BONDING TO COMPOSITE RESIN, DENTIN, AND COMPOSITE-DENTIN INTERFACE, REGARDING RESTORATION REPAIR

Isabella S. Manso[1], Lisia L. Valente[1], Eliseu A. Münchow[2], Cristina P. Isolan[1], Fábio G. Lima[1], Rafael R. Moraes[1]

ABSTRACT

This study evaluated the repair bond strength (RBS), contact angle (θ) and surface morphology of composite resin repairs on dentin (DE), composite resin (CR) and dentin-composite resin interface (DE-CR), after different surface treatments. Bovine incisors were used for RBS and θ tests; CR blocks (Opallis, FGM, Brazil) were prepared for θ evaluation with water. All samples were separated into four groups (n=10 for RBS; n=5 for θ), according to the bonding agent applied: no surface treatment (C); acid-etching followed by adhesive application (Ac+Ad); silane (S); and acid-etching + silane + adhesive (Ac+S+Ad). For RBS test, the microshear bond strength test was carried out. For θ test, the samples were evaluated by dropping water onto their surface after treatment with the bonding agents. All tested substrates were analyzed using scanning electron microscopy (SEM), and data were analyzed with ANOVA and Student-Newman-Keuls test (α = 0.05). In DE, the application of Ac+S+Ad reduced dentin wettability. In CR, all bonding agents increased wettability, compared with C. For RBS, a significantly higher repair bond strength was observed for groups treated with adhesive, compared with C and S groups, at both DE and DE-CR interface. In CR, only C showed lower bond strength values, compared with the others. In conclusion, dental practitioners should be aware that the repair bonding performance of composite restorations may depend on the substrates involved in the repairing procedure, with the application of adhesive system being the most advisable chemical treatment for obtaining proper bonding to all substrates.

KEYWORDS: Dental materials. Repair. Composite resin. Bond strength. Surface treatments.

1. Universidade Federal de Pelotas, Faculdade de Odontologia, Programa de Pós-Graduação em Odontologia (Pelotas/RS, Brazil).

2. Universidade Federal de Juiz de Fora, Instituto de Ciências da Saúde, Departamento de Odontologia (Governador Valadares/MG, Brazil).

DOI: https://doi.org/10.14436/2447-911x.16.2.054-068.oar

INTRODUCTION

Composite resin is a reliable material for restoring teeth with esthetical appearance or shape compromised by wear, trauma, or caries.[1,2] Compared with glass-ceramics, composite resins have the advantage of being less expensive, and their durability is dependent on several factors, including those related to the patient, tooth, restorative material, and operator.[3,4] Despite the acceptable clinical performance of composite restorations, secondary caries and fracture are common reasons for restoration failure,[3-5] leading to complete replacement of the failed material. Changes in color and shape, as well as tooth sensitivity, are also frequent reasons for complete replacement of restorations. Nevertheless, the replacement of restorations with fresh materials may unavoidably result in additional removal of sound tooth structure due to the difficulty in removing only the defective material. Alternatively, repair procedures may lead to a more conservative approach in the treatment of failed or defective restorations.[6] For instance, only the defective portion of the restoration is completely removed and filled with fresh material, thus contributing for a significant reduction in chair time, costs, and removal of sound tissues. It has been reported that repair may increase the clinical longevity of composite resin restorations.[7-9]

Even though composite repairs may present several advantages over the complete removal of failed restorations, concerns regarding the mechanical retention and bonding between the fresh and old materials should be considered.[10] The effectiveness of composite repairs depends on the appropriate interface connection between fresh and old composites[11]. Several surface treatment methods as well as bonding agents have been tested in order to increase the bonding performance of composite repairs.[12] According to a systematic review[13] on the impact of physical and chemical surface treatments on the repair bond strength of methacrylate-based dental composites, the authors suggested that the combination of physical abrasion techniques with the application of chemical agents may improve the overall repair bond strengths. In addition, silane coupling agents appeared to have a minor role as compared with adhesives in improving the repair potential.

Although previous studies have focused on testing the effect of physical and chemical surface treatments on the repair of composite resins, the literature is still scarce on the impact that the bonding substrate may have on the repair procedure. It is true that the chemical agents listed before (e.g., silane, adhesives) may indeed produce a positive bonding effect on composite, but there is no previous information regarding their effect on the surface characteristics and bonding ability of dentin and the dentin-composite interface during repair. For instance, the dentist will usually have to repair defective restorations that perhaps failed not only at the 'old' composite bulk structure, but also by extending it to the dental substrates.[6]

The purpose of the present study was to evaluate the repair bond strength of composite resin on substrates clinically relevant to repairing procedures, namely dentin, composite resin, and the dentin-composite interface, after different surface treatments. The surface characteristics such as water contact angle and morphology of each substrate were also evaluated. The null hypothesis was that the repair bonding performance would be similar at the different substrates tested, regardless of the surface treatment.

MATERIALS AND METHODS

Experimental design and sample size estimation

This in vitro study evaluated the effect of two factors on the bonding performance of composite repairs: type of substrate (dentin, composite, and dentin-composite interface) and type of surface treatment (none — Control, adhesive system, silane, and silane+adhesive). The materials used were: 37% phosphoric acid gel (Condac 37, FGM, Joinville, SC, Brazil); two-step dental adhesive (Single Bond 2, 3M ESPE, St. Paul, MN, USA); silane coupling agent (Silane, Dentsply Caulk, Milford, DE, USA); and a nanohybrid composite resin (Opallis; FGM Equipamentos Odontológicos, Joinville, SC, Brazil). Sample size was estimated by using SigmaPlot (version 12.0; Systat Software, San Jose, CA, USA), and based on the results of a previous study conducted under the same conditions.[11] The response variables were repair bond strength (MPa), failure mode, and water contact angle. Scanning electron microscopy (SEM) was used for evaluation of the surface and interfacial morphology of the selected substrates.

Preparation of the specimens

Bovine incisors were obtained, disinfected, and kept frozen until their use. Medium dentin was exposed at the buccal surface and the adhesive system was applied as follows: phosphoric acid application for 15 s, followed by water rinsing and drying with absorbent paper points; adhesive application for 10 s with a disposable microbrush, followed by solvent volatilization for 10 s and light-activation for 20 s using a light-emitting diode (LED Radii, Bayswater, VIC, Australia) with irradiance of 900 mW/cm^2. Composite resin was then placed using two increments of approximately 2 mm each, which were light-activated for 20 s with the LED. After 24 h storage in distilled water, the specimens were cut at the longitudinal axis, obtaining two halves for each restored teeth (N=80), which were then embedded in acrylic resin. The interfaces were wet-polished with 600- and 1200-grit SiC abrasive. The protocol is shown in Figure 1A.

Repair in different substrates

The obtained samples, i.e., each half of the restored teeth, were comprised of three distinct substrates: dentin (DE), composite resin (CR), and the dentin-composite interface (DE-CR), as shown in Figure 1A (insert in the SEM micrograph). The specimens were randomly allocat-

ed into four groups (n=20), according to the combination of bonding agents applied: control, i.e. no surface treatment (C), acid-etching followed by adhesive application (Ac+Ad), silane (S), and acid-etching + silane + adhesive (Ac+S+Ad). The phosphoric acid and adhesive were applied as aforementioned. Silane was applied following the manufacturer directions, i.e., application for 10 s with a disposable microbrush, air-drying for 5 s, and let to rest for 60 s. A silicone mold containing three orifices (1.5 mm in diameter × 1.5 mm in thickness) was placed at the top of each sample. The intermediary orifice was exactly placed over the DE-CR interface, so that the other orifices could be each one positioned over

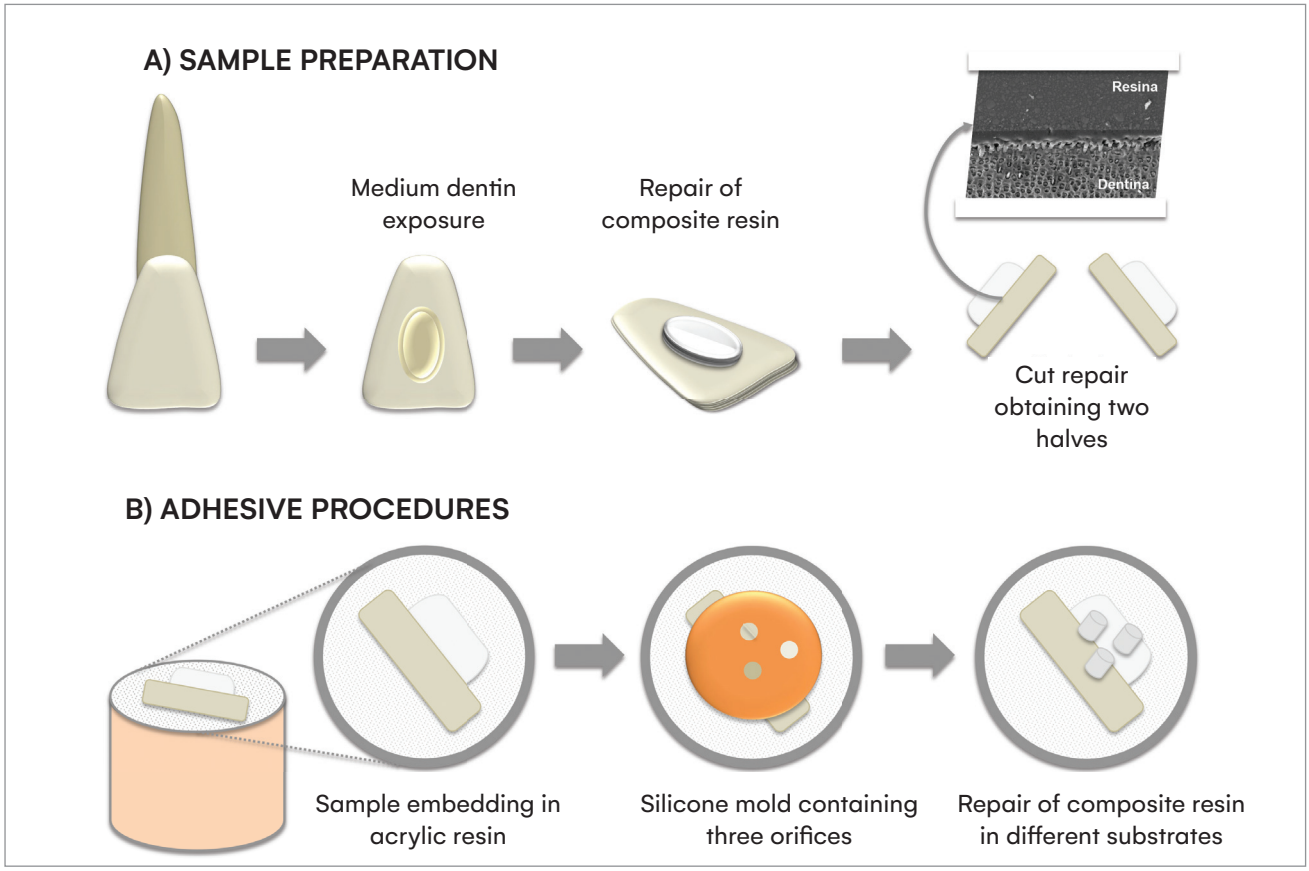

Figure 1:
Protocol for preparation of the specimens (**A**) and bonding procedures (**B**).

DE or CR substrates, respectively. Groups treated with adhesive (Ac+Ad and Ac+S+Ad) had the adhesive layer light-activated only after placement of the mold. Fresh composite resin was filled into each orifice and light-activated with the LED for 20 s. The mold was gently removed, resulting in three composite cylinders per each sample tested (Figure 1B). The samples were all stored in distilled water at 37°C for 24 h.

Bond strength test and failure mode analysis

All composite specimens were submitted to a shear bond strength test. Briefly, a stainless-steel wire (0.2 mm in diameter) was looped around each cylinder and aligned with the bonded interface. The shear bond strength test was conducted on a mechanical testing machine (DL500; EMIC, São José dos Pinhais, PR, Brazil) at a crosshead speed of 0.5 mm/min until failure. Fractured specimens were observed under 40× magnification using a stereomicroscope to determine the failure mode: adhesive (interfacial), cohesive within dentin, cohesive within composite resin, or mixed (partially adhesive and partially cohesive within dentin-composite). Pre-failures were considered as specimens that failed before testing.

SEM morphological analysis

Two additional specimens for each surface treatment group were prepared for SEM evaluation. The specimens were treated accordingly with the respective bonding agents tested, and two increments of composite resin were placed on the top of the specimens. Each increment was light-activated with the LED for 20 s. Each specimen was embedded cross-sectionally in epoxy resin for visualization of the composite resin repairs. After 24 h, the surfaces were wet-polished with 600-, 1200-, 1500- and 2000-grit SiC abrasive papers and polished with 3-, 1-, and 0.5-µm diamond suspensions. The surfaces were etched with a 50% phosphoric acid aqueous solution for 5 s and deproteinized by immersion in 2.5% NaOCl aqueous solution for 10 min. The samples were ultrasonically cleaned with distilled water and dried in a container with silica gel for 2 h, at room temperature. The polished surfaces were sputter-coated with gold and the bonded interfaces examined using scanning electron microscopy (JSM 6610, JEOL, Tokyo, Japan).

Water contact angle analysis

Twenty additional bovine incisors were prepared as described before until medium dentin was exposed. Composite resin blocks were also prepared by placing two increments of approximately 1.5 mm-thick each into a mold (18 mm long, 10 mm width, 3 mm thickness). The tooth samples and composite blocks were allocated into four groups (n=5) according to the foregoing combination of bonding agents used: C; Ac+Ad; S; and Ac+S+Ad. A standard 5-µl drop of distilled water was placed on the surface of each specimen and a profile digital image was recorded after 5 s using a 105-mm lens (f/2.8 EX DG OS HSM,

Sigma; Ronkonkoma, NY, USA). The contact angle (θ) was calculated by averaging the angles formed between the surface and the left and right borders of the water drop (ImageJ, National Institute of Health; Bethesda, MD, USA).

Statistical analysis

Statistical analyses were carried out using SigmaPlot software. Bond strength data (MPa) were non-parametric, thus all data were analyzed using Analysis of Variance (ANOVA) on Ranks. Contact angle data (θ,°) were parametric and subjected to two-way ANOVA. Pairwise multiple comparisons were performed using the Student-Newman-Keuls test. Linear regression analyses were used to investigate the relationship between water contact angle and bond strength data in dentin and composite resin. The significance level of all analyses was set at $\alpha = 0.05$.

RESULTS

Repair bond strength

The repair bond strength results are shown in Table 1. While the factors investigated were not significant ($p>0.05$), there was a statistical interaction between each other ($p<0.001$). A significantly higher repair bond strength was observed for groups treated with adhesive (Ac+Ad or Ac+S+Ad) compared with the control group (untreated) and the group treated with silane (S) only, at both the dentin and dentin-composite interface. In composite resin, only the control group showed lower bond strength values when compared with the other treatments, which presented similar results.

Table 1:
Repair bond strength median values (minimum-maximum), in MPa, for tested groups at different substrates.

SURFACE TREATMENT	SUBSTRATE		
	DE	INTERFACE DE-RC	RC
Control	0,7 (0,2-1,2)^{B,a}	1,1 (0,1-5,5)^{B,a}	3,4 (0,3-8,1)^{B,a}
Acid + Adhesive	8,3 (1,1-20,6)^{A,a}	9,9 (0,5-16,6)^{A,a}	9,3 (2,2-29,6)^{A,a}
Silane	0,6 (0,2-2,7)^{B,b}	2,6 (0,1-9,7)^{B,b}	6,7 (1,7-17,8)^{A,a}
Acid + Silane + Adhesive	10,0 (3,1-18,3)^{A,a}	9,6 (3,3-18,7)^{A,a}	9,7 (2,6-20,2)^{A,a}

Uppercase letters in columns and lowercase letters in rows indicate, respectively, statistical significant differences among surface treatments and substrates ($p<0.05$).
DE: dentin; DE-CR: dentin-composite; CR: composite resin.

Table 2:

Failure mode distribution among groups.

SUBSTRATE	SURFACE TREATMENT	FAILURE MODE				
		AD	CD	CR	M	FP
Dentin	Control	1	–	–	1	17
	Acid + Adhesive	2	6	2	18	–
	Silane	5	–	–	1	16
	Acid + Silane + Adhesi-ve	11	2	–	9	–
Dentin-composite interface	Control	8	–	–	2	9
	Acid + Adhesive	–	2	8	16	–
	Silane	10	–	–	8	6
	Acid + Silane + Adhesi-ve	3	2	1	17	–
Composite resin	Control	21	–	3	–	3
	Acid + Adhesive	8	–	11	7	1
	Silane	14	–	10	6	2
	Acid + Silane + Adhesi-ve	2	–	5	15	–

AD: adhesive; CD: cohesive in dentin; CR: cohesive in composite resin; MX: mixed; PF: premature failure.

Groups treated with the same bonding protocol showed similar bond strength values when dentin, composite resin, and dentin-composite interface substrates were compared, except for groups treated with silane only, which had a better bonding performance in composite resin than at the other substrates tested.

Concerning the failure mode results, which are shown in Table 2, premature failures occurred in all substrates, although they were more frequent in dentin (36%), followed by dentin-composite interface (18%) and composite resin (6%). Also, premature failures occurred for the untreated groups or groups treated with silane only. Overall, there was an equilibrium between adhesive and mixed failures for all bonding substrates. Cohesive failures were more frequently found when the bonding substrate was composite resin.

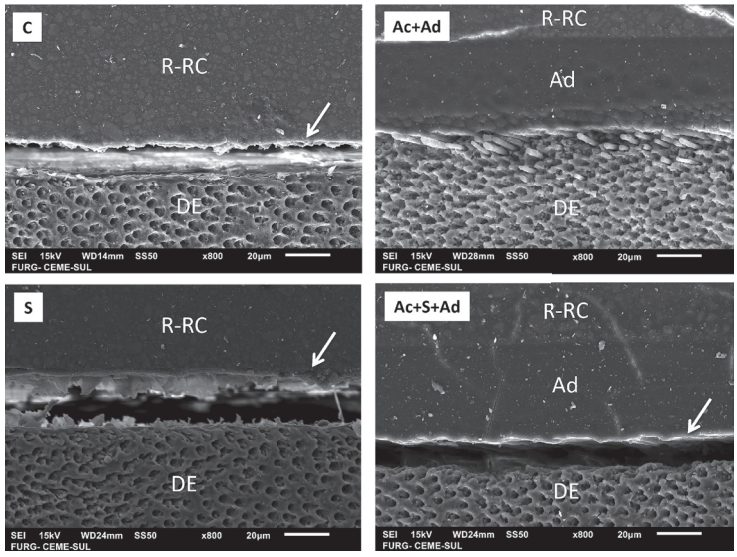

Figure 2:
SEM micrographs showing the bonding interface of composite resin repairs made on dentin after different surface treatments. The most appropriate bonding interface seemed to be produced when 37% phosphoric acid and adhesive (Ac+Ad) were applied in dentin (**DE**), with formation of hybrid layer. Conversely, the bonding interaction between repair material (**R–CR**) and DE was not satisfactorily obtained, as suggested by the absence of interfacial interlocking between R-CR and DE (white arrows) shown for the other surface treatments tested.

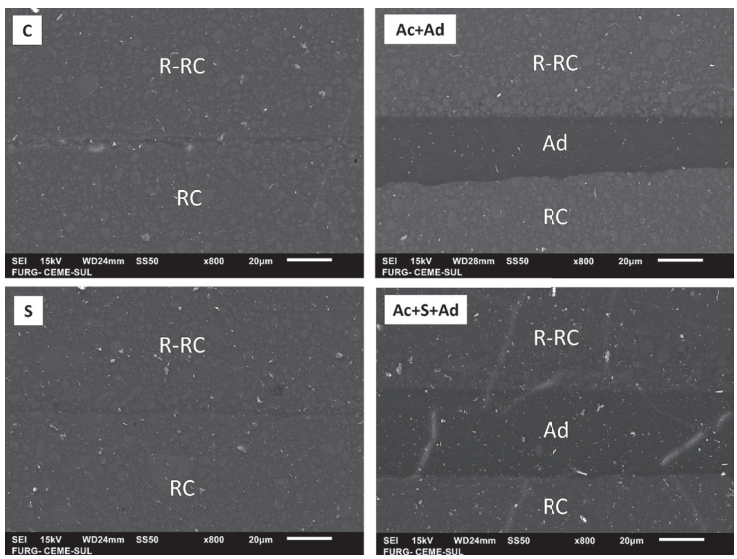

Figure 3:
SEM micrographs showing the bonding interface of composite resin repairs made on composite resin after different surface treatments. The bonding interface between the composite resin used as repair material (**R–CR**) and the repaired composite resin (**CR**) seemed to be effective for all tested groups. The adhesive layer (Ad) tended to be thicker when silane was applied prior to the adhesive agent.

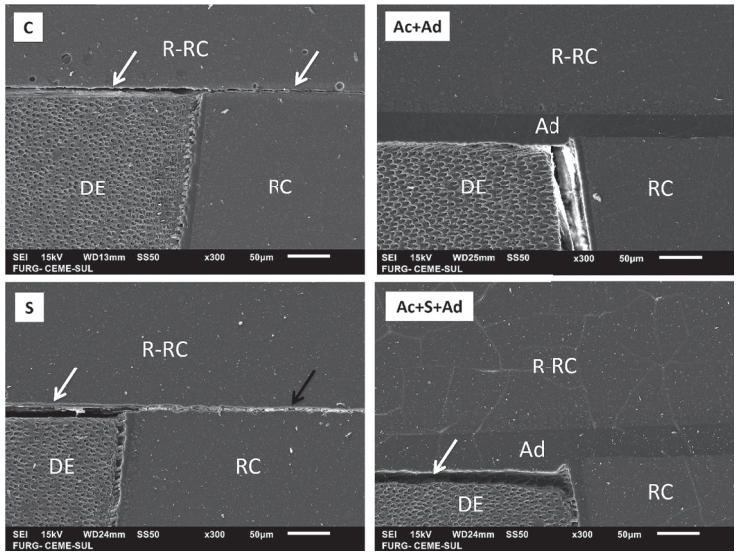

Figure 4:
SEM micrographs showing the bonding interface of composite resin repairs made on the dentin–composite resin interface after different surface treatments. At the dentin (**DE**) part of the interface, a satisfactory bonding interface could be observed by applying 37% phosphoric acid and adhesive (Ac+Ad); also, it seems that silane does not induce a proper interaction to DE, as suggested by the absence of close contact (white arrows) between silane-treated DE and the repair material (**R–CR**). On the other hand, silane application seemed to produce a better surface interaction between the R-CR and the repaired composite resin (**CR**), as demonstrated by the black arrow. In the absence of any surface treatment (**C**), the bonding interface between the R-CR and the CR seemed to be defective.

SEM evaluation

SEM images of composite resin repairs in dentin, composite resin, and dentin–composite interface are shown in Figures 2, 3, and 4, respectively. In dentin, only the Ac+Ad group demonstrated the formation of a hybrid layer. In composite resin, the fresh restorative material was smoothly in contact with the aged composite for the 'C' and 'S' groups, whereas a nearly 20 µm-thick adhesive layer could be observed connecting the fresh and aged composites for the 'Ac+Ad' and 'Ac+S+Ad' groups. In the dentin–composite interface, the interaction between the fresh composite and the substrates seemed to be better obtained for the 'Ac+Ad' and 'Ac+S+Ad' groups. Application of silane without any other bonding agent seemed to produce a better bonding effect on composite resin only, not on dentin. Application of fresh composite at the dentin–composite interface without any bonding agent (control) did not produce a satisfactory connection between the repairing material and the bonding substrates.

Table 3:

Mean and standard deviation (**SD**) values for the water contact angle (θ, °) formed at tested groups at different substrates.

TRATAMENTO DE SUPERFÍCIE	SUBSTRATO	
	DENTINA	RESINA COMPOSTA
Control	24,5 (4,1)^{B,b}	48,8 (5,3)^{A,a}
Acid + Adhesive	25,5 (2,1)^{B,b}	32,9 (2,8)^{C,a}
Silane	27,6 (4,7)^{B,b}	40,0 (2,0)^{B,a}
Acid + Silane + Adhesive	34,3 (7,1)^{A,a}	33,4 (2,3)^{C,a}

Uppercase letters in columns and lowercase letters in rows indicate, respectively, statistical significant differences among surface treatments and substrates ($p<0.05$).

Water contact angle

The results of water contact angle for each substrate investigated in the study are displayed in Table 3. While the factors investigated were not significant ($p>0.05$), there was a statistical interaction between each other ($p<0.001$). Concerning dentin, the application of phosphoric acid followed by adhesive or silane only did not change the wettability of dentin ($p\geq0.227$) compared with the control group. Conversely, the sequential application of phosphoric acid, silane, and adhesive significantly reduced the water contact angle of dentin wettability, which was greater than the other groups ($p<0.001$). In composite resin, all bonding agents reduced ($p\leq0.001$) the water contact angle of the material when compared with the control group. Among all bonding agents tested, those comprised of phosphoric acid and adhesive (Ac+Ad or Ac+S+Ad) were more effective in reducing the water contact angle of the composite resin as compared with silane application only ($p\leq0.001$). The water contact angle of dentin ($\theta=24.5^{o}$) was approximately half of that of composite resin ($\theta=48.8^{o}$). After the application of silane only or phosphoric acid followed by adhesive, the dentin still showed greater wettability than composite resin ($p<0.001$). However, upon the sequential application of phosphoric acid, silane, and adhesive, dentin and composite resin acquired similar water contact angle results ($p=0.635$).

Correlation analyses

The water contact angle data obtained in dentin and composite resin after application of each bonding agent showed a strong correlation to the repair bond strength values for composite ($R^2=0.9995$), but not for dentin ($R^2=0.433$).

DISCUSSION

This study tested the effect of two factors in the repair process of composite restorations: the type of bonding agent and the type of substrate, which may be comprised of dentin, the aged composite material needing repair, as well as the dentin–composite interface. It must be considered that during the repair procedure of composite restorations, the superficial characteristics of each substrate would play a significant role on the overall repairing ability, so that we evaluated both the water contact angle of substrates and the bond strength of each repair.

In the absence of a chemical treatment (negative control), the water contact angle obtained in dentin was lower than in composite resin, probably due to the more hydrophobic nature of the latter.[14,15] Dentin is comprised of nearly 10 wt% water and one could expect that the different wettability between dentin and composite would affect their repair bonding ability. However, without the application of any bonding agent, the bond strength results were similar regardless of the substrate tested. This may be due to the quite low bond strength values displayed by the negative control group, indicating that a chemical treatment is necessary to increase the repair bonding ability of composite resin restorations. It is noteworthy that the repair bond strength in composite showed a wider value range when compared with dentin; also, the bond strength value in composite was approximately three times greater than in the dentin–composite interface, suggesting that effective repairs may be more easily obtained at the composite part of the restoration rather than in the dentin part or at the interface between dentin and aged composite. This assumption can be also corroborated by the findings of the failure analysis, which indicated that premature failures occurred at almost all of the repairs (~90%) made in dentin, whereas repairs at the dentin–composite interface and aged composite resin had considerable lower premature failures (47% and 11%). One could suggest that the roughening step performed before application of the fresh composite produced a sufficiently rough topography in the composite substrate,[11] but not in dentin, making the repair bonding ability of composite resin greater than dentin.

Three bonding protocols were tested in the present study: the application of adhesive system (i.e., a two-step, etch-and-rinse adhesive), silane alone, and the combination of silane with the adhesive. Silane has been widely used as an important chemical coupling agent for the repair of defective ceramic- or resin-based restorations.[16–18] A recent systematic review demonstrated that silane shows less ability than adhesive agents in improving the repair potential of aged composite restorations.[13] According to our findings, silane exhibited a hydrophilic behavior, since it reduced significantly the water contact angle of the composite resin, increasing its wettability. Conversely, silane did not affect the wettability of dentin, probably because dentin is already hydrophilic in nature. To the best of our knowledge, this is the first study that

investigated the effect of silane and other bonding agents on the bond strength of all substrates involved in repairing procedures of composite resin restorations. Interestingly, we demonstrated that the application of silane alone does not allow a proper interaction between fresh composite and dentin. Of note, silane does not possess the ability of etching dentin, hampering smear layer removal and hybridization, i.e., two microscopic conditions of clinical importance for satisfactory adhesion in dentin when using an etch-and-rinse adhesive approach.[19] Concerning the failure analysis observed in dentin after silane application, premature failures accounted for approximately 73%, opposed by only 23% and 4% of adhesive and mixed failures, respectively. It is worth to consider that the fresh composite, which is moderately hydrophobic, would not interact smoothly to the hydrophilic, silane-coated dentin, so that, it seems to be necessary to reduce dentin wettability by applying other bonding agents in order to better match its superficial tension characteristics with that from the fresh composite resin.

Differently from the dentin substrate, repairs made in composite resin after application of silane alone presented higher bond strength results, indicating that silane possesses a more suitable affinity to resin-based substrates. Even though the repair bond strength results were not satisfactory at the dentin-composite interface, a greater value range was observed for this group when compared with the repairs made in dentin only, probably due to the presence of at least a minimal amount of composite resin in the interfacial substrate, favoring the interaction between the fresh and aged restoratives. The occurrence of premature failures was also lower (25%) at the dentin-composite interface, and only 6% in composite, confirming the better interaction between silane and the composite resin.

According to Valente et al.[13], the application of adhesive agents may allow greater repair potential of defective composite restorations as compared with the application of silane alone, corroborating our findings. In fact, the application of the two-step, etch-and-rinse adhesive system, combined or not with silane, resulted in the highest bond strength values of the study. One should consider that the adhesive component was always the final bonding agent applied prior to the placement of any fresh composite, thus suggesting that the chemical composition and the superficial characteristics of the adhesive may produce an optimal wettability for the substrates. Surprisingly, the application of the adhesive system without silane increased the wettability of the aged composite, but not of dentin, which maintained its water contact angle similar to that of the control group. On the other hand, when silane was applied in combination with the adhesive system (i.e., phosphoric acid followed by silane and then the adhesive resin), the wettability of dentin was significantly reduced, becoming similar to that from the composite substrate treated with the same bonding agents. Here, it can be considered that the solvent-based composition of the silane

used in the present study could have acted as a solvating agent, removing residual water molecules from the acid-etched dentin, which would result in better hybridization between the adhesive resin and the acid-exposed collagen fibrils in dentin.[20] This phenomenon would be similar to that observed in other studies,[21,22] which tested the effect of solvents such as ethanol or acetone on the drying process of dentin, before adhesive application, in order to eliminate the overwetness of dentin before photo-polymerization; this would account for more durable adhesion of resin-based restorations. Conversely, the combination of phosphoric acid, silane, and adhesive resin as bonding agents of composite repairs resulted in similar bonding performance to the group that applied the adhesive system alone, thereby suggesting that silane may be not a necessary bonding agent for improving the repairing ability of composite restorations.

The mixed failure mode is usually desired in bond strength analyses, since it may be understood as a close interaction between the restorative material and the substrate, with satisfactory hybrid layer formation. In this study, mixed failures prevailed over the other modes for all groups that applied adhesive system as bonding protocol, except when combined with silane in dentin or composite resin, which showed equilibrium between adhesive and mixed failures. According to the SEM analysis, a true hybridization was detected in dentin only upon the application of the adhesive system alone, without silane. This was expected since dentin needs to be acid-etched and infiltrated by resin monomers to properly create a satisfactory hybrid layer in etch-and-rinse approaches,[20] whereas silane does not possess a chemical composition to do the same. Notwithstanding, Figure 3 suggests that a proper surface interaction is better obtained in the composite resin part of the restoration regardless of the bonding protocol. Once again, it can be explained that the roughening procedure performed prior to the bonding agent' application contributed for an improved adhesion between fresh and aged composite materials, as demonstrated elsewhere[11]. In that study, the surface roughening of fresh or aged resin composites with diamond burs improved retention of the repair material, with fine-grit burs generally performing better than medium- and extra-fine-grit burs. Worth mentioning, the repairs made after adhesive system application exhibited greater bond strength values, probably because resin adhesives are less viscous than resin composites, thus allowing a better surface interaction of the former with the aged composite. Not less important, Figure 4 shows that when considering the repair bonding ability of the dentin-composite interface, the application of adhesive system alone seems to result in the best superficial contact between the fresh and aged composites, indicating that adhesives are important bonding agents for the repair of defective composite restorations.

Gathering all the findings of this study together, we must reject the null hypothesis, since the repair bonding ability of dentin may be different from that of composite resin depending on the bonding

agents used. In addition, the dentin–composite interface may play a crucial role for the overall bonding performance of the repair material if silane is used. Lastly, the water contact angle data obtained in dentin and composite after application of each bonding agent were correlated to the repair bond strength values of this study, showing a strong correlation for composite (R^2=0.9995), but not for dentin (R^2=0.433). This reinforces the idea that dentin is a much more complex substrate to obtain a proper repairing effect as compared with the aged composite substrate itself. Of note, the best repair bond strength values found in this study were obtained when the substrate exhibited water contact angles nearly 33–34°, for both dentin and composite, thereby suggesting that these values could be within the optimal wettability range for satisfactorily bonding of fresh composites to a defective composite resin restoration.

CONCLUSION

Dentists should be aware that the repair bonding performance of composite resin restorations may depend on the substrates involved in the repairing procedure, with the application of phosphoric acid followed by adhesive being the most advisable chemical treatment for obtaining proper bonding to all substrates.

ACKNOWLEDGEMENTS

The authors thank FGM Produtos Odontológicos for donation of the resin composite used in this study.

REFERENCES

1. Coelho-De-Souza FH, Camargo JC, Beskow T, Balestrin MD, Klein-Junior CA, Demarco FF. A randomized double-blind clinical trial of posterior composite restorations with or without bevel: 1-year follow-up. J Appl Oral Sci. 2012 Mar-Apr;20(2):174-9.
2. Mahmoud SH, El-Embaby AE, AbdAllah AM, Hamama HH. Two-year clinical evaluation of ormocer, nanohybrid and nanofill composite restorative systems in posterior teeth. J Adhes Dent. 2008 Aug;10(4):315-22.
3. Moura FR, Romano AR, Lund RG, Piva E, Rodrigues Junior SA, Demarco FF. Three-year clinical performance of composite restorations placed by undergraduate dental students. Braz Dent J. 2011;22(2):111-6.
4. Demarco FF, Corrêa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. Dent Mater. 2012 Jan;28(1):87-101.
5. Mjör IA, Reep RL, Kubilis PS, Mondragón BE. Change in size of replaced amalgam restorations: a methodological study. Oper Dent. 1998 Sept-Oct;23(5):272-7.
6. Ribeiro JS, Moreira AG, Isolan CP, Valente LL, Munchow EA. Dental cosmetics: direct repair with composite resin. Odontologia Clínico-Científica. 2016;15:303-5.
7. Fernández EM, Martin JA, Angel PA, Mjör IA, Gordan VV, Moncada GA. Survival rate of sealed, refurbished and repaired defective restorations: 4-year follow-up. Braz Dent J. 2011;22(2):134-9.
8. Opdam NJ, Bronkhorst EM, Loomans BA, Huysmans MC. Longevity of repaired restorations: a practice based study. J Dent. 2012 Oct;40(10):829-35.
9. Hickel R, Brüshaver K, Ilie N. Repair of restorations—criteria for decision making and clinical recommendations. Dent Mater. 2013 Jan;29(1):28-50.
10. Ferracane JL, Lohbauer U, Palin WM. The mechanical behavior of the material-tissue and material-material interface in dental reconstructions. Int J Adhes Adhes. 2016;69:2-14.
11. Valente LL, Silva MF, Fonseca AS, Munchow EA, Isolan CP, Moraes RR. Effect of diamond bur grit size on composite repair. J Adhes Dent. 2015;17:257-63.
12. Ilie N, Stawarczyk B. Efficiency of different repair kits on bonding to aged dental resin composite substrates. Int J Adhes Adhes. 2015;58:7-12.
13. Valente LL, Sarkis-Onofre R, Gonçalves AP, Fernández E, Loomans B, Moraes RR. Repair bond strength of dental composites: systematic review and meta-analysis. Int J Adhes Adhes. 2016;69:15-26.
14. Ferracane JL. Resin composite—state of the art. Dent Mater. 2011 Jan;27(1):29-38.
15. Ferracane JL, Pfeifer CS, Hilton TJ. Microstructural features of current resin composite materials. Curr Oral Health Rep. 2014;1(4):205-12.
16. Kimmich M, Stappert CF. Intraoral treatment of veneering porcelain chipping of fixed dental restorations: a review and clinical application. J Am Dent Assoc. 2013 Jan;144(1):31-44.
17. Raposo LH, Neiva NA, Silva GR, Carlo HL, Mota AS, Prado CJ, et al. Ceramic restoration repair: report of two cases. J Appl Oral Sci. 2009;17(2):140-4.
18. Staxrud F, Tveit AB, Rukke HV, Kopperud SE. Repair of defective composite restorations. A questionnaire study among dentists in the Public Dental Service in Norway. J Dent. 2016 Sept;52:50-4.
19. Nakabayashi N, Kojima K, Masuhara E. The promotion of adhesion by the infiltration of monomers into tooth substrates. J Biomed Mater Res. 1982 May;16(3):265-73.
20. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res. 2005 Feb;84(2):118-32.
21. Amaral CM, Diniz AM, Arantes EB, Santos GB, Noronha-Filho JD, Silva EM. Resin-dentin bond stability of experimental 4-META-based etch-and-rinse adhesives solvated by ethanol or acetone. J Adhes Dent. 2016;18:513-20.
22. Kuhn E, Farhat P, Teitelbaum AP, Mena-Serrano A, Loguercio AD, Reis A, et al. Ethanol-wet bonding technique: Clinical versus laboratory findings. Dent Mater. 2015 Sept;31(9):1030-7.

How to cite: Manso IS, Valente LL, Münchow EA, Isolan CP, Lima FG, Moraes RR. Bonding to composite resin, dentin, and composite-dentin interface, regarding restoration repair. J Clin Dent Res. 2019 May-Aug;16(2):54-68.

Submitted: December 27, 2018 - Revised and accepted: May 06, 2019.

Contact address: Rafael R. Moraes
Rua Gonçalves Chaves, 457 — Pelotas/RS — CEP: 96.015-560
E-mail: moraesrr@gmail.com

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.