ORIGINAL RESEARCH

Influence of the Restorative Strategy on Push-out Bond Strength of the Self-adhesive Composite

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ABSTRACT

Aim: This study evaluated the influence of the resin composite and bonding strategy on the push-out bond strength of the self-adhesive, Fusio liquid dentin (FUS) (Pentron Clinical), and of two conventional resin composites of different viscosities, Filtek Z250 (3M ESPE) and tetric flow (Ivoclar Vivadent).

Materials and methods: Thirty-two bovine incisors were used after disinfection. The roots were sectioned and the buccal and lingual surfaces were polished until a 2-mm slab was achieved, maintaining enamel at the buccal surface and dentin at the lingual surface. Standardized cavities were then prepared (2.0 × 1.5 mm) and restored according to the following bonding strategies: Fusio liquid dentin with selective etching (FUSSE) in enamel, FUS, Filtek Z250, and tetric flow-total etching (TET). All groups were restored in bulk. After 24 hours of storage in distilled water, finishing and polishing were performed. The push-out test was conducted on a universal testing machine (0.05 mm/minute). Data were analyzed through Kruskal–Wallis and Mann–Whitney tests ($p = 0.05$). The extruded restorations were evaluated under a stereomicroscope (10×) for failure-mode evaluation.

Results: There were no statistically significant differences between the groups TET, Z250, and FUS, with 145.59, 108.91, and 104.12 MPa means, respectively. The FUSSE group (40.92 MPa) showed a statistically significant lower bond strength. The predominant failure mode was a mixed failure for all groups.

Conclusion: The self-adhesive resin composite achieved a satisfactory result on bond strength when compared to conventional composites with regular and low viscosities, except when selective enamel etching was done.

Clinical significance: This study shows that the clinicians must be aware of the viscosity of the phosphoric acid to avoid dentin contamination whenever performing selective enamel etching. And the self-adhesive resin composite studied presented as another restorative alternative.

Keywords: Bond strength, Push-out force, Self-adhesive composite.

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INTRODUCTION

Over the years, manufacturers have invested in the development of restorative materials with a simplified technique by reducing the number of clinical steps, making the procedure technically more straightforward and faster. Restorative resin composites have been used in dentistry for nearly 40 years,[1] and their composition of filler content and polymeric matrix of material has evolved significantly to develop systems with reduced polymerization shrinkage and shrinkage stress and with improved mechanical properties.[2,3]

In this context, self-adhesive composites have been developed. Initially, self-adhesive resin cement and, more recently, self-adhesive resin composites were marketed as flowable, low viscosity resin composites.[4] This new class of resin composites does not require any etching or bonding strategy before cavity filling.[5,6] The procedure is simplified by eliminating the adhesive application, which is the most technique-sensitive step. The formulation is based on traditional methacrylate systems with the incorporation of acidic monomers. These monomers can be typically found in dentin bonding agents and are capable of crosslinking and copolymerizing with other methacrylates, generating adhesion through mechanical and chemical interactions with the tooth structure.[7–9] Commercial examples are FUS (launched in 2009 by Pentron Clinical, Orange, CA, USA), Vertise flow (launched in 2010 by Kerr, Orange, CA, USA), and Embrace Wetbond (marketed since 2002 by Pulpdent, Watertown, MA, USA) and can be considered the precursors of self-adhesive flowable composites.[10]

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Both self-adhesive resin cements and self-adhesive resin composites have achieved a lower bond strength when compared to restorations placed with a conventional resin composite that require a separate adhesive procedure.[11] Low bond strength can be attributed to the low etching capacity of the acidic monomers, preventing their penetration within tooth structures and, therefore, not promoting an adequate resin infiltration. Additionally, the viscosity of the flowable material is not low enough to thoroughly wet the cavity walls, preventing a satisfactory adaptation.[9] For stronger enamel adhesion and improved bond strength, selective enamel etching prior to the application of a self-etching restorative material is the suggested strategy.[12,13]

This study aimed to evaluate the push-out bond strength of conventional resin composites of different viscosities and

self-adhesive restorations in two bonding strategies (with and without selective enamel etching). The hypothesis was that the self-adhesive resin composites have a low bond strength regardless of the bonding strategy used.

MATERIALS AND METHODS

Specimen Preparation

This study was developed at the Center for Research in Biomaterials and at the Laboratory of Surgical Pathologies of the Faculty of Dentistry of Pernambuco, University of Pernambuco (FOP/UPE). Bovine incisors were selected, donated from the public slaughterhouse of the city of São Lourenço da Mata—PE, with the consent of the responsible veterinarian.

Thirty-two sound extracted bovine incisors were used in this experimental study. The teeth were stored in 0.5% chloramine T solution at room temperature for 7 days for disinfection.[14] The roots were cut under refrigeration with a diamond double-sided flexible disk (Ref. 7011, KG Sorensen, Barueri, SP, Brazil) mounted on a handpiece (Kavo, Joinville, SC, Brazil). Crowns were included in the polyvinyl chloride (PVC) molds using acrylic resin to facilitate specimen handling. The buccal and lingual surfaces of the teeth were ground flat under running water using a polisher (Politriz ERIOS—27000, São Paulo, SP, Brazil) with silicon carbide abrasive paper (#100, #220, #320, #400, and #600 grit, Carborundum Abrasivos Ltd, São Paulo, SP, Brazil) to obtain specimens with a 2.0-mm thickness.

Conical cavities were prepared on the buccal surface of each tooth with copious air–water spray using a round edge-tapered bur (#3131 diamond bur, KG Sorensen, Cotia, SP, Brazil) in a high-speed handpiece coupled to a standard cavity preparation device. The final cavities presented a 2.0-mm Ø at the buccal surface and 1.5-mm Ø at the lingual surface with 2.0 mm in height. Diamond burs were replaced after every five preparations.

Restorative Procedures

The materials used in this study and their compositions are listed in Table 1. Teeth were randomly divided into four groups ($n = 08$) according to the material, and restorative protocol used as follows: (1) total etch bonding procedures and restoration with Filtek Z250, (2) total etch bonding procedures and restoration with tetric flow, (3) selective enamel etching and restoration with FUS, and (4) no substrate preparation and restoration with FUS (Table 2). The specimens were placed on a glass plate with a Mylar strip interposed between them. Cavities were filled with the resin composites, and then another Mylar strip and a microscope glass slide were placed on top. Digital pressure was then applied for 10 seconds to allow a better accommodation of the resin composite inside the cavity. The glass slide was removed, and the tip of the curing light was placed in direct contact with the Mylar strip. Light curing was done with a halogen curing unit (Optilight Plus, Gnatus, Ribeirão Preto, SP, Brazil) for 20 seconds at 600 ± 50 mW/cm^2. Specimens were then stored in distilled water at 37°C for 24 hours and then finished with Sof-Lex discs orange series (3M ESPE, St. Paul, MN, USA).

Push-out Bond Strength

Samples were submitted to a push-out experimental design in a universal testing machine (KRATOS IKCL3-USB, Taboão da Serra, SP, Brazil). A 1.0-mm Ø tip was coupled to a 200-kgf load cell with compressive strength on the central region of the restoration at 0.5 mm/minute until the rupture of the tooth-restoration bonding along the lateral walls (restoration extrusion) (Fig. 1). The maximum

Table 1: Materials used in the study

Material	Composition	Manufacturer
Filtek Z250™	Organic matrix: Bis-GMA, UDMA, Bis-EMA. Filler: zirconia/silica	3M/ESPE (St. Paul, MN, USA)
	Filler loading (wt%/vol%): 82/60	
Tetric™ flow	Organic matrix: Bis-GMA, urethane di-methacrylate	Ivoclar/Vivadent (Schaan, Liechtenstein)
	Filler: Ba-Al-F silicate glass	
Fusio™ liquid dentin	Organic matrix: UDMA, TEGDMA, HEMa, 4-MET (4-methacryloxyethyl trimellitic acid)	Pentron Clinical (Orange, CA, USA)
	Filler: silicate glass	
	Filler loading (wt%/vol%): 65/52	
Adper Single Bond 2™	Bis-GMA, HEMA, di-methacrylates, ethanol, water, photoinitiator, copolymers of acrylic and itaconic acids silane-treated silica	3M/ESPE (St. Paul, MN, USA)

Bis-GMA, bisphenol A glycidyl dimetacrylate; UDMA, urethane dimetacrylate; Bis-EMA, bisphenol A ethoxylate dimetacrylate; TEGDMA, triethylene glycol dimetacrylate; HEMA, 2-hydroxyethyl methacrylate; 4-MET, 4-methacryloxyethyl trimellitic acid

Table 2: Experimental groups according to restorative protocol

Composite	Group	Restorative protocol
Filtek Z250™	Z250	Total etching (enamel and dentin) with 35% phosphoric acid (15 seconds); bonding agent application; light cure (10 seconds); and bulk-filling insertion and light curing (20 seconds)
Tetric™ flow	TET	Total etching (enamel and dentin) with 35% phosphoric acid (15 seconds); bonding agent application; light cure (10 seconds); and bulk-filling insertion directly from the tip and light curing (20 seconds)
Fusio™ liquid dentin	FUSSE	Enamel selective etching with 35% phosphoric acid (15 seconds); application of a 1 mm layer of the material, followed by a vigorous application on the cavity walls with a microbrush (20 seconds); light cure (10 seconds); and bulk-filling insertion and another light cure (10 seconds)
	FUS	Application of a 1 mm layer of the material, followed by a vigorous application on the cavity walls with a microbrush (20 seconds); light cure (10 seconds); and bulk-filling insertion and another light cure (10 seconds)

force recorded (kgf) was divided by the interfacial bonded area and converted into pressure values (MPa).

Fracture-mode Analysis

The extruded restorations were evaluated under a stereomicroscope, at 10× magnification (SteREO Discovery.V12, ZEISS, Oberkochen, BW, Germany). The fracture mode was classified as cohesive failure in dentin, cohesive failure in resin composite, adhesive failure, or mixed failure (adhesive and cohesive together).
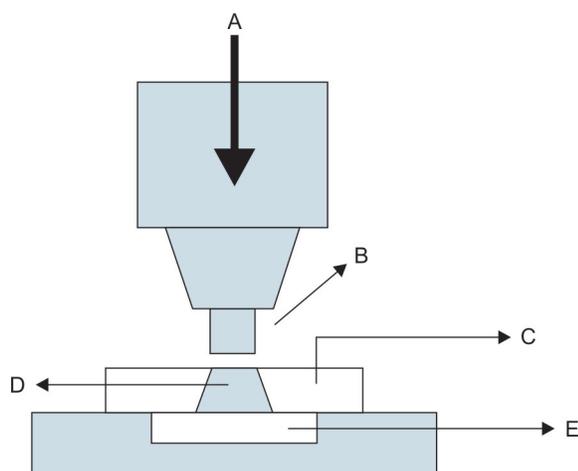
Fig. 1: Schematic illustration of push-out test; (A) Compressive force direction; (B) Intender; (C) Bovine incisive; (D) Conical restoration; (E) Area for displaced restoration

Table 3: Mean push-out bond strength (MPa) and standard deviation of the studied groups (n = 8). Different superscript letters indicate statistically significant differences (p < 0.05)

Groups	Bond strength (MPa)
Z250	108.91 (15.33)[A]
TET	145.59 (68.39)[A]
FUSSE	40.92 (22.73)[B]
FUS	104.12 (42.56)[A]

Table 4: Percentage of fracture mode of extruded restorations after push-out bond strength test

Groups	Mixed (%)	Adhesive (%)	Cohesive resin (%)	Cohesive dentin (%)
Z250	75	0	25	0
TET	87.5	0	12.5	0
FUSSE	62.5	25	0	12.5
FUS	75	25	0	0

Statistical Analysis

Statistical analysis was performed with SPSS 13.0 for Windows (Chicago, IL, USA). Descriptive statistics were obtained and the Kruskal–Wallis test was used for multiple comparisons between groups. A pairwise comparison was performed using the Mann–Whitney test to identify where the differences were. The statistical significance was preset at $\alpha = 0.05$.

RESULTS

Push-out Bond Strength

The results for the push-out bond strength are shown in Table 3. The Kruskal–Wallis test detected statistically significant differences between groups (p = 0.004). The TET group showed highest bond strength mean (145.59 MPa) and FUSSE presented the lowest mean bond strength (40.92 MPa), and the Mann–Whitney pairwise comparisons identified that this result was statistically different from all the other groups (p < 0.05).

Fracture Mode

The mixed failure was the predominant fracture mode for all groups (Table 4 and Fig. 2). For the conventional resins, Z350 and TET which require a separate bonding step, some cohesive failures were observed in the resin composite (25% and 12.5%, respectively). However, selective enamel etching before the FUS application resulted in a cohesive failure in the dentin (12.5%).

The viscosity of the resin composites that require prior bonding procedures did not influence the bond strength. However, it was interesting to observe that the most undesirable failure modes (adhesive and cohesive in dentin) were observed for the self-adhesive resin composite, with or without selective enamel etching.

DISCUSSION

The tested hypothesis that self-adhesive resin composites have a low bond strength regardless of the restorative technique employed was partially rejected when it was compared to conventional systems that require the prior use of a bonding agent. Self-adhesive resin composites had a satisfactory performance
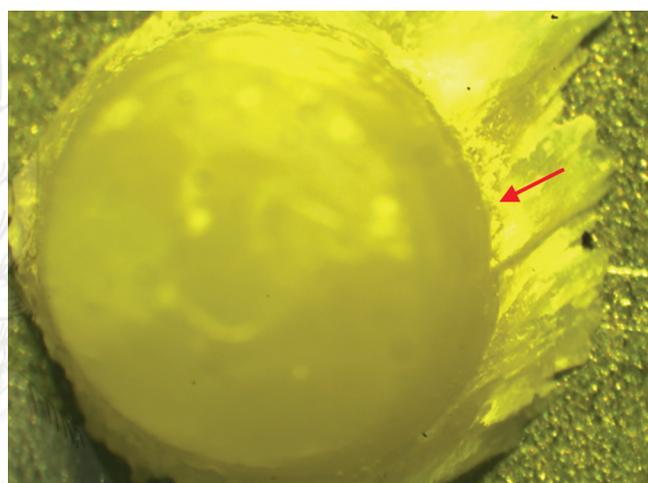
Fig. 2: Mixed fracture on tetric flow-total etching group

compared to the conventional ones, except when combined with the selective enamel etching technique.

Although the bond between the dentin and the self-adhesive resin composites is considered satisfactory, the bond to the enamel substrate seems relatively weak. Therefore, selective enamel etching has been advocated to increase the bond strength to enamel.[11,13] Phosphoric acid removes the smear layer and increases the surface energy of the enamel substrate, favoring higher bond strength values.[11,15–19] On the contrary, negative effects have been observed when dentin is preetched before the application of the self-adhesive resins, especially to the marginal sealing.[12]

The low bond strength to dentin observed in this study could be due to probable acid contamination during the selective enamel etching. The small thickness of the enamel substrate and the viscosity of phosphoric acid could have caused dentin etching, exposing its collagen fibers.[20] Several bonding agents and other restorative materials indicate the use of selective enamel etching. In view of the need to be precise, some manufacturers have raised the viscosity of the phosphoric acid etchant, such as Bisco (35% Select HV Etch from Bisco, Lombard, IL, USA). This material has benzalkonium chloride (BAC) to increase the superficial tension

of the acid, enabling a pinpoint accuracy and preventing the unnecessary etching of areas.

Different methods are used to measure the bond strength of resin composites, such as the shear and tensile strength tests. The drawback to these methods is that they are performed on flat surfaces. Thus, the use of three-dimensional cavities may be employed by the push-out test. The bond strength of a resin composite to dentin can be evaluated in cavities with a high C-factor, simulating clinical conditions.[21]

Numerous studies have shown that self-adhesive resin composites have lower bond strength values to tooth structures than conventional restorative systems.[7,11,22–27] Poitevin et al.[11] evaluated the microtensile bond strength of self-adhesive resin composites to dentin and enamel with or without selective enamel etching. It was concluded that the application of self-adhesive resin composites needs to be very carefully considered, especially in cases where there is no macroretention. Vichi et al.[22] evaluated the bond strength and marginal sealing of a self-adhesive resin composite (Vertise Flow, Kerr) used in combination with a single-step adhesive. The results showed lower shear strength values and microleakage compared to the "all-in-one" adhesive systems. However, the results from this study did not show any differences on the bond strength between the resin composites that require prior bonding procedures and the self-adhesive resin composite without selective enamel etching.

Celik et al.[15] studied the clinical performance of FUS to noncarious cervical lesions compared to a nanohybrid composite associated with a three-step etch-and-rinse adhesive system through a randomized, controlled clinical trial. The clinical evaluations were executed after 1 week and 6 months according to World Dental Federation (FDI) criteria. After 6 months, the retention rate of FUS was only 33% in comparison to the 100% retention of a conventional restorative composite; 27 out of 40 restorations filled with FUS were clinically unacceptable.

The analysis of the failure mode of the specimens revealed that most of the fractures occurred by mixed failure mode (Fig. 2), wherein part of the fracture portion has an adhesive and cohesive failures in the resin or dentin. Cohesive failure in resin seems to be the most common result, which is probably related to the adequate bond between the adhesive and substrate. Adhesive failures were observed only in the self-adhesive resin composites group (Fig. 3).
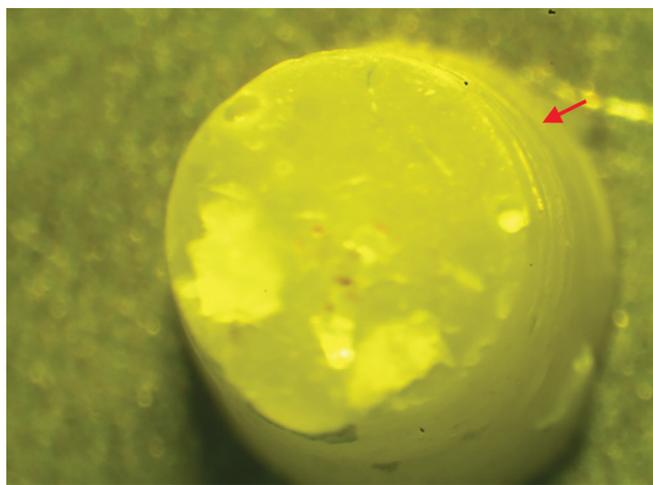
Fig. 3: Adhesive fracture on Fusio liquid dentin with selective etching group

The generation of stresses during photopolymerization in bulk filling a cavity with a high C-factor may have contributed to this failure mode.

Despite the laboratory-controlled conditions, phosphoric acid probably leaked beyond the enamel surface reaching the dentin resulting in lower bond strength values. This should be noted with caution by clinicians, as most of the manufacturers do not report the true viscosity of the etchant. Still, due to inconsistencies between the correlation of *in vitro* and *in vivo* studies, future studies should be performed under clinical settings to evaluate the long-term success rate of the restorations.

CONCLUSION

Based on this study, it can be concluded that the self-adhesive resin composite obtained a satisfactory result compared to conventional resin composites of regular and low viscosities, except when associated with selective etching in enamel. The results of the failure-mode analysis revealed predominantly mixed failure in all groups. This is not an ideal failure mode but may be related to the relatively good bonding between the adhesive material and the dental substrate.

Whenever performing selective enamel etching to enhance the bond strength of any self-etch and self-adhesive restorative material, clinicians must be aware of the viscosity of the phosphoric acid to avoid dentin contamination which is clinically indicated with great caution.

CLINICAL SIGNIFICANCE

This study shows that the clinicians must be aware of the viscosity of the phosphoric acid to avoid dentin contamination whenever performing selective enamel etching. In addition, the self-adhesive resin composite studied presented as another restorative alternative.

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