 to 24 MPa for dentin.[7,22] The only source for SBS values specifically for the SBU adhesive application was 3M ESPE, which found the SBS for enamel was 25 MPa and 30 MPa for dentin,[30] which are comparable but higher than those of this current study.

On the other hand, the SBS values for composite resin restoration repair vary greatly according to several factors, such as the composition of the composite material, the surface pretreatment protocol, and the aging method. In any case, it is clearly stated in the literature that the use of intermediate bonding agents and silanization could enhance bonding when repairing composite resin restorations.[21-25,31,32] Our results confirm the importance of these bonding and silanization steps in composite repairs.[14,33,34] The bifunctional molecule of the silane coupling agent bonds the inorganic filler particles of the resin with the methacrylate of the adhesive system, and increases the wettability of the adhesive system to infiltrate into the irregularities of the treated composite surface.[34]

Shear tests lead to non-homogeneous stress distribution in the bonded interface, which may eventually cause erroneous interpretation of the results due to failure occurring in the substrate rather than the adhesive zone.[34] Thus, the mode of failure, which was evident microscopically by the different shades of composite materials used (A2 enamel for the repairing layers versus A2 dentin for the original samples), was assessed more precisely by stereomicroscope. Of the control group samples, 80% failed adhesively, while 100% of the test group samples showed cohesive failure and a mixed mode of failure. The types of failure exhibited by the composite resin restorations repaired with an application of the SBU adhesive confirm the stronger effect of this solution in comparison to a silane coupling agent and a bonding adhesive applied separately.

Conclusion

In this study, composite resin restorations repaired with the application of single bond adhesive demonstrated significantly higher shear bond strength than that of the restorations repaired with silane coupling agent and bonding adhesive applied separately. Within the confines of this study, we conclude that the application of the SBU adhesive when repairing composite resin restorations is efficacious, efficient and convenient.

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قوة الربط لترميم الحشوات الراتنجية البيضاء باستخدام عبوة الربط اللاصق الواحدة

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الملخص

أهداف البحث: هدف الدراسة الحالية هو تقييم وفحص قوة الربط للحشوات البيضاء الراتنجية المرممة باستخدام أنبوبة المادة اللاصقة العالمية المنفردة.

الأدوات والأساليب: تم تحضير ستين عينة اسطوانية من الحشوات البيضاء الراتنجية، وتم تصليبها بالضوء وتخزينها في الماء المقطر لمدة ستة أسابيع، ثم تم تخريش السطح باستخدام المثقب وتنظيفه باستخدام حامض الفوسفوريك، ومن ثم تم توزيع العينات على مجموعتين، المجموعة الأولى وهي المجموعة المرجعية حيث تم معالجتها تقليديا بمادة السايلاين والمادة اللاصقة من خلال خطوتين منفصلتين، أما المجموعة الثانية وهي مجموعة الاختبار فتم معالجتها بالمادة اللاصقة العالمية المنفردة بخطوة واحدة، ثم تمت اضافة طبقة من الحشوة الراتنجية على السطح المعالج لكل عينة وتم تخزينها في الماء المقطر لمدة ستة أسابيع أخرى. تم فحص قوة الربط وقياسها وتحليلها احصائيا من خلال استخدام جهاز قياس قوة الربط والفحص. ثم تم تقييم وفحص العينات مجهرياً باستخدام المجهر الالكتروني.

النتائج: تم إفشال قوة الربط مبدئيا عند قياسات أعلى ودالة احصائيا لعينة الاختبار المعالجة بالمادة اللاصقة العالمية المنفردة بخطوة واحدة عن المجموعة المرجعية المعالجة بمادة السايلاين والمادة اللاصقة من خلال خطوتين منفصلتين، 80% منم عينات المجموعة المرجعية تم فصل طبعات الحشوات التجميلية في منقطة التقاء طبقات الحشوات الأصلية وطبقات الحشوات الترميمية المضافة لاحقا، بينما أظهرت مجموعة الاختبار فصلا مختلطا وفصلا في طبقات الحشوات الراتنجية بعيداً عن منطقة الترميم.

الخلاصة: توفر أنبوبة المادة اللاصقة العالمية المنفردة قوة ربط أفضل لترميم الحشوات البيضاء الراتنجية بالمقارنة مع الطريقة التقليدية المتمثلة بخطوتي مادة السايلاين والمادة اللاصقة.

الكلمات الدالة: الحشوات الراتنجية البيضاء، عبوة الربط اللاصق.