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Composite repair using universal adhesive improves bonding stability

Reparo em resina composta usando adesivo universal melhora a estabilidade da união

La reparación de resina compuesta con adhesivo universal mejora la estabilidad de la unión

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Abstract
Repair in resin-based composite is a procedure that has shown good results, when properly indicated. In cases of fracture or stainning, the total removal of the restoration can cause unnecessary wear on the dental element. This study evaluated the aging effect on the bond strength of a universal adhesive containing silane, and/or application of silane separately for composite repairs. Resin composite blocks were thermocycled and divided according to adhesion protocol (n=10): silane(Sil), conventional adhesive(CA), universal adhesive(UA), Sil+CA(SilCA), and Sil+UA(SilUA). Layers of resin composite were added and blocks were sectioned and divided into 2 subgroups: 24h and 4 months of water storage. Microtensile bond strength test was performed and data were statistically analyzed (α = 0.05). After 4months of aging SilCA and SilUA showed a significant bond strength reduction, while for UA the bonding remained stable.
Keywords: Dental restoration repair; Dentin-bonding agents; Composite resins.

Resumo
O reparo em resinas compostas é um procedimento que tem demonstrado bons resultados, quando bem idicado. Em casos de fratura ou manchamento, a remoção total da restauração pode ocasionar desgastes desnecessários no elemento dental. Este estudo avaliou o efeito do envelhecimento na resistência de união de um adesivo universal contendo silano e/ou aplicação de silano separadamente para reparos em resinas compostas. Os blocos de resina composta foram termociclados e divididos de acordo com o protocolo de adesão (n = 10): silano (Sil), adesivo convencional (AC), adesivo universal (AU), Sil + AC (SilAC) e Sil + AU (SilAU). Camadas de resina composta foram adicionadas e os blocos seccionados e divididos em 2 subgrupos: 24h e 4 meses de armazenamento em água. O teste de microtração foi realizado e os dados foram analisados estatisticamente (α = 0,05). Após 4 meses de envelhecimento, o SilAC e o SilAC mostraram uma redução significativa da resistência de união, enquanto que para o AU a união permaneceu estável.
Palavras-chave: Reparação de restauração dentária; Adesivos dentinários; Resinas compostas.

Resumen
La reparación de resinas compuestas es un procedimiento que ha mostrado buenos resultados, cuando está debidamente indicado. En los casos de fractura u oscurecimiento, la retirada total de la restauración puede provocar un desgaste innecesario del elemento dental. Este estudio evaluó el efecto del envejecimiento en la fuerza de unión de un

adhesivo universal que contiene silano y / o la aplicación de silano por separado para reparaciones de resinas compuestas. Los bloques de resina compuesta se termociclaron y dividieron según el protocolo de adhesión (n = 10): silano (Sil), adhesivo convencional (AC), adhesivo universal (AU), Sil + AC (SilAC) y Sil + AU (SilAU). Se agregaron capas de resina compuesta y los bloques se seccionaron y dividieron en 2 subgrupos: 24 horas y 4 meses de almacenamiento de agua. Se realizó la prueba de microtensión y los datos se analizaron estadísticamente (α = 0.05). Después de 4 meses de envejecimiento, SilAC y SilAC mostraron una reducción significativa en la fuerza de unión, mientras que para AU la unión se mantuvo estable.
Palabras clave: Reparación de restauración dental; Recubrimientos dentinarios; Resinas compuestas.

1. Introduction

In fractures cases or color changes, complete removal of resin-based restorations may result in additional loss of dental tissue, which it could be avoided by performing a repair, a conservative technique consisting of removing only the unsatisfactory part of the restoration and adding a new resin composite (Imbery et al., 2014). its success depends on proper case selection, material, and technique (da Costa et al., 2021).

The use of silane coupling agent in repairs has been reported as important for obtaining improved adhesive interface (de Rosatto, Roscoe, Novais, Menezes & Soares, 2014; Staxrud & Dahl, 2015; Mendes et al., 2020). Silane increases the bonding surface wetting, which it is expected to allow the bonding agent to infiltrate the surface irregularities, while a silane coated composite is more reactive for methacrylate groups of repair material (Loomas et al., 2011). On the other hand, a recent study suggest that the application of the adhesive with or without the silane improve the bond strength of repairs in resin-based composite (Chen, Chen, Wu & Du, 2021). Furthermore, in bulk fill resins the repair using the universal or conventional solvent-free adhesive showed better independent adhesive of the tested composite (Tsutsumi et al., 2021).

Currently, universal adhesives were developed to ensure the bond strength of several dental materials. In some universal systems, silane has been added to provide broader indications, such as adhesion to dental ceramics and repair of resin composites (Elias et al., 2015). Some studies verified that a universal adhesive showed similar bond strength compared to separate use of silane or an adhesive system; however, the bonding stability was not evaluated (Staxrud & Dahl, 2015; Fornazari, Wille, Meda, Brum & Souza, 2017).

The bond strength can be reduced after thermal cycling or storage (Konno, Sinhoreti, Consani, Correr Sobrinho & Consani, 2003; Lima et al., 2014), thus to assess the bond strength longevity after repair provides important information for clinical decisions. For this reason, in this study was evaluated the bond strength stability of a universal adhesive system used for repairs on an aged resin composite. The null hypothesis tested was that the universal adhesive would exhibit similar bond strength durability as the separate use of silane coupling agent and/or conventional adhesive system.

2. Methodology

2.1 Experimental design

The experimental design in this study was a two-factor randomized of block arrangement. The factors considered were the adhesion protocols (Pure Silane, Conventional Adhesive and Single Bond Universal alone and associated with silane) and time after the repair procedure (Immediately and 4 months)

The table 1 presents the materials that were used in the adhesive protocol of repair procedures.

Table 1 – Materials used in this study.

Material	Trade mark	Composition
Phosphoric acid	Scotchbond Etching (3M ESPE)	35% of phosphoric acid, pyrogenic silica and a water-soluble surfactant, blue dye, distilled water
Conventional adhesive system	Single Bond 2 (3M ESPE)	Bis-GMA, HEMA, dimethacrylate diurethane, copolymers of polyalkanoic acid, camphorquinone, water and ethanol, glycerol 1,3 dimethacrylate, 10% by weight of colloidal silica
Silane coupling agent	RelyX Ceramic Primer (3M ESPE)	Water, ethyl alcohol, methacrylate of 3- trimetoxysylylpropyl
Universal adhesive system	Single Bond Universal (3M ESPE)	BisGMA, 2-hydroxyethyl methacrylate, decamethylene dimethacrylate, water, ethanol, Silane treated silica, 1,10-decanediol phosphate methacrylate, acrylic copolymer and itaconic acid, 2-dimethylaminoethyl methacrylate, N, N-dimethylbenzocaine, caforquinone, methyl ethyl ketone
Resin composite	Filtek Z350 (3M ESPE)	Organic content: Bis-GMA, UDMA, TEGDMA, PEGDMA and Bis-EMA. Inorganic content: non-agglomerated 20 nm silica nanoparticles, non-agglomerated zirconia nanoparticles having a size of 4 to 11 nm, and combined zirconia (4 to 11 nm) and silica (20 nm) aggregate loading. The average size of agglomerates ranges from 0.6 to 1 μm. The amount of filler particles is 78.5% by weight and 63.3% by volume

Source: www.3m.com.br.

2.2 Specimen preparation

Fifty resin composite (Filtek Z350; 3M ESPE, St. Paul, MN, USA) square blocks with dimensions of 8 x 8 x 4 mm were prepared by the incremental technique using a metal matrix and submitted to thermal cycling (5 - 55°C) for 5,000 cycles (Cho & Dikens, 2004) for specimen aging.

After thermocycling, all composite blocks were ground with #320 granulation abrasive paper using a polisher machine (Biopdi, São Carlos, SP, Brazil), cleaned with 35% phosphoric acid (3M ESPE) for 15 s, and then washed for 10 s and dried.

Composite blocks were randomly divided into 5 groups (n = 10) according to adhesion protocol (Çakir, Demirbuga, Balkaya &, Karadaş, 2018): (1) Silane coupling agent (Sil): active application of silane for 10 s using a microbrush and dried for 1 min with air spray; (2) Conventional adhesive system (CA): active application of one layer of conventional adhesive for 10 s, gently air dried for 5 s, and light curing for 20 s; (3) Universal adhesive system (UA): active application of one layer of universal adhesive for 10 s, gently air dried for 5 s, and light curing for 20 s; (4) Sil + CA (SilCA): active application of silane for 10 s using a microbrush and dried for 1 min with air spray, active application of one layer of conventional adhesive for 10 s, gently air dried for 5 s, and light curing for 20 s; and (5) Sil + UA (SilUA): active application of silane for 10 s using a microbrush and dried for 1 min with air spray, active application of one layer of universal adhesive for 10 s, gently air dried for 5 s, and light curing for 20 s.

After adhesion protocols, incremental layers of resin composite were added directly on treated surface of composite blocks, up to a 4 mm height. Light curing of resin-based materials was carried out using a polywave LED (Bluephase N,

Ivoclar Vivadent, Schaan, Liechtenstein) at 1,200 mW/cm^2 monitored by a radiometer. Repaired composite block was taken to cutting saw (Isomet 1000; Buehler Inc., Lake Bluff, IL, USA) to obtain the beams with symmetrical adhesive interface (0.8 x 0.8 mm ± 0.1 mm). A total of 16 beams were obtained from each composite block, the were randomly divided into 2 subgroups, according to the storage conditions: (a) 24 h evaluation (8 beams) - specimens were submitted after 24 h to adhesion testing and (b) water storage for 4 months (8 beams) - specimens were stored in distilled water for 120 days (weekly changed) and tested.

2.3 Bond strength

Bonding area of specimens was measured using a digital caliper (Starret Ind. Com. Ltd., Itu, SP, Brazil) prior to testing. Each beam was positioned parallel to test device long axis and was applied to universal test machine, parallel to the application of tensile load at a 0.5 mm/min speed (EMIC 23-2S; Instron, São José dos Pinhais, PR, Brazil).

2.4 Failure mode

Failure mode was evaluated in composite cohesive or adhesive using a stereomicroscope. The values obtained for cohesive failure in resin composite resin were not analyzed statistically, to evaluate the bond strength of adhesive interface. Bond strength (MPa) was calculated by formula: F/A, where F is the force (N) of failure and (A) is the interfacial area of beam (mm^2).

2.5 Statistical analysis

Shapiro Wilk and Bartlett tests were performed to verify the normality and homoscedasticity of residues, respectively. Data were analyzed using two-way ANOVA (Analysis of Variance) and Tukey's post-test, at a 5% of significance level.

3. Results

Table 2 shows bond strength values. After 24 h, the application of only silane coupling agent resulted in significantly lower bond strength (16.6 ± 3.33), indicating the relevance of using adhesive system. However, when using only the conventional adhesive, which does not present silane in its composition, the bond strength values (26.0 ± 5.11) were intermediate, showing a superior performance to Sil group and statistically similar to universal adhesive group (30.0 ± 4.78). SilCA (35.4 ± 4.11) and SilUA (36.3 ± 4.06), where silane was applied separately from the adhesive systems, showed values statistically similar to UA group.

Tests performed after 4 months of water storage showed a significant decrease in bond strength values for Sil (13.3 ± 2.12), SilCA (29.0 ± 2.49) and SilUA (30.8 ± 3.96) groups. CA (25.8 ± 1.65) and UA (29.7 ± 3.42) groups were more stable, with no statistically significant reduction on the bond strength. After 4 months of storage, the Sil group was observed to have lower bond strength values, while the other groups had statistically similar values between them.

In table 2, it is important to note that the use of the adhesive system, regardless of the repair time and the adhesive used, there are no differences between groups. Also, it is noteworthy that only the group that used silane did not present good adhesive properties, compared to the others.

Table 2 - Bond strength* (MPa) values (SD) according to surface treatments and timespan study.

Surface treatment	24 h			Water storage			p-value
	Bond strength	SD	CV	Bond strength	SD	CV	
Sil	16.6^{Ca}	3.33	20.08	13.3^{Bb}	2.12	15.87	
CA	26.0^{Ba}	5.11	19.62	25.8^{Aa}	1.65	6.38	
UA	30.0^{ABa}	4.78	15.92	29.7^{Aa}	3.42	11.53	0.038
SilCA	35.4^{Aa}	4.11	11.63	29.0^{Ab}	2.49	8.59	
SilUA	36.3^{Aa}	4.06	11.18	30.8^{Ab}	3.96	12.83	

*Different capital letters in the same column indicate that there was statistical difference between the surface treatments. Different lowercase letters in the row indicate that there was statistical difference between timespan study (24 h and 4 months of water storage). Sil: silane, CA: conventional adhesive, UA: universal adhesive, SilCA: Sil + CA, SilUA: Sil + UA, SD: standard deviation, CV: Coefficient of variation; p-value: two-way analysis of variance (surface treatment and timespan study).
Source: Authors.

The cohesive fractures were discarded, for reasons that have already been described previously. Cohesive fractures in groups 24 h after repair for the Sil were 2 (2.5%), CA 7 (8.7%), UA 8 (13.7%), SilCA 9 (11.25%), and SilUA 9 (11, 25%), After water storage the Sil showed 1 (1.3%) cohesive fracture, CA 5 (6.3%), UA 6 (7.5%), SilCA 6 (7.5%), and SilUA 7 (8.8%).

4. Discussion

Some studies indicate the Sil use as a coupling agent in repair procedures, since increases the bond strength (Staxrud & Dahl, 2015; Halvoson, Erickson & Davidson, 2003; Eliasson, Tibballs & Dahl, 2014) In addition to increasing surface wetting function, the Sil molecules have two groups: silanol that bonds to silica particles and methacrylate that bonds to organic matrix of resin composite (Imbery et al., 2014; Ahmadizenouz et al., 2016). Sil use relevance as a bonding agent was confirmed in the present study, since the bond strength values were significantly higher when using silane coupling agent combined with a conventional adhesive and universal adhesive, compared to use of both same adhesive systems only.

However, the application of only Sil coupling agent does not provide a satisfactory bonding between the old and fresh resin composite (Ahmadizenouz et al., 2016). The surface of aged material must be prepared to create macro and micro retentive characteristics (Ahmadizenouz et al., 2016). However, the resin composite cannot easily adapt to rough surface to create an effective bonding; therefore, the use of a low viscosity resin-based material, the adhesive system, on the substrate prior to composite repair is indispensable (Lima et al., 2014; Manennut, Sakoolnamarka & Tyas, 2011; Acharya & Manjunath, 2012).

Recently, a UA containing Sil and several monomers was developed in a single bottle to optimize the clinical steps (Lung & Matinlinna, 2012). Therefore, it is possible to apply only the UA, without pre-application of Sil coupling agent, since it presents similar results as the use of Sil and adhesive system applied separately (Staxrud & Dahl, 2015; Gutierrez et al., 2019).

A significant reduction on the bond strength was observed after 4 months water storage when the silane was used separately, whereas the use of UA showed higher stability. This may have occurred due to the silane exhibits long-term hydrolytic instability, which causes hydrolysis by dividing the Si-O cations over time. Bond strength depends on hydrogen bonds and molecular attraction forces, such as Van der Waals forces, rather than the stronger covalent or ionic bonds. Therefore, the bonding between the Sil and old composite resin is always susceptible to hydrolysis of relatively weak bonds.

As such, it is not yet possible to state whether the favorable effects of Sil are long lasting (Staxrud & Dahl, 2015; Lung & Matinlinna, 2012). UA group showed improved adhesive stability after 4 months of water storage. It is believed that this durability on the bond strength occurred because the silane present in the UA is pre-hydrolyzed, which gives better stability (3M ESPE). The UA success is linked to its ability to separate hydroxyl groups and form oxygen bridges to surface cations (Staxrud et al., 2015). Moreover, the Sil enveloped by monomers can favor the longevity and decrease its hydrolysis (Staxrud & Dahl, 2015; Lung & Matinlinna, 2012).

The UA presents lower technique sensitivity, allowing use in a shorter clinical time and it shows a bond strength comparable to application protocol of silane coupling agent and adhesive system separately. Therefore, the UA seems to be a viable alternative for repairing nanoparticulate resin composite, although it is important to conduct clinical studies to validate the restoration repair longevity in the oral environment.

5. Conclusion

The universal adhesive showed bond strength similar to separate application of silane coupling agent and adhesive system (conventional or universal) and its performance was stable after water storage. More studies are still needed to answer the existing gaps, therefore, more laboratory studies simulating oral conditions (chewing strength, parafuctional habits) are needed, in addition to conducting clinical studies.

References

3M ESPE. Scotchbond Universal Adhesive technical product profile. Retrieved online http://multimedia.3m.com/mws/media/754751O/scotchbond-universal-adhesive-technical-product-profile.

Acharya, G. S., & Manjunath, M. (2012) The effect of surface treatments and bonding regimens on microtensile bond strengths of repaired composite: An in vitro study. *J Conserv Dent*, 15(4):383-387.

Ahmadizenouz, G., Esmaeili, B., Taghvaei, A., Jamali, Z., Jafari, T., Amiri Daneshvar, F., & Khafri, S. (2016) .Effect of different surface treatments on the shear bond strength of nanofilled composite repairs. *J Dent Res Dent Clin Dent Prospects*., 10(1):9-16.

Çakir, N. N., Demirbuga, S., Balkaya, H., & Karadaş, M. (2018) Bonding performance of universal adhesives on composite repairs, with or without silane application. *J Conserv Dent*, 21(3):263-268.

Chen, K. K., Chen, J. H., Wu, J. H., & Du, J. K. (2021) Influence of commercial adhesive with/without silane on the bond strength of resin-based composite repaired within twenty-four hours. *J Dent Sci*, 16(3):877-884.

Cho, B. H. & Dickens, S. H. (2004) Effects of the acetone content of single solution dentin bonding agents on the adhesive layer thickness and the microtensile bond strength. *Dent Mater*, 20(2):107-15.

da Costa, J. B., Frazier, K., Duong, M. L., Khajotia, S., Kumar, P., & Urquhart, O. (2021) Council on Scientific Affairs. Defective restoration repair or replacement: An American Dental Association Clinical Evaluators Panel survey. *J Am Dent Assoc*, 152(4):329-330.e2.

de Rosatto, C. M., Roscoe, M. G., Novais, V. R., Menezes, M. S., & Soares, C. J. (2014) Effect of silane type and air-drying temperature on bonding fiber post to composite core and resin cement. *Braz Dent J*, 25(3):217-224.

Elias, S. T., Santos, A. F., Garcia, F.C., Pereira, P. N., Hilgert, L. A., Fonseca-Bazzo, Y. M., Guerra, E. N., & Ribeiro, A. P. (2015) Cytotoxicity of universal, self-etching and etch-and-rinse adhesive systems according to the polymerization time. *Braz Dent J*, 26(2):160-168.

Eliasson, S.T., Tibballs, J., & Dahl, J. E. (2014). Effect of different surface treatments and adhesives on repair bond strength of resin composites after one and 12 months of storage using an improved microtensile test method. *Oper Dent*, 9(5):E206-E216.

Fornazari, I.A., Wille, I., Meda, E.M., Brum, R. T., & Souza, E. M. (2017) Effect of Surface Treatment, Silane, and Universal Adhesive on Microshear Bond Strength of Nanofilled Composite Repairs. *Oper Dent*, 42(4):367-374.

Gutierrez, N.C., Moecke, S.E., Caneppele, T. M., Perote, L. C., Batista, G. R., Huhtalla, M. F., & Torres, C. R. (2019) Bond Strength of Composite Resin Restoration Repair: Influence of Silane and Adhesive Systems. *J Contemp Dent Pract*, 20(8):880-886.

Halvorson, R. H., Erickson, R. L., & Davidson, C. L. (2003) The effect of filler and silane content on conversion of resin-based composite. *Dent Mater*, 19(4):327-333.

Imbery, T. A., Gray, T,, DeLatour, F., Boxx, C., Best, A. M., & Moon, P. C. (2014) Evaluation of flexural, diametral tensile, and shear bond strength of composite repairs. *Oper Dent*, 39(6):E250-E260.

Konno, A.N., Sinhoreti, M. A., Consani, S., Correr Sobrinho, L., & Consani, R. L. (2003) Storage effect on the shear bond strength of adhesive systems. *Braz Dent J*, 14(1):42-47.

Lima, A. F., Ferreira, S. F., Catelan, A., Palialol, A. R., Gonçalves, L. S., Aguiar, F. H., & Marchi, G. M. (2014) The effect of surface treatment and bonding procedures on the bond strength of silorane composite repairs. *Acta Odontol Scand*, 72(1):71-75.

Loomans, B. A., Vivan Cardoso, M., Roeters, F.J., Opdam, N.J., De Munck, J., Huysmans, M.C., & Van Meerbeek, B. (2011) Is there one optimal repair technique for all composites?. *Dent Mater*, 27:701-709.

Lung, C. Y., & Matinlinna, J. P. (2012) Aspects of silane coupling agents and surface conditioning in dentistry: an overview. *Dent Mater*, 28(5):467-477.

Maneenut, C., Sakoolnamarka, R., & Tyas, M. J. (2011) The repair potential of resin composite materials. *Dent Mater*, 27(2):e20-E27.

Mendes, L.T., Loomans, B. A. C., Opdam, N. J. M., Silva, C. L. D., Casagrande, L., & Lenzi, T. L. (2020) Silane Coupling Agents are Beneficial for Resin Composite Repair: A Systematic Review and Meta-Analysis of In Vitro Studies. *J Adhes Dent*, 22(5):443-453.

Staxrud, F.; Dahl, J. E. (2015). Silanising agents promote resin-composite repair. Int Dent J., 65(6):311-315.

Tsutsumi M. S. C., de Souza F. T., Batista V. E. S., Matuda L. S. A., dos Santos P. H. & Catelan A. (2021) Bond strength repair of a bulk-fill composite using different adhesive systems and resin composites. Research, Society and Development, 10(5):3141051495.