Immediate and Late Repair of Microhybrid Resin Composites: Effect of Silane Coupling Agent, Universal Adhesives and Photo Polymerization

Keywords

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ABSTRACT

This study investigated the effect of silane coupling agent and universal adhesive application on repair bond strength of resin-based composite after bur grinding. Micro-hybrid resin composite (Charisma Smart) blocks (N=80; 8x8x4 mm³) were prepared, aged (37°C; 1 month), roughened, etched and randomly divided into two groups. Silane was applied to half of the groups (Porcelain Primer, Bisco), before one of the following universal primers/adhesives was applied: a) Scotchbond Universal (3M), b) All-Bond Universal (Bisco), c) G-Premio Bond (GC), and d) Clearfil SE Bond (Kuraray). In each adhesive group half of the group was photo-polymerized. The blocks were repaired with the same size resin composite and segmented into beams. Half of the beams were subjected to micro-tensile bond test (1 mm/min), while the other half was aged (37°C; 6 months) prior to testing. Failure modes were analyzed using Scanning Electron Microscopy (SEM). Data were analyzed using repeated measures of ANOVA, Tukey's post-hoc, and paired t-tests (alpha=0.05). The silane application did not affect the repair bond strength regardless of photo-polymerization of the adhesive resin. The repair bond strength decreased significantly after 6 months when adhesive resin was not photo-polymerized ($p<0.05$). Photo-polymerizing universal adhesives might ensure higher repair bond strength and its maintenance after aging.

INTRODUCTION

In restorative dentistry, the resin-based composite materials (hereon: resin composite) are commonly preferred as universal restorative materials as they fulfil both minimal invasive principles and aesthetic demands of the patients. Against the advances in improved properties of resin composites, restorations made of such materials may fail as a consequence of discoloration, wear, chipping, and bulk fracture.[1] The failed resin composite restorations may be repaired using different procedures instead of completely removing the restoration.[2-4] The repair of restorations ensures saving sound tooth structure and avoiding trauma, thus increasing the longevity of restorations.[4,5] Until now, a gold standard procedure to repair resin composites has not been described.[3,4] However, it has been stated that the application of silane and adhesive resin might be beneficial for improving the repair bond strength following surface roughening procedures.[4,5]

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The surface roughening treatments play an important role in promoting repair bond strength of resin composites[2] as they clean the surface, increase the surface energy by removing the superficial layer and at the same time increase the surface area of the aged resin composite.[2] Previous studies have tested various roughening procedures, including air-borne particle abrasion (air-abrasion) with aluminium oxide particles, roughening with diamond burs, lasers, silica-coating, silanization and etching with hydrofluoric acid.[2,3,6-13] There is no consensus for the most appropriate method to roughen the aged resin composite surface[2] but favourable results were obtained more frequently after silica-coating and silanization.[5,11,12] Nevertheless, such technologies are not available globally, the use of diamond burs for roughening the aged resin composite surface is still considered as an easy and cost-effective method in general practice as the do not require any additional armamentarium.[14]

It has been reported that the application of a silane coupling agent prior to adhesive resin improved the repair bond strength of resin composites.[9,15-17] There are two main functional groups in the silane coupling agents, namely silanol and organofunctional group.[18] The silanol group bonds mainly to the silica filler particles of the resin composite. The organofunctional group on the other hand, bonds to the methacrylate matrix of the bonding agent.[18] The silane might promote the infiltration of the bonding agent to the irregularities created by the surface roughening procedures, enhancing the wettability of the surface,[3,12] through which the silane applied resin composite surface become more reactive for the methacrylate groups of the repair resin composite.[3] Nonetheless, in some studies, no benefit of silanes on repair bond strength of resin composite was reported.[2,12,19] According to other studies however, when the surface is silica-coated, the effect of silane becomes distinct. However, inorganic fillers may not be exposed to the surface, meaning the silane reacts mainly with the monomer matrix only.

While the beneficial effect of the silanes remains unclear for resin composite repair, the use of adhesive resin was reported to be beneficial.[8,15] The universal adhesives might be also useful in various direct and indirect restorative treatment procedures as they were claimed to provide reliable bond strength to both dental hard tissues and various materials, such as metals, polycrystalline oxide ceramics (i.e. zirconia), and resin composite.[12-23] The universal adhesives were reported to have thin film thickness[22] which was claimed ensure a stronger repair bond strength[24] through a more hermetic sealing between the substrate and repair resin composite.[15] Additionally, a previous study concluded that no photo-polymerization of the adhesive before placement of fresh resin composite improved repair bond strength due to the presence of a thinner adhesive layer.[15] Nevertheless, the effect of universal adhesive type considering various filler load and type and effect the photo-polymerization of the adhesive resins on the repair of resin composites is remains unclear.

The objective of this study therefore was to assess the effect of silane coupling agent and universal adhesive application with and without photo-polymerization on repair bond strength of resin-based composite after bur grinding. The hypotheses tested were that a) the silane application before universal adhesives would not influence the repair bond strength and that b) there would be no impact of photo-polymerization of universal adhesives before repair on the repair bond strength at early and late repair procedures.

MATERIALS AND METHOD

SPECIMEN PREPARATION

The brands, chemical composition and application procedures of the materials are listed in Table 1. The schematic diagram of the study protocol is shown in Figure 1. Resin composite blocks (N=80) (8x8x4 mm^3) were prepared from a microhybrid resin composite (Charisma Smart, Heraeus Kulzer, Hanau, Germany, Shade A3) using silicone molds. The resin composite was inserted into the mold in two layers of 2 mm. A Mylar strip (SS White Co., Philadelphia, PA, USA) was compressed on the top of mold surface with glass plates to produce a flat superficial layer. The resin composite was photo-polymerized through the glass plate using an LED photo polymerization device (Smartlite Focus, Dentsply, Milford, DE, USA; light intensity: 1000 mW/cm^2) according to the manufacturer's instructions. Each resin composite block was removed from the mold, and all surfaces of the specimens were polished with a multi-step polishing system (Super Snap Rainbow Technique Kit, Shofu, Kyoto, Japan, Batch no: 0413007). After each polishing step, all specimens were thoroughly rinsed with water and air-dried to remove debris. They were then stored in distilled water at 37°C for 1 month, and the distilled water was changed weekly.

REPAIR PROCEDURE

After the storage period, one surface of the resin composite blocks was roughened with a 60-74 µm fine-grit diamond bur (Komet, Lemgo, Germany) at 100'000 rpm for 10 seconds under water cooling. A 35% phosphoric acid etchant (Scotchbond Etchant Gel, 3M ESPE, St Paul, MN, USA) was applied for 30 seconds to clean the surface of all specimens. After water-rinsing and air-drying, the specimens were randomly divided into two groups. Half of the group received silane coupling agent and the other half not. A pre-hydrolyzed silane solution (Porcelain Primer; Bisco, Schaumburg, IL, USA) was applied on the surface of half of the specimens.

The specimens were randomly subdivided into four subgroups considering different adhesive resins. Three universal adhesives and a two-step self-etch adhesive were employed: Scotchbond Universal (3M, St. Paul, MN, USA), All-Bond Universal (Bisco, Schaumburg, IL, USA), G-Premio Bond (GC, Tokyo, Japan), and Clearfil SE Bond (Kuraray Noritake,

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Table 1. The materials, chemical composition and application procedure.

Material	Composition	Application procedure
Charisma Smart Composite (Heraeus Kulzer, Hanau, Germany) Lot no: K010516	Bis-GMA, Barium Aluminum Fluoride glass, silicon dioxide	1. Apply the material in thin layers (max. 2 mm) 2. Polymerize the material using a light-curing unit with light output of 1550 -550 mW/cm²
Porcelain Primer (BISCO, Schaumburg, IL, USA) Lot no:1800003839	3-(Trimethoxysilyl)propyl-2-Methyl-2-Propenoic Acid, ethanol, acetone	1. Apply 1 thin coat to surface and allow to dwell for 30 seconds. 2. Dry with air syringe
Scotchbond Universal (3M Oral Care, St. Paul, MN, USA) Lot no: 602724	10-MDP phosphate monomer, dimethacrylate resins, HEMA, methacrylate-modified polyalkenoic acid copolymer, filler, ethanol, water, initiators, silane	1. Apply the adhesive with a microbrush and rub it in for 20 s 2. Direct a gentle stream of air over the liquid for about 5 s until it no longer moves and the solvent is evaporated completely 3. Light-cure for 10 s
All-Bond Universal (BISCO, Schaumburg, IL, USA) Lot no: 1500005353	10-MDP phosphate monomer, Bis-GMA, HEMA, ethanol, water initiators	1. Apply the adhesive as two separate coats in a scrubbing mode with a microbrush for 10-15 s per coat 2. Dry for at least 10 s 3. Light-cure for 10 s
G-Premio Bond (GC, Tokyo, Japan) Lot no: 1903122	10-MDP, 4-MET, dimethacrylate resins, photo-initiator, butylated hydroxytoluene, acetone, water	1. Apply the adhesive and wait for 10 s. 2. Dry thoroughly with maximum air pressure for 10 s 3. Light-cure for 10 s
Clearfil SE Bond (Kuraray Noritake, Osaka, Japan) Lot no: 000273	Primer: Water, 10-MDP, HEMA, camphorquinone, hydrophilic dimethacrylate Bond: 10-MDP, Bis-GMA, HEMA, camphorquinone, hydrophobic dimethacrylate, N,N-diethanol p-toluidine bond, colloidal silica	1. Apply primer and leave in place for 20 s 2. Dry with air stream to evaporate the volatile ingredients 3. Apply bond and then create a uniform film using a gentle air stream 4. Light-cure for 10 s

Composition as provided by the manufacturers: Bis-GMA, bisphenol-glycidyl methacrylate; 10-MDP, 10-methacryloyloxydecyl dihydrogen phosphate; HEMA, hydroxyethylmethacrylate; 4 MET, 4-methacryloxyethyl trimellitate.

Okayama, Japan). Each adhesive was applied according to the manufacturer's instructions. Each adhesive group was further assigned into two subgroups: photo-polymerized and not photo-polymerized. After adhesive application, a silicone mold (8x8x8 mm^3) was used to standardize the placement of 4 mm of fresh resin composite. Each specimen was repaired with the same microhybrid resin composite but this time with shade A1 for easy differentiation of the substrate from the adherent. The resin composite was inserted in two horizontal layers and photo-polymerized for 20 s per layer. After removing the mold, the specimens were photo-polymerized for 20 s from all four lateral sides. The repaired resin composite blocks were then stored in distilled water at 37°C for 24 h.

The repaired composite blocks were fixated with cyanoacrylate glue (Loctite Super Glue, Henkel, Germany) to over a metallic base that was attached to a sectioning machine (Minitom, Struers, Denmark). The blocks were positioned perpendicular to the diamond disc of the machine. The first outer section, measuring approximately 1 mm, was discarded. A total of 16 beams with a cross-sectional area of approximately 1 mm^2 were produced from each block. Half of the beams acquired from the central and peripheral region from each block was used to measure the immediate micro-tensile bond strength test (μTBS); the other half were stored in distilled water at 37°C for 6 months and tested with the same protocol to evaluate the μTBS after aging. Forty μTBS beams were tested per each group.

MICRO-TENSILE BOND STRENGTH TEST

After recording the exact dimension of each beam with a digital caliper (Digimatic Caliper, Mitutoyo, Tokyo, Japan), they were attached to a custom-made micro-tensile testing jig with cyanoacrylate glue (Loctite Super Glue,) and stressed in a Universal Testing Machine (Autograph AGS-X, Shimadzu,

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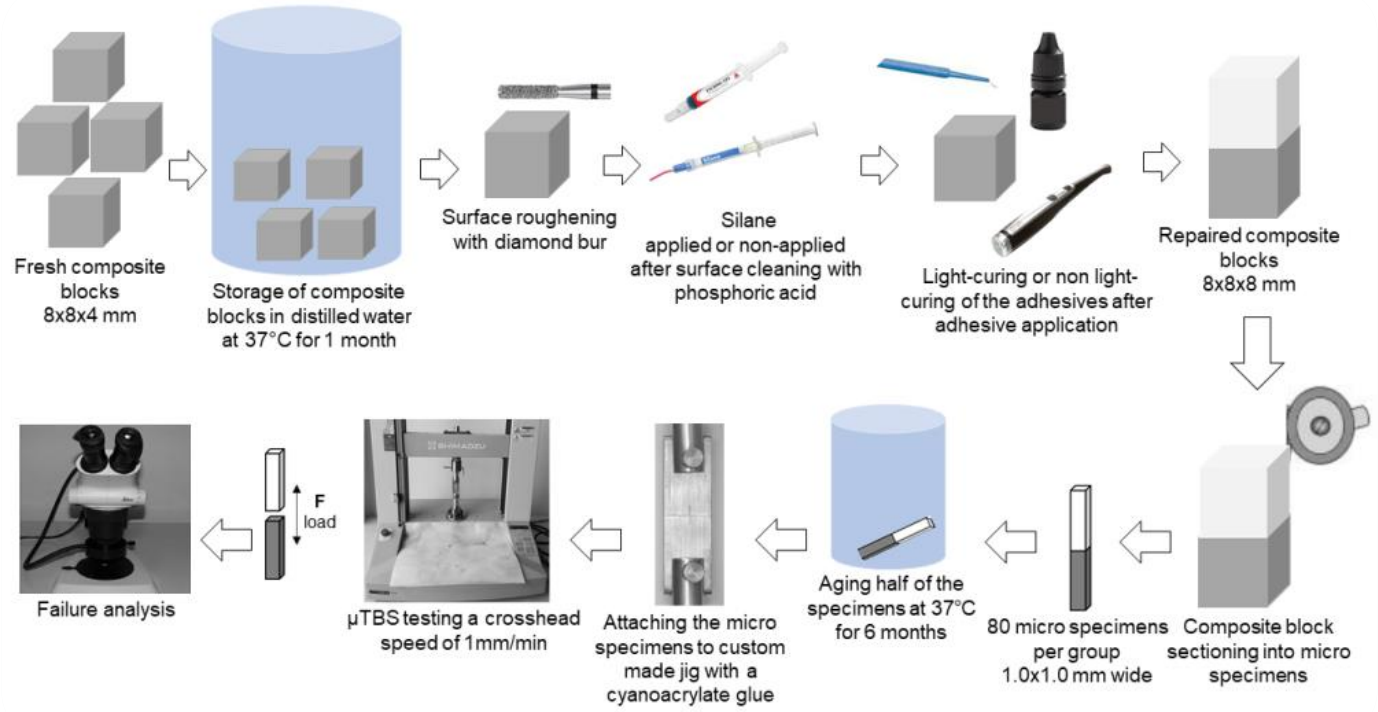

Figure 1: Schematic illustration of the experimental study design.

Kyoto, Japan) at a crosshead speed of 1 mm/min until failure. The mean μTBS was calculated in MPa, as derived from dividing the imposed force (in N) at the time of failure by the bond area (in mm^2).

FAILURE ANALYSIS

The failure modes were examined under x80 magnification using an optical microscope (S4E, Leica Microsystems, Wetzlar, Germany). The failure modes were categorized as an adhesive failure (interfacial failure), cohesive failure in substrate resin composite, cohesive failure in repair composite, and mixed failure (partially adhesive and partially cohesive failure). The selected representative specimens were placed in an aluminum sample holder with a carbon glue and observed with a scanning electron microscope (SEM)n (Quanta Feg 250, FEI, Eindhoven, The Netherlands).

STATISTICAL ANALYSIS

The mean of μTBS of the beams from each resin composite block was calculated, and this mean bond strength was considered as one unit for the statistical analysis. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS Program version 20.0, Chicago, IL, USA). The Kolmogorov-Smirnov and Levene's test was used to test the normality of data distribution and homogeneity of variances, respectively. Data were analyzed with repeated measures of ANOVA, considering the silane application, adhesive types and photo-polymerization as independent variables, and the storage time as the repeated measure. The Tukey's test was used for post-hoc comparisons. The paired t-test was performed to compare the means regarding storage time (24 h versus 6 months). The p-value less than 0.05 was considered statistically significant for all statistical analyses.

RESULTS

The ANOVA revealed statistically significant differences for adhesive resin ($p=0.004$), photo-polymerization ($p=0.000$) and storage time ($p=0.000$), but not for silane application ($p=0.445$). Also, no significant interaction was found between the factors *(Table 2)*. The overall mean μTBS of all experimental groups and standard deviations, including the results of multiple comparisons are presented in Table 3.

Application of silane coupling agent prior to adhesive resin application did not affect the repair bond strength after aging regardless of photo-polymerization of the adhesives ($p>0.05$). Regarding immediate repair bond strength, there was no statistically significant difference between the adhesive resins ($p>0.05$). The repair of resin composite without photo-polymerization of the adhesives caused a significant reduction in the repair bond strength for each group. Additionally, repair bond strengths decreased after 6 months aging ($p<0.05$). Concerning repair bond strength after aging, there was no statistically significant difference between the non-polymerized adhesive resins ($p>0.05$). There was also no statistically significant difference between the adhesive resin groups neither when silane is applied not photo-polymerized ($p>0.05$). Significantly higher repair bond strength was acquired with Clearfil SE Bond than Scotchbond Universal and All-Bond Universal in the photo-polymerized groups without silane application ($p<0.05$).

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Table 2. The ANOVA results for microtensile bond strength test.

Source	Sum of Squares	df	Mean Square	F	p
Silane	43.081	1	43.081	0.589	0.445
Adhesive	1064.995	3	354.998	4.857	0.004*
Light-curing	8716.444	1	8716.444	119.258	0.000*
Storage time	1333.984	1	1333.984	45.352	0.000*
Interaction	7.086	3	2.362	0.080	0.970

*Statistically significant differences ($p<0.05$)

Table 3. The means and standard deviations (μTBS in MPa ± SD) of composite repair strength for all experimental groups.

Silane	Adhesive	Immediate μTBS (24 h)	Aged μTBS (6 m)
Applied	Scotchbond Universal/light-cured	49.88 ± 7.43^{aA}	48.61 ± 7.30^{acdA}
	Scotchbond Universal /non-light-cured	38.66 ± 6.43^{bA}	28.94 ± 6.27^{bB}
Non-applied	Scotchbond Universal /light-cured	48.76 ± 7.17^{aA}	42.07 ± 7.04^{cA}
	Scotchbond Universal /non-light-cured	40.55 ± 6.75^{bA}	30.95 ± 6.05^{bB}
Applied	All-Bond Universal /light-cured	48.82 ± 7.31^{aA}	47.03 ± 7.39^{acdA}
	All-Bond Universal /non-light-cured	38.84 ± 6.51^{bA}	27.84 ± 6.69^{bB}
Non-applied	All-Bond Universal /light-cured	47.55 ± 7.20^{aA}	41.80 ± 7.19^{cA}
	All-Bond Universal /non-light-cured	38.86 ± 6.37^{bA}	29.51 ± 5.95^{bB}
Applied	G-Premio Bond/light-cured	55.10 ± 8.64^{aA}	56.27 ± 8.89^{dA}
	G-Premio Bond/non-light-cured	40.93 ± 6.65^{bA}	29.23 ± 6.24^{bB}
Non-applied	G-Premio Bond/light-cured	52.67 ± 7.81^{aA}	46.55 ± 7.59^{acdA}
	G-Premio Bond/non-light-cured	41.49 ± 7.15^{bA}	34.73 ± 6.67^{bB}
Applied	Clearfil SE Bond/light-cured	55.57 ± 8.80^{aA}	56.07 ± 8.55^{dA}
	Clearfil SE Bond/non-light-cured	40.97 ± 7.25^{bA}	33.87 ± 6.61^{bB}
Non-applied	Clearfil SE Bond/light-cured	54.90 ± 8.75^{aA}	54.77 ± 8.19^{adA}
	Clearfil SE Bond/non-light-cured	40.97 ± 7.25^{bA}	33.87 ± 6.61^{bB}

SD, standard deviation; n= 40, total number of specimens for each experimental group; Same superscript small or capital letter indicates no statistically significant difference in the columns and rows, respectively.

No pre-test failures were observed. The distribution of failure modes is presented in Figure 2a-b. In each group, mostly adhesive failure types were observed. The rate of adhesive failure mode in non-polymerized groups was higher than those of the photo-polymerized groups. The cohesive failures were observed more in the aged original composite. The representative SEM photomicrographs from different failure types are illustrated in Figures 3-5.

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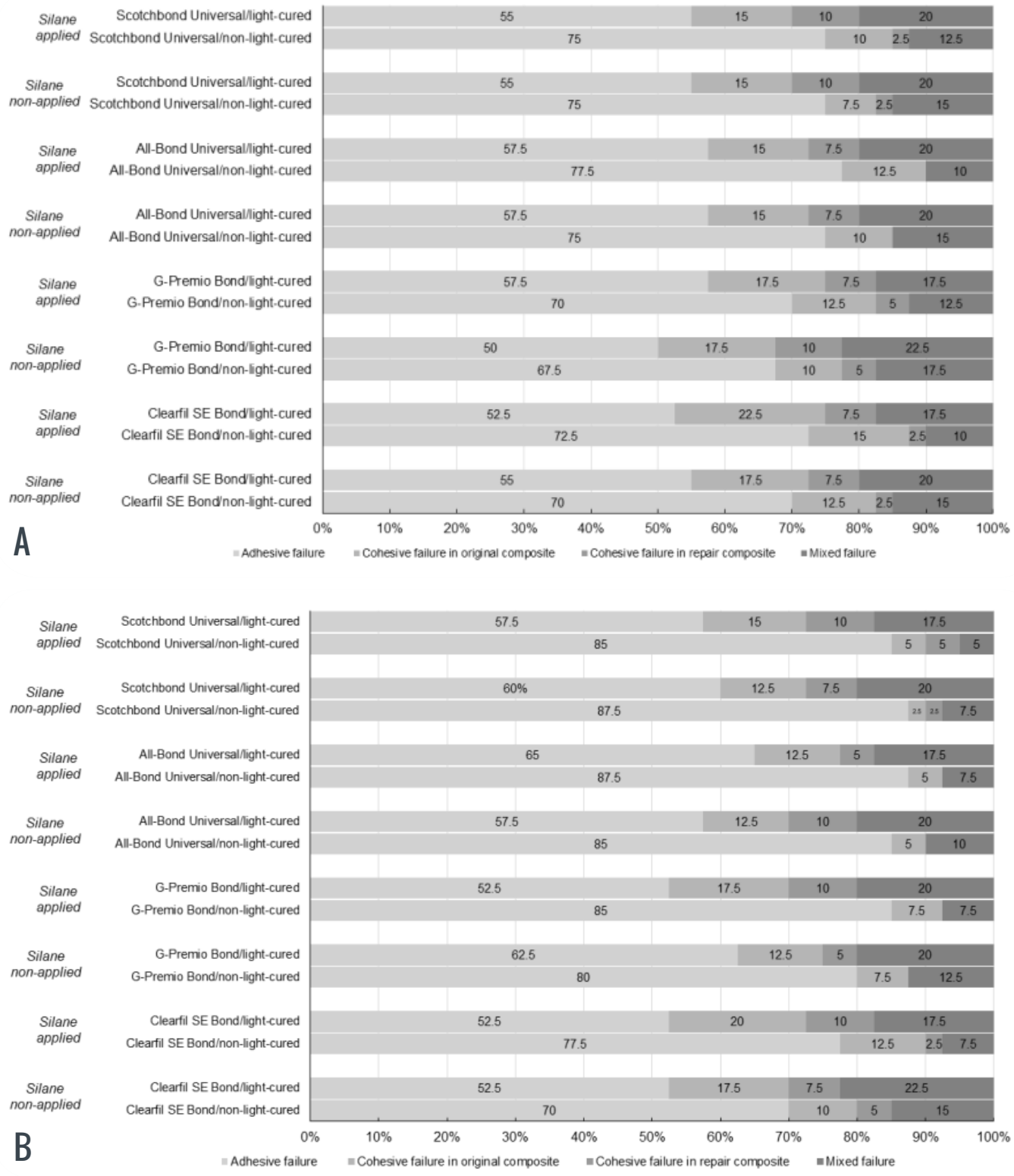

Figure 2: Incidence of failure modes after immediate A) (24 h), B) aged (6 months) μTBS testing.

DISCUSSION

Repair of failed resin composite restorations is a conservative treatment approach in order to prolong the longevity.[4,25] Numerous procedures have been introduced for the repair of resin composites.[4,5] Yet, in clinical practice, the use of burs followed by acid etching and application of adhesive resin is the most preferred method for the repair of failed resin composite restorations.[15] The application of a silane coupling agent prior to adhesive resin is recommended to improve the repair bond strength.[4,5] In this study, the effect of silane application and polymerization of adhesives resins on the repair bond strength of resin composite after roughening with a fine-grit diamond bur was evaluated using micro-tensile testing.

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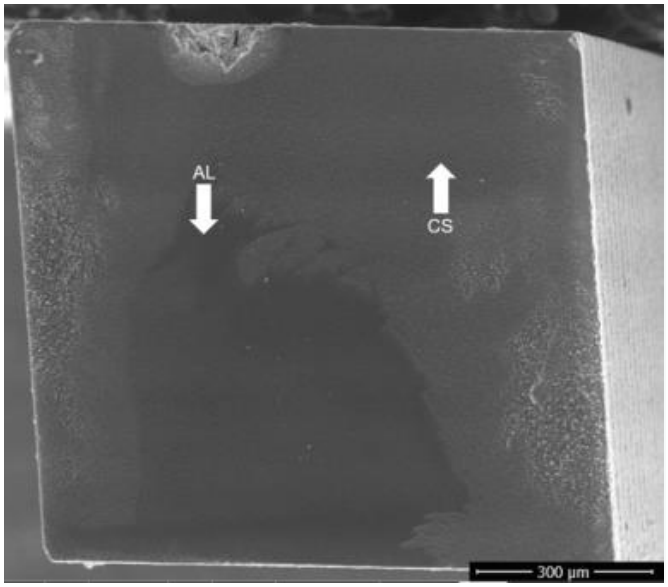

Figure 3: SEM photomicrograph of adhesive failure on the aged resin composite side from the silanized, non-polymerized Scotchbond Universal group. AL: Adhesive layer on aged resin composite surface. CS: Composite surface of aged resin composite without an adhesive layer.

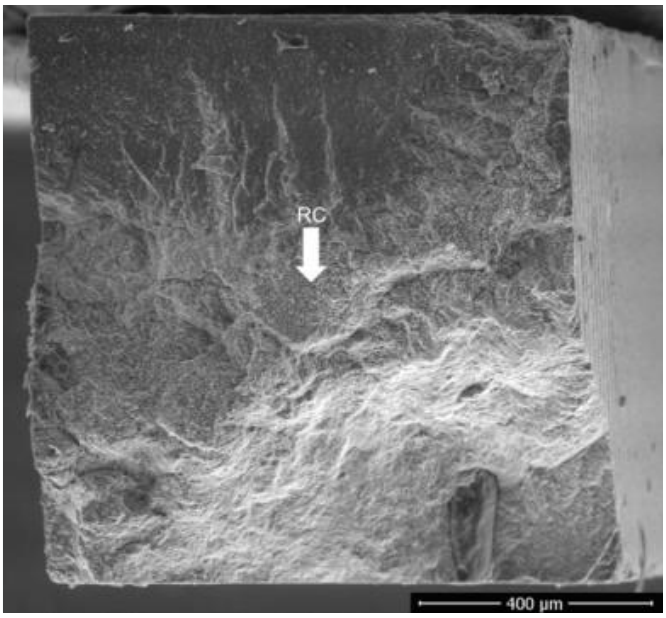

Figure 4: SEM photomicrograph of cohesive failure on the aged resin composite side from the non-silanized, photo-polymerized G-Premio Bond group. RC: Resin composite.

Both shear and micro-tensile testing have been used in previous studies regarding the repair of resin composite.[4] The shear testing may lead to more cohesive failures in the substrate or the repair composite due to inadequate stress distribution, thus unreliable results.[6,25] It has been stated that the micro-tensile testing is more reliable due to the uniform stress distribution created by concentrated forces at the interface.[6,25]

Roughening the repair surface by removing the superficial layer from the aged resin composite before the repair is required for improved, stable bond strength after aging.[8,11,26,27]

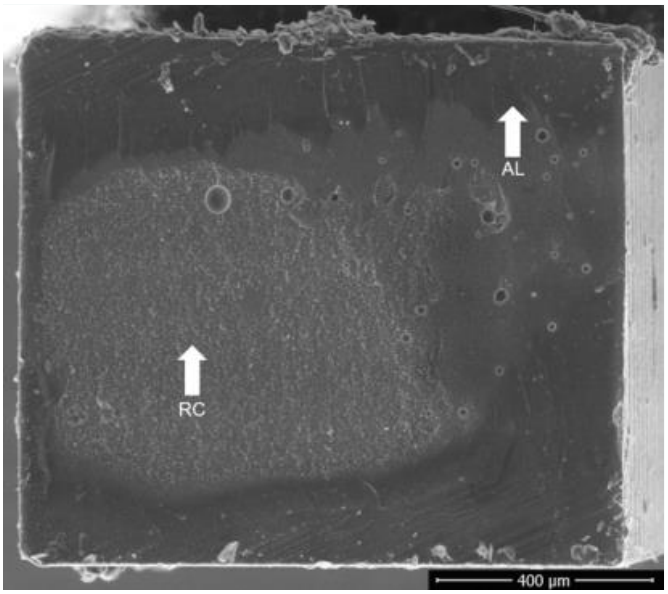

Figure 5: SEM photomicrograph of mixed failure on the aged resin composite side from the silanized, photo-polymerized All Bond Universal group. AL: Adhesive layer on the aged resin composite surface. RC: Fresh resin composite on the aged resin composite surface.

Surface roughening provides micromechanical retention and also increases the wettability of adhesive resins on the surface.[11,26] The use of diamond burs is one such surface roughening method.[10,27] In this study, a fine grit diamond bur was used to roughen the aged composite surface due to its greater clinical applicability. A previous study reported that fine grit burs showed better performance than medium and extra-fine grit burs in the repair of resin composite.[27]

The effect of silane application prior to adhesive resin application on the repair bond strength of resin composite has previously been reported.[16,17,19,24,26] In this study, the silane application did not improve the repair bond strength. Therefore, the first hypothesis that the silane application before universal adhesives would not influence the repair bond strength was accepted. some other studies have also concluded that the silane application either decreased or did not affect the repair bond strength.[2,8,10,28] Moreover, the reliable repair bond strength results were obtained through the only adhesive application without applying silane after surface treatments.[14,29,30] The differences in the results of studies may be due to differences in methods and used materials, as commercially available silanes for dentistry do differ from each other largely. It has been reported that the chemical content of the silane and the filler type of the resin composite may change the effectiveness of the silane on the composite repair.[10,12] The effectiveness of the silane may also be related to type of surface conditioning practiced. It has been reported that the use of adhesives resin only provided high repair bond strength results after surface roughening treatment with burs.[8,30] After bur grinding only a mechanical interlocking occurs between the aged composite surface and the repair resin composite.[4,11,26] The use of an adhesive resin

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contributes to the micromechanical retention by increasing the wettability of the metallic or ceramic surfaces.[7,12] The adhesive layer is the weakest zone between the aged and the fresh resin composite.[15,31] The reduction of the adhesive layer thickness may ensure a reliable repair through hermetic sealing.[15] It has been stated that no photo-polymerization of the adhesive resin before repair might provide a better wettability due to the formation of a thinner adhesive layer.[15] Resin-matrices were reported to influence the repair strength as well. However, in the present study, when adhesive resin was not photo-polymerized lower repair bond strength was achieved and the bond strength was not stable after 6 months. Therefore, the second hypothesis was rejected.

The lower repair bond strength may be due to inadequate chemical bonding. A chemical bonding forms between the aged and fresh resin composites in addition to the mechanical interlocking.[4,9,32] This type of bond occurs mainly between the glass filler particles of the aged resin composite and the fresh resin via adhesive resins.[9] Silanes are in fact expected to react with the glass fillers embedded in the monomer matrix.[5,12] An unpolymerized adhesive did not provide adequate chemical bonding, thus resulting in lower repair bond strength. Nonetheless, the polymerization degree of adhesive resins strongly impacts the repair strength.[33] The monomers in the adhesive resin may not completely polymerize after photo-polymerization following composite placement, with an expected degree of conversion of micro-hybrid resin composite of 69% according to the manufacturer.[34,35] The unpolymerized adhesive resin might only act as a wetting agent similar to silane but do not contribute to chemical adhesion at the repair interface.

Wettability alone did not ensure chemical bonding and therefore did not promote the repair bond strength.[2] After 6 months of water storage, the repair bond strength of resin composite without photo-polymerization of adhesive resin decreased significantly. This may be due to a lack of sufficient free radicals that promotes bond durability.[16,21,36] The use of bonding agents significantly affects the quality of the resin composite repair.[8,37] In the present study, three universal adhesives and a two-step self-etch adhesive was used for the repair procedures with varying results. The adhesives contain 10-MDP as a functional monomer which has superior bonding efficacy and resistance to hydrolytic degradation.[38] The phosphate esters of the monomer can directly bond to various materials, such as polycrystalline ceramics such as zirconia and some resin-based composite materials.[12] 10-MDP monomer may promote the repair bond strength of aged resin composites by providing additional chemical bonding[21,30] as it is a solvent monomer that may penetrate to a cross-linked network including aged resin composite.[30] Among the tested adhesives, Scotchbond Universal also involves an organosilane agent in its composition. However, it has been stated that the silane content of universal adhesive did not affect the performance of adhesive for repair bond strength of resin composites.[17] The inefficacy of the silane content of universal adhesives may be due to the low hydrolytic stability of the silane in the adhesive resin.[38] The silanol groups of the silane may undergo dehydroxylation in the acidic adhesive solution containing water and thereby, the bonding capacity may decrease.[39] Clearfil SE Bond on the other hand, is defined as a gold-standard two-step self-etch adhesive and considered as reference adhesive resin in previous studies.[22,23] It has been reported that the dentin bond strength of Clearfil SE Bond was higher than other universal adhesives.[22,23] However, a former study has also concluded that the obtained immediate repair bond strengths of resin composite with Scotchbond Universal and Clearfil SE Bond were similar.[30] It has been reported that the universal adhesives have thin film thickness, providing that the thickness is dictated by the filler content in their composition.[22] The adhesive layer thickness was not evaluated in the study which needs further investigation.

The clinical situations requiring repair of composite restorations may be seen after a long time of clinical use.[4,8] The repairability of resin composites is decreased with time due to a reduction in unreacted methacrylate groups.[25,32] Residual monomers in the resin composites may in part release from the surface within the first 7 days following polymerization.[25,39] Yet, much of the unreacted monomers remain in the body of the resin matrix entrapped. In laboratory studies, there is currently no consensus on the aging procedure completely simulating the *in vivo* conditions.[4,21] The storage in water is one of the aging methods[4,12] which causes a reduction of unreacted methacrylate carbon double bonds of the resin composite, needed for the chemical bond in a repair situation.[25,40] A number of different aging methods were proposed in the literature but this study focused mainly on early repair actions and for this reason temperature elevations for instance in a thermocycle were not included. On the other hand, long-term water sorption may have more detrimental aging effect on the substrate resin composite.[41]

In the present study, the repair bond strength of the resin composite was not compared to the cohesive strength of resin composite, as a positive control group. In previous studies, the repair bond strength was compared to the original cohesive strength of resin composites.[3,11] It has been reported that the repair bond strength is not higher than 60% of the original cohesive strength of the resin composite.[26] Thus, we focused to compare only the repair techniques. In this study, cohesive failures were observed more in the aged composite. It may be related to the decreasing cohesive strength of the resin materials by water aging, as reported previously.[15] During aging, water absorption occurs in the material, the water plasticizes the polymer matrix and diffuse into the silane-treated filler-matrix interface yielding to hydrolysis within the resin matrix and at the resin-filler interface.[40] Moreover, the adhesive failure mode was the most commonly observed failure mode. In non-photo polymerized groups, the percentage of adhesive failure mode was higher than

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polymerized groups which can be attributed to weaker repair interface. In this study, same resin composite was used as both the aged and fresh resin composite. The homogeneity of aged resin composite and repair composite could be beneficial to improve the copolymerization between their resin matrix monomers.[40] Notwithstanding, these results were revealed in laboratory conditions, hence further *in vitro* and clinical studies are required to validate the results.

CONCLUSIONS

From this study, the following could be concluded:

1. Following surface roughening with a fine diamond bur, application of a silane coupling agent prior to adhesive resin coating did not improve the repair bond strength of the tested microhybrid resin composite tested.
2. Application of universal adhesives might ensure reliable repair bond strength also after aging.
3. Photo-polymerization of adhesive resins tested increased the repair bond strength and hydrolytic durability of the repaired interface.

CLINICAL RELEVANCE

When repairing resin composite restorations, general practitioners may consider surface roughening with a fine-grit diamond bur followed by photo-polymerized universal adhesive application when they do not acquire silica-coating and silanization kits in their armamentarium, providing that the majority of the failures were adhesive in nature which needs clinical attention.

DISCLOSURE

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