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| ORIGINAL

Evaluation of bond strength of self-adhesive resin composite repairs

Avaliação da resistência de união de reparos com resina composta auto-adesiva

João Victor Gonçalves da **SILVA**[1] https://orcid.org/0000-0002-3338-9687

Jonathas José de **PAULO**[1] https://orcid.org/0000-0002-8945-8901

Rodolfo Scavuzzi Carneiro da **CUNHA**[1] https://orcid.org/0000-0001-7110-848X

Rodivan **BRAZ**[2] https://orcid.org/0000-0003-3926-8736

Márcia de Almeida **DURÃO**[2] https://orcid.org/0000-0001-7557-2319

ABSTRACT

Objective: To evaluate the bond strength of repairs with the self-adhering flowable composite Vertise Flow (Kerr) and a conventional composite resin Filtek Z350 (3M ESPE) subjected to different surface treatments. **Methods**: Forty specimens were divided into four groups: ZV (Filtek Z350 + Vertise Flow, without prior treatment); ZAV (Z350 + Vertise Flow with prior treatment with Single Bond Universal Adhesive System (3M ESPE)); ZAZ (Filtek Z350 + Filtek Z350 with prior treatment with Single Bond Universal Adhesive System (3M ESPE)); VV (Vertise Flow + Vertise Flow, without prior treatment). After 15 days of storage, the specimens were subjected to microtensile tests (Kratos IKCL3-USB, SP, Brazil), with speed of 0.5 mm/min and 20kg load. For statistical analysis, ANOVA with Tukey tests were used ($p < 5\%$). **Results**:The mean values of the bond strength were highest respectively in the groups: ZV (36.07 ± 37.63); ZAZ (24.04 ± 28.51); VV (19.39 ± 28.24) and ZAV (16.06 ± 15.66). The bond strength of the repairs between the groups presented satisfactory results. **Conclusion**: The self-adhesive composite resin Vertise Flow seems to be a viable and fast alternative for composite resins repairs.

Indexing terms: Composite resins. Dental materials. Mechanical tests.

RESUMO

***Objetivo**: Avaliar a resistência de união dos reparos com resina composta auto-adesiva Vertise Flow (Kerr) e uma resina composta convencional Filtek Z350 (3M ESPE) submetida à diferentes tratamentos de superfície. **Métodos**: Quarenta amostras foram divididas em quatro grupos: ZV (Filtek Z350 + Vertise Flow, sem tratamento prévio); ZAV (Z350 + Vertise Flow com tratamento prévio com Sistema Adesivo Universal Single Bond (3M ESPE)); ZAZ (Filtek Z350 + Filtek Z350 com tratamento prévio com Sistema Adesivo*

[1] Faculdade Mauricio de Nassau, Curso de Odontologia. Recife, PE, Brasil.
[2] Universidade de Pernambuco, Faculdade de Odontologia, Departamento de Odontologia. Av. General Newton Cavalcanti, 1650, Tabatinga, 54756-220, Camaragibe, PE, Brasil. Correspondence to: MA DURAO. E-mail: <marciadurao.fop@gmail.com>.

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Universal Single Bond (3M ESPE)); VV (Vertise Flow + Vertise Flow, sem tratamento prévio). Após 15 dias de armazenamento, as amostras foram submetidas ao teste de microtração (Kratos IKCL3-USB, SP, Brasil), com velocidade de 0,5 mm / min e carga de 20kg. Para análise estatística, foram utilizados os testes ANOVA com Tukey (p <5%). ***Resultados****: Os valores médios da resistência de união foram maiores, respectivamente, nos grupos: ZV (36,07 ± 37,63); ZAZ (24,04 ± 28,51); VV (19,39 ± 28,24) e ZAV (16,06 ± 15,66). A resistência de união dos reparos entre os grupos apresentou resultados satisfatórios.* ***Conclusão****: A resina composta auto-adesiva Vertise Flow parece ser uma alternativa viável e rápida para reparos em restaurações com resinas compostas.*

Termos de indexação: *Resinas compostas. Materiais dentários. Testes mecânicos.*

INTRODUCTION

Adhesive dentistry began in 1955 with a paper of Buonocore on acid etching to increase the adhesion of acrylic materials to enamel surfaces through a micro-retentive pattern that was created on the dental structure that favored the interaction with the acrylic resin [1], increasing the micromechanical attachment and improving the retention of adhesive restorations [2,3].

After the 60's with Bowen advents [4], intense changes have occurred in the composition of the composite resins, initially in their inorganic fillers both in concentration, distribution, size and shape, culminating with the development of nanometric particles [5].

The incorporation of new monomers to the organic matrix, besides Bis-GMA was also done, which allowed greater incorporation of filler particles, handling, viscosity and degree of conversion, and consequently in better mechanical properties of composite resins [6,7].

In order to simplify the technique and optimize the clinical time, self-adhesive composite resins of low viscosity were introduced to dental market. According to the manufacturer's instructions, this composite does not require any previous etching protocol or adhesive system application [8] The VertiseTM flowable composite resin shares the same inherent characteristic of self-etching materials. It is chemically bond to dental structures through functional phosphate monomer GPDM (glycerophosphate dimethacrylate) and calcium ions of enamel and dentin. This reduces postoperative sensitivity and clinical time [8] The Self-Adhering Flowable Composite Vertise Flow has multiple indications such as small class I restorations, base/liner for class I and II restorations, sealant and repair of composite and ceramic restorations [9].

When a restoration is compromised due to marginal discoloration, micro-infiltration, marginal gap, crack or fractures, it needs to be repaired or replaced [10] The complete replacement of deficient restorations is very common in dentistry and leads to loss of dental structure, higher cost and longer clinical time [11]. However, instead of replacing, it has been recommended to perform repair as a viable alternative to reduce the cycle of restoration replacements [12-14]

Partial replacement or repair is an insertion of restorative material only on the fractured or defective part of the existing restoration, restoring aesthetics and dental function of a more conservative way [15] It is performed in cohesive fracture of restorative materials or dental structure and in adhesive fractures in tooth-restoration interface. The success and longevity of the repair depends on the quality and durability of the adhesion, considering the surface treatment and material types [16-18], being evident the importance of the bond strength analysis at the repair interface.

The aim of this study was to evaluate the bond strength of repairs with a self-adhering flowable composite (Vertise Flow, Kerr), and conventional composite resin of regular viscosity (Filtek Z350, 3M ESPE) subjected to different surface treatments. The null hypothesis tested was that there would be no significant difference between the results among the different groups.

METHODS

The table 1 shows the composite resins used in this in vitro experimental study. For specimen preparation, a device (figure 1) was made of tempered glass and consisted of two parts: a base and a matrix. The rectangular base, similar to a glass plate for laboratory manipulation, having on the upper surface a channel in the form of a rail composed of coverslips of one-millimeter thickness. The matrix was formed by two equal, rectangular coverslips inserted in the rail fixed in the base with dimensions of 1mm height and width and 70mm length.

Table 1. Manufacturers' specifications of the materials used in the experiment.

Material	Composition	Recommended technique	Manufacturer (batch number)
Vertise Flow™	Organic matrix: GPDMA, HEMA, Bis-GMA and catalysts. Filler particles: silanized glass prepolimers of Ba, SiO2 and YF3 (70% weight and 57% volume).	1- Insertion of thin layer (0.5mm) 2- Shake with a microbrush (15-20s) 3- Ligh-curing 20s 4- 2mm incremental insertion 5- Light-curing of each increment for 20s.	Kerr, Orange, CA, USA (4917943)
Filtek Z350™	Organic matrix: Bis-GMA, UDMA and Bis-EMA. Organic matrix: zirconia and silica (82% weight e 60% volume).	1- 2mm incremental insertion 2- 20 seconds light curing	3M ESPE St. Paul, MN, USA (N427790)
Single Bond Universal™	Bis-GMA, HEMA, dimetacrilate, ethanol, water, initiator, polyacrylic and polyalkanoic acid methacrylate functional copolymer and silanized silica nanoparticles.	1- Etching for 30s 2- Adhesive application for 20s 3- Drying for 5s 4- Light-curing for 10s	3M ESPE St. Paul, MN, USA (507329)
Condac 37% FGM	37% Phosphoric acid, thickener, stain and ionized water.	1- Etching for 30s 2- Washing for 60s. 3- Dry with air spray for 20s.	FGM Joinville, Santa Catarina, Brazil (282085)

Note: Bis-GMA - Bisphenyl Glycidyl Methacrylate, UDMA - Urethane Dimethacrylate, Bis-MA - Bisphenol ethyl methacrylate, TEGDMA - Triethylene Glycol Dimethacrylate, EBPDMA - Bisphenol A Ethoxylate Dimethacrylate.

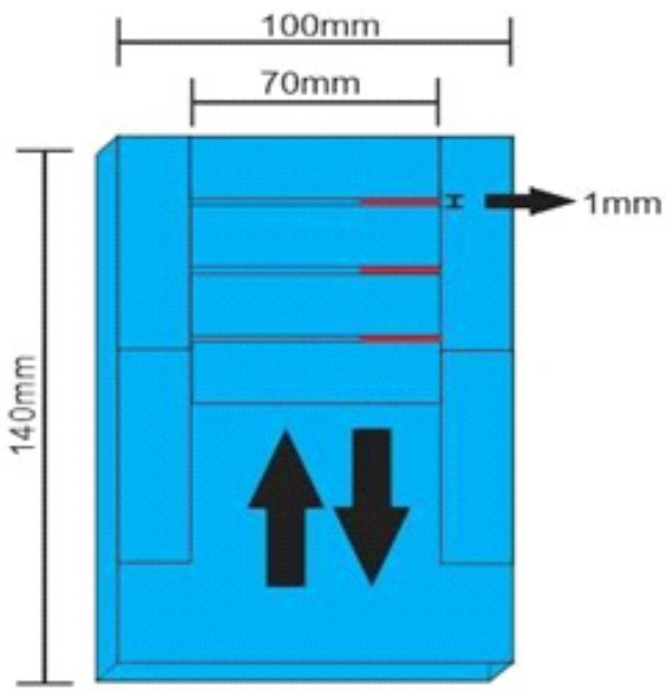

Figure 1. Device design for sample preparation.

Forty specimens were prepared and divided into four groups, which are described in table 2. The composites were inserted until complete filling of the device area (1mm x 1mm x 35mm) (figure 1). A glass cover slip was placed on a polyester strip positioned on the resin under gentle pressure for surface regularization. The coverslip was removed, and photopolymerization was carried with Optilight Max (Gnatus, Ribeirão Preto, São Paulo, Brazil) for 40 seconds. Before photoactivation of each restoration, the 600mW/cm^2 irradiance of the light curing unit was checked with a radiometer (Gnatus, Ribeirão Preto, São Paulo, Brazil).

All the specimens were finished and polished with Sof-Lex discs (3M ESPE). Then, with the use of a digital caliper, the specimens were measured and stored in distilled water, for fifteen days, at room temperature. After the storage period, the specimens had the surface to be repaired slightly prepared with a diamond bur (1092FF/ KG Sorensen, São Paulo, Brazil) positioned perpendicular to the specimen surface.

The prepared area received the surface treatment selected for each group as described in Table 1. The specimens were fitted into the device and the resins were inserted and the repairs were performed with the remaining 35mm length of the device (DPCP), in the same way as described for the preparation of the specimens. The groups and their respective surface treatments are described in table 2. After the repairs were carried out, all samples were kept in distilled water for 24 hours and then submitted to the microtensile test.

Table 2. Groups according to material and surface treatment prior to restoration repair.

Group	Material used for restoration	Material used for repair	Acid etching + Universal Adhesive
ZV	Z350 composite resin	Vertise Flow	No
ZAV	Z350 composite resin	Vertise Flow	Yes
ZAZ	Z350 composite resin	Z350 composite resin	Yes
VV	Vertise Flow	Vertise Flow	No

The specimens were attached with a cyanoacrylate (Super Bond, Loctite, Henkel Ltda, Brazil) to a device similar to Geraldelli's Claw (figure 2). The "claw" was adapted to a universal test machine (Kratos IKCL3-USB, SP, Brazil) with the adhesive interface perpendicular to the long axis of the tensile stress with speed of 0.5 mm/min and 20kg load until the rupture of the specimen. The data obtained in Newton (N) were converted to Megapascal (MPa) dividing to cross-sectional bonding area.

The data were expressed as mean and standard deviation (Mean ± SD). Data normality was verified by the Shapiro-Wilk test. F test (ANOVA) with Tukey's multiple comparison test was used for comparison between the composites. Paired Student's t-test was used for comparison between sites (top and base). The techniques were compared through Student's t-test for independent samples. For all analysis, the significance level was 5%.

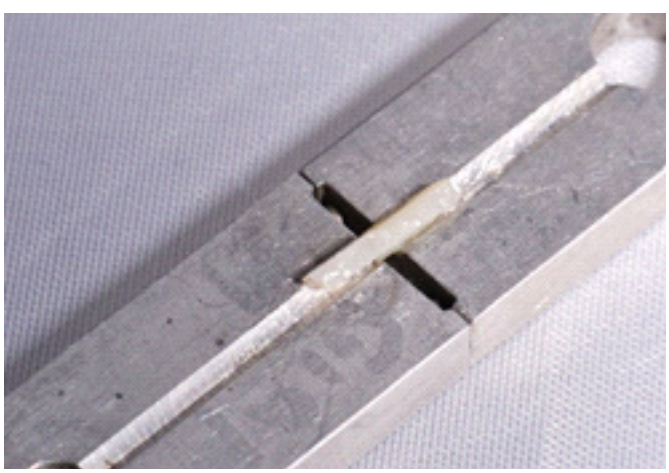

Figure 2. The specimen attached to the microtensile device.

RESULTS

The bond strength values of the specimens of the four experimental groups, with their mean and standard deviations, are shown in table 3. Mean and median values were higher in the ZV group (mean of 36.07 MPa and median of 37.63 MPa) and lower in the ZAV group (mean of 16.06 MPa and median of 15.66 MPa); the mean values in the ZAZ and VV groups varied from (24.04 to 28.51 MPa) and the medians (19.39 to 28.24 MPa).

Significant differences were found between the groups and through the multiple comparison tests, except for the ZAZ and VV groups, significant differences were verified between the other groups. The variability of the data expressed through the coefficient of variation was not elevated was less than 50% in each group.

DISCUSSION

The null hypothesis tested was not accepted given that there was a significant difference in the values of bond

Table 3. Bond strenght according to each group.

Group	Mean	Standard-Deviation	Coeficiente of variation	Median	P25	P75
ZV	36,07$^{(A)}$	9,52	26,39	37,63	29,36	44,07
ZAV	16,06$^{(B)}$	7,19	44,77	15,66	10,05	20,05
ZAZ	28,51$^{(C)}$	9,25	32,44	28,24	19,52	34,66
V V	24,04$^{(C)}$	9,64	40,10	19,39	15,26	34,43
p-value					< 0,001* (1)	

Note: *Statistical significance difference (α = 5.0%) (1) Through the Kruskal-Wallis test for comparison between the groups. Different letters show statistical significant difference.

strength. The ZAV group presented the worst result (16.06 MPa) and there was no statistically significant difference between the ZAZ (28.51 MPa) and VV (24.04 MPa) groups.

The repair of composite resins presents great difficulty in establishing long-lasting adhesion between the previous composite resin and the new composite resin used to perform the repair [19].

This is influenced by the type of composite resin and the surface treatment performed [20].

The decision to repair or replace the entire restoration is part of the clinical routine and usually the complete removal of the restoration leads to tooth structure loss. Repair represents a more conservative alternative and may extend the duration of the existing restoration. When deciding to perform the repair, it should be considered the material involved, the expected longevity of the restoration, presence of secondary caries, and the location and size of the area be repaired [18].

Considering that in vitro bond strength testes loads are applied until the complete fracture of the specimen, if there is a defect in the adhesive interface, the fracture starts in this point and tends to increase until the complete fracture. In a clinical situation, adhesive failure may occur differently, since there is no application of continuous force, but a series of intermittent forces overtime with a slower crack propagation [20].

In the present study, composite resin was used. Vertise Flow is a self-adhering resin composite, based on traditional methacrylate monomers, with the incorporation of GPDM (glycerolphosphate dimethacrylate), acidic monomer peculiar component of some self-etching adhesive systems. According to the manufacturers, such monomers may be capable of bonding through mechanical and chemical interactions with the calcium ions of the tooth structure.8 A micromechanical bond resulting from the polymerized monomers and dentin collagen fibers also contribute to adhesion and can react with other monomers in adhesive systems and resin composite; this improved quality of the polymer network and enhanced mechanical properties [21].

The Phosphoric acid simultaneously promotes porosity and cleaning the conditioned surface, thus optimizing adhesion [1,22,23] In this context, it was believed that this surface treatment (acid + Adhesive) made in composite resin Z350, prior to the repair carried out with Vertise flow (ZAV) would present better results, however, it was the lowest bond strength group. Single Bond Universal, containing functional monomer MDP capable of chemical bonding, this was important for the quality and durability of bonding [24] However, this was not achieved in this study, when performed using etching and vertise flow. Teixeira et al. [25] described chemical interaction mechanisms for the bond strength of the flowable. 1) the adhesion between the polymer matrices, from both flowable composites and ceromer; 2) the adhesion between the fillers particles exposed of both composites; and 3) the formation of a micro-network of the polymer chains and the fillers particles of both composites. This latter mechanism would likely dominate and produce the greatest contribution with regards to acceptable bond strength, as it was possible to observe inside both the control and self-adhering groups [25].

In contrast, the study by Abdelraouf et al. [26], evaluated the shear bond strength of a self-adhering flowable resin composite (Dyad-flow, Kerr, USA) versus total-etch one to different surfaces of enamel and dentin surfaces of permanent molars. They reported that the mechanical interlocking of the resin tags of the bonding agent with the acid-etched enamel leads to the best bond to the enamel [26].

Demonstrating that the adhesion of self-adhering composite resin to the dental substrate was better when compared with the results of this study, because the group (ZAV) with prior acid etching and application of Single Bond Universal on the Z350 resin, in which the repair was performed with the self-adhering composite resin obtained the worst result [27,28].

When the self-adhering flowable composite Vertise Flow was used without surface treatment (ZV and VV), following the manufacturer's instructions, the adhesive quality was satisfactory. The manufacturer informs that the type, proportion, and size of each filler particles were carefully chosen for optimized wetting, mechanical strength, and polishability [8] According to some studies, the hygroscopic expansion of this composite may compensate the polymerization shrinkage and thus, contribute to improve the marginal adaptation and adhesion [27,28].

This was observed between the ZV and ZAV groups, in which the use of the adhesive system prior to the repair led to inferior bond strength values.

All of this is in line with studies that report that the GPDM adhesive monomer acts like a coupling agent. On one

hand, it has an acidic phosphate group for etching the tooth structure and also for chemically bonding to the calcium ions within the tooth structure. On the other hand, it has two methacrylate functional groups for copolymerization with other methacrylate monomers to provide increased crosslinking density and enhanced mechanical strength for the polymerized adhesive [21,25,26] We believe that the eatching performed prior to repair with the self-adhering composite resin has prevented its proper interaction with the Z350 resin, impairing its adhesion. After all, when the adhesive strategies recommended by the respective manufacturers were used, in the ZV, ZAZ and VV groups the results were satisfactory, although statistically superior for the ZV group (36.07 MPa).

As the samples were stored in water, it is also speculated that the diffusion of water through the polymer chains and interfaces with the load, as well as the hydrolytic deterioration of the polymer chains caused loss of resin components. Initially, this process normally affects properties such as hardness and wear resistance, but it can also interfere with the properties of inorganic filler particles, such as the fracture resistance of the material [27,28].

In a clinical trial of self-adhering flowable composite, Serin et al. [29], showed good clinical results with a predominance of alpha score after 1 year of follow-up in occlusal cavities of primary teeth. Emphasizing the practicality, convenience of the technique, minimizing handling errors. The self-adhering flowable composite holds great potential with respect to saving chair time and minimizing handling errors. The advantages for pediatric dentistry are reducing operative procedures, minimizing the technical sensitivity, simultaneous demineralization and resin infiltration as well as in reducing postoperative complaints like pain [30].

The mechanism involved in composite resin repairs is complex, and the bond strength provides only partial information given that in vitro experiments have some limitations. With the development of operative techniques and dental materials, further studies on the properties of this material are necessary, to understand the behavior and durability when used in repairs.

CONCLUSION

The bond strength of the composite resin repairs presented satisfactory results. The self-adhering flowable composite Vertise Flow can be a viable and faster alternative to composite resin repairs.

Collaborators

JVG Silva and JJ Paulo, conceptualization, investigation, methodology, project administration, resources, writing-original draft. RSC Cunha, conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision and validation. R Braz, conceptualization, data curation, methodology, project administration, supervision, validation writing-original draft. MA Durão, conceptualization, formal analysis, investigation, methodology, project administration, supervision, writing-original draft.

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