Artículo Original

Comparing bond strength and marginal integrity with direct bulk-fill resin composites and indirect composites

Comparación de la fuerza de unión y la integridad marginal con compuestos de resina de relleno masivo y compuestos indirectos

Yolanda Barros[1] https://orcid.org/0000-0002-9688-2495
Mateus Bandéca[2] https://orcid.org/0000-0002-8099-8821
Andrés Millán[2] https://orcid.org/0000-0002-7434-3327
Fabiana Siqueira[3] https://orcid.org/0000-0002-1079-3476
Milton Kuga[4] https://orcid.org/0000-0001-5728-8293
Eduardo Fernandez[5,6] https://orcid.org/0000-0002-2616-1510
Alain Manuel Chaple Gil[7*] https://orcid.org/0000-0002-8571-4429
Alvaro Borges[1] https://orcid.org/0000-0001-9510-6542
Mateus Tonetto[1] https://orcid.org/0000-0003-2733-8733

[1]University of Cuiaba–UNIC, School of Dentistry, Department of Restorative Dentistry. Brasil.
[2]CEUMA University, Dentistry Masters Program, Department. Chile
[3]Ponta Grossa State University, School of Dentistry, Department of Restorative Dentistry. Brasil.
[4]São Paulo State University – Unesp, School of Dentistry/Unesp. Brasil.
[5]Restorative Dentistry Departament, University of Chile. Chile.
[6]Instituto de Ciencias Biomédicas–Universidad Autónoma de Chile. Chile.
[7]Medical Universitiy of La Habana, Medical Faculty "Victoria de Girón", Department of Dentistry. Cuba.

*Autor para correspondencia: chaple@infomed.sld.cu

ABSTRACT

Introduction: The clinical longevity of tooth restoration —whether directly or indirectly using composites— greatly depends on the quality and stability of the marginal adaptation. Even today, dental restoration failure is a major complication in everyday dental practice.

Objective: To evaluate the effect of restoration techniques on the microtensile bond strength and marginal integrity of class II cavities.

Methods: An experimental *in vitro* investigation was made. Preparations (5 × 4 × 2 mm) below the cement-enamel junction were performed in 45 human maxillary premolars (n= 15) that were the sample of the study selected to random. The G1 group incrementally received Spectrum TPH3 Dentsply De trey in three horizontal incremental layers. The G2 group received a bulk restoration technique (one 4-mm increment of Surefill SDR flow plus one 1-mm horizontal capping layer of Spectrum TPH3 Dentsply De trey using a metal matrix band. For the G3 group, impressions were made from each cavity preparation, and Spectrum was used to complete an indirect composite restoration. After storage (24 h/37 °C), the proximal surfaces of each tooth were polished with Sof-Lex disks. For microtensile bond strength testing, all premolars were sectioned into resin-dentine beams (0.8 mm^2) and were tested under tension (0.5 mm/min).

Results: Microtensile bond strength testing and marginal integrity values were not statistically significantly affected by the type of restoration technique used ($p > 0.05$).

Conclusions: The Surefill SDR flow that used a capping layer made of conventional composite can be an alternative to reduce procedure durations as well as additional steps in the restorative technique.

Keywords: resin cement; fiber post; bond strength.

RESUMEN

Introducción: La longevidad clínica de una restauración dental —utilizando compuestos bien directa o indirectamente— depende en gran medida de la calidad y la estabilidad de la adaptación marginal. Incluso hoy en día las restauraciones dentales fallidas constituyen una importante complicación en la práctica dental cotidiana.

Objetivo: Evaluar el efecto de las técnicas de restauración en la fuerza de unión microtensil y la integridad marginal de las cavidades clase II.

Métodos: Se llevó a cabo una investigación experimental *in vitro*. Se realizaron preparaciones (5 × 4 × 2 mm) por debajo de la unión cemento-esmalte en 45 premolares maxilares humanos (n= 15), los que constituyeron la muestra aleatoria del estudio. El Grupo G1 recibió incrementalmente Spectrum TPH3 Dentsply (De Trey) en tres capas horizontales incrementales. El Grupo G2 recibió una técnica de restauración masiva (un incremento de 4-mm de flujo de SureFil SDR más una capa de tapado horizontal de 1-mm de Spectrum TPH3 Dentsply (De Trey) utilizando una banda matriz metálica. En el Grupo G3 se realizaron impresiones de la preparación de cada cavidad, y se usó Spectrum para completar una restauración indirecta con compuesto. Después del almacenamiento (24 h / 37 °C), se pulieron las superficies proximales de cada diente con discos Sof-Lex. Para evaluar la fuerza de unión microtensil, todos los premolares fueron seccionados en haces de resina-dentina (0,8 mm^2) y fueron examinados bajo tensión (0,5 mm/min).

Resultados: Las pruebas de fuerza de unión microtensil y los valores de integridad marginal no fueron afectados significativamente desde el punto de vista estadístico por el tipo de técnica de restauración utilizado (p> 0,05).

Conclusiones: El flujo de SureFil SDR que emplea una capa de tapado hecha de compuesto convencional puede ser una alternativa para reducir la duración del procedimiento, así como los pasos adicionales de la técnica de restauración.

Palabras clave: resina-cemento; poste de fibra; fuerza de unión.

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INTRODUCTION

The clinical longevity of tooth restoration —whether directly or indirectly using composites— greatly depends on the quality and stability of the marginal adaptation. Even today, dental restoration failure is a major complication in everyday dental practice.[1,2]

The most common reasons for composite restorative replacement include tooth fracture, micro-gap formation with rupture of adhesive bonds, and, consequently, marginal microleakage and secondary caries.[3,4] All of these are related to the polymerization shrinkage of the composite. Polymerization of dimethacrylate-based composites is accompanied by substantial volumetric shrinkage ranging from 1 % to 3 %.[5]

The magnitude of the stress generated by polymerization shrinkage depends on several factors, including the composite modulus of elasticity, molecule size, the relationship between the filler volumetric percentage and organic matrix percentage, methacrylate groups, extension, depth and speed of polymerization and the cavity configuration factor (C-factor), which has a direct relationship with the capacity to release the stresses generated during polymerization. Thus, higher C-factor values correspond to lower bond strengths due to the greater stress generated in the tooth structure at the bond interface.(6)

To reduce the effects of polymerization shrinkage and internal/ marginal gap formation, modifications in material composition have been suggested, such as modified methacrylate organic matrixes(7) and higher photo-initiator concentrations using restoration techniques.

The incremental layering technique is the standard protocol to prevent gap formation due to polymerization stresses and to keep the resin composite bonded to the dental tissue. Unfortunately, this technique requires more attention to detail during the placement of each layer in extended or deep cavities, and it carries an implicit risk of incorporating impurities or air bubbles between the layers. Furthermore, higher thicknesses (up to 2 mm) can result in a poor degree of conversion of monomers, and inadequate polymerization may compromise mechanical properties of composite All of this increases the required treatment time when compared with other techniques.(8)

For these reasons, today, indirect resin composite restoration (IRC) constitutes an option of contemporary restorative treatment. IRC involves fabricating the restoration outside the oral cavity using an impression of the prepared tooth. This technique overcomes some of the disadvantages associated with direct resin composites, such as polymerization shrinkage to the width of the luting gap. Furthermore, it provides better physical and mechanical properties, ideal occlusal morphology, proximal contouring and wear compatibility with opposing natural dentition. However, this technique is more time consuming and requires extra cost and appointments that may, in turn, be out of patient wishes and Budget.(1)

In order to overcome the shortcomings of incremental filing technique with conventional composites and eliminate extra cost and additional steps with IRC, some manufacturers have re-introduced resin composites for specific use with the bulk filling technique. Manufacturers claim that flowable resin composite can be placed in bulk (up to 4 mm thickness) and be efficiently photopolimerized to maintain low polymerization shrinkage stress at the same time.(9)

Although these flowable bulk-fill materials were developed to achieve better sealing of cavity margins, controversial results in terms of marginal properties, marginal leakage, marginal integrity, or gaps are reported in the literature,[10,11] and this controversy extends to IRC. Thus, the aim of this *in vitro* study was to determine whether different types of restoration techniques (i.e., incremental filling vs. bulk-fill vs. indirect resin composite restoration) affected the resin-dentin bond strength and marginal integrity of class II cavities. The null hypothesis was that the bond strength and marginal integrity would not be affected by the type of restoration technique used.

METHODS

An experimental *in vitro* investigation was made

Tooth preparation and experimental group

The sample were forty-five human maxillary premolars without caries that were extracted and selected to random. The teeth were collected after the patients provided their informed consent. The University Ethics Committee approved this study under protocol number 813.512. The teeth were disinfected in 0.1 % thymol, stored in distilled water, and used within 3 months after extraction. The maximum buccal-palatal width of each tooth was measured with a digital caliper (Absolute Digimatic, Mitutoyo; Tokyo, Japan) prior to inclusion. All teeth were individually mounted in a polyvinyl chloride (PVC) ring filled with acrylic resin (Aut Clear, DentBras; Pirassununga, SP, Brazil) up to 1.0 mm below the cement enamel junction.[12]

Teeth were then divided into groups according to the type of restoration technique used (i.e., G1: Incremental filling; G2: bulk-fill; G3: indirect resin composite).

Restorative procedure

Standardized class II cavities were prepared in all teeth. The depth of the occlusal box used with these preparations was 5 mm, and the mesio-distal length at the bottom of the proximal box was 3 mm. The depth of the proximal box (mesially and distally) was 6 mm, and it had margins located 1 mm below the cement-enamel junction. The internal walls of each cavity were perpendicular to the top and bottom surfaces, and they had round angles defined by the bur's shape. The cavities were prepared using a diamond bur under water cooling (#4103, KG Sorensen; Barueri, SP, Brazil), and the margins were not beveled.[12]

After this stage, the teeth were divided into groups according to the following criteria:

- G1: The medium-viscosity composite (Spectrum TPH3, Dentsply, De trey) was applied in a horizontal layer with a thickness of 1.5 to 2 mm. Each increment was separately light cured for 20 s; for each, the light source made contact with the coronal edge of the matrix band.

-G2: The flowable bulk-fill resin composite (Surefill SDR flow resin composite, Dentsply De Trey) was applied in a 3.5- to 4 mm layer and then light cured. Subsequently, the conventional composite was placed in a horizontal layer with a thickness of 1 to 1.5 mm. Each increment was separately light cured for 20 s; for each, the light source made contact with the coronal edge of the matrix band.

-G3: Impressions were made from each cavity preparation using silicone (Express XT - 3M ESPE St. Paul, USA) to produce stone dies (Durone, Caulk/Dentsply) that were used to prepare the indirect composite restoration. The restorations were built from a composite resin (Spectrum TPH3, Dentsply, De trey) that was applied in a horizontal layer that was 1.5- to 2 mm thick. Each increment was separately light cured for 20 s; for each, the light source made contact with the coronal edge of the matrix band. After completing the restoration, the marginal adaptation was checked. Finishing and polishing were completed with flexible disks (SofLex Pop-on, 3M ESPE; St Paul, MN, USA).

In all cavities, the two-step etch-and-rinse adhesive XP Bond (Dentsply DeTrey, Konstanz, Germany) was applied according to the manufacturer's instructions (table 1), and the cavities were light cured with an LED light for 20 s at 1200 W/cm^2 (Radii-cal, SDI; Bayswater, Victoria, Australia). For indirect restoration, luting was performed with Enforce dual-resin cement (Dentsply, De trey). The indirect restorations were maintained in place, and the excess cements were removed with scalers before light curing for 40 seconds in each of the dental surfaces.

Table 1 - Division of groups, restorative technique and restorative procedures

Group	Restorative Technique	Restorative Procedures	Increments
G1	Direct	TPH Resin (Dentsply)	Increments of 2 mm each
G2	Direct	*Bulk - Fill* Resin	Increment of up to 4 mm
		(Dentsply)	-
		TPH Resin (Dentsply)	Increment of up to 2 mm
G3	Indirect	TPH Resin (Dentsply)	Increments of 2 mm each

After 24 h in distilled water at 37 °C, the proximal margins of all restored teeth were finished with flexible disks (SofLex Pop-on, 3M ESPE; St Paul, MN, USA). A single operator carried out all bonding and restorative procedures in an environment with controlled temperature and humidity.

Microtensile bond strength (µTBS) test

Forty-five restorations (n = 15 teeth per experimental condition) were longitudinally sectioned in both the "x" and "y" directions across the bonded interface with a diamond saw in a Labcut 1010 machine (Extec; Enfield, CT, USA) under water cooling at 300 rpm. This was performed in order to obtain resin-dentin sticks from the cavity floor with a rectangular cross-sectional area of approximately 0.8 mm^2. The number of premature failures per tooth during specimen preparation was recorded. The cross-sectional area of each stick was measured with a digital caliper to the nearest 0.01 mm and recorded for subsequent calculation of the µTBS (Absolute Digimatic, Mitutoyo).

Each stick was attached to a modified device for µTBS testing with cyanoacrylate resin (Super Bonder, Loctite; São Paulo, SP, Brazil) and subjected to a tensile force in a universal testing machine (Kratos; São Paulo, SP, Brazil) at a crosshead speed of 0.5 mm/min. The failure mode was evaluated at 40X (HMV-2, Shimadzu; Tokyo, Japan) and classified as cohesive in dentin (failure exclusively within dentin, CD); cohesive in resin (failure exclusively within resin, CR); adhesive (failure at the resin/dentin interface, A); or mixed (failure at the resin/dentin interface that included cohesive failure of the neighboring substrates, M).

Marginal integrity

Impressions of the mesial and distal surfaces of 45 restorations (n = 15 teeth per experimental condition) were then taken with a low-viscosity vinyl polysiloxane material (Express, 3M ESPE). These impressions were used for preparation of replicas in epoxy resin (Epofix, Struers; Rødovre, Denmark). Replicas were coated with platinum (MED 020, Bal-Tec; Balzers, Liechtenstein) for analysis using a scanning electron microscope (Stereo Scam/ LEO; Cambridge, UK). For quantitative margin evaluation, the adhesive interface was observed under 400X magnification. On each proximal surface of the restoration, the interface was divided into 15 areas for conservative preparation and 21 areas for extended preparation (Fig. 1). [(13)] Each area received a score according to the gap presence: 0 = no gaps observed; 1 = presence of at least one gap/irregularity. The evaluation was performed by a technician under blinded conditions. The marginal integrity was expressed as a percentage of the entire margin length using Adobe Photoshop CC 2014 software (Adobe Systems; Mountain View California, CA, USA).

Statistical analysis

For µTBS and marginal integrity, the experimental unit in the current study was the tooth. The µTBS values of all sticks from the same tooth were averaged for statistical purposes. Similarly, the marginal integrity values of the two proximal surfaces from the same tooth were averaged for statistical purposes. The µTBS (MPa) marginal integrity (%) data were subjected to one-way ANOVA. Tukey's post-hoc test was used (a = 0.05) using the Statistica for Windows software (StatSoft; Tulsa, OK, USA).

All procedures were developed with high degree of seriously and medical ethic agree with the kind of study. Ethical certifications weren't necessary because research was *in vitro*.

RESULTS

Approximately 5 to 6 sticks were obtained per tooth, including those with premature failures. Most of the specimens (80.8 to 100 %) showed adhesive/mixed failures (table 2). For all experimental conditions, no significant difference was observed between the groups (table 3; p> 0.05)

Table 2 - Percentage of adapted margin of the restorations

Group	Mean (%)	Standard Deviation
G1	91.02 ^{A}	9.26
G2	86.76 ^{A}	14.78
G3	83.98 ^{A}	8.41

Means with the same letter are not significantly different from each other (Tukey test, *p*> 0.05).

Table 3 - Mean and standard deviation of shear bond strength in Mpa

Groups	Mean (MPa)	Standard Deviation
G1	21.77 ^{A}	8.15
G2	21.07 ^{A}	8.79
G3	19.73 ^{A}	7.55

Means with the same letter are not significantly different from each other (Tukey test, p> 0.05).

No significant difference was observed in terms of marginal integrity among the restoration techniques used (table 3; p> 0.05). Representative images of restoration technique groups (Fig. 1 and 2) show adequate, good or excellent marginal integrities obtained with the different restorative techniques.

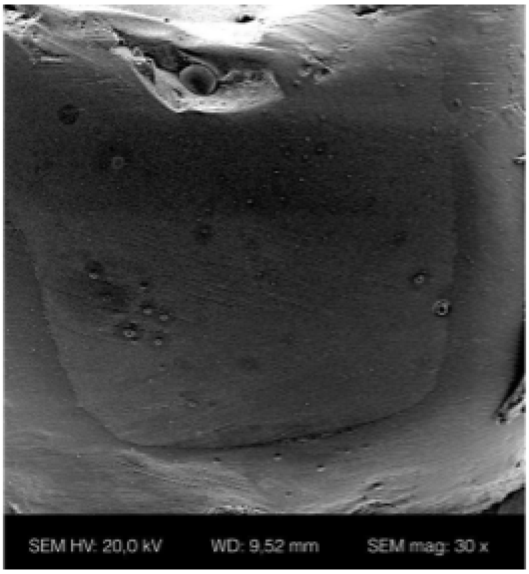

Fig. 1 – Image from Scanning Electronic Microscopy (MEV 30X) of the proximal surface of the restored tooth.

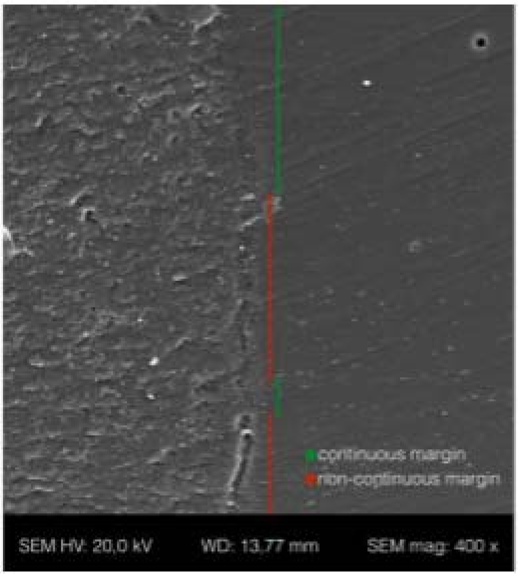

Fig. 2 – Image from Scanning Electronic Microscopy (MEV 400X), where “continuous” and “non-continuous” margins are related to the external adaptation.

DISCUSSION

Bulk filling is highly desired in routine restorative practice, but concerns about shrinkage stress have prompted hesitation among practitioners. In this study, the decision was made to employ a µTBS and marginal integrity test to evaluate the potential impact of bulk filling on the bond strength of class II cavity dentin when compared with incremental filling and indirect resin composite restoration techniques.

It was assumed that polymerization shrinkage stress would impose tensile stress on the adhesive interface at the bottom of the cavity and thus affect the bond strength and marginal integrity of restorations, especially when adhesive procedures are performed in a high C-factor cavity, as was the case in our study. Contrary to previous studies that evaluated the resin-dentin bond strength on a flat dentin surface, the present research examined bond strength values from a constrained surface. This is important because previous studies found that the bond strength of flat cavities is usually higher than that measured in constrained, high C-factor cavities.(6)

In the present study, there were no significant differences between the values of µTBS obtained using different restorative techniques (direct and indirect). There were also no significant differences between the means of the µTBS values using different resin composites. This is similar to the results of de Assis et al. (2016),(13) where the use of composite bulk-fill Surefill SDR flow was favorable.

The use of this material did not jeopardize the resin-dentin bond strength to the bottom of the cavity. A high degree of conversion for Surefil SDR has been reported when used in layers up to 4 mm thick.(11) Additionally, this material also generates less polymerization shrinkage and shrinkage stress, causing less cuspal deflection when compared to a conventional composite applied incrementally.(14,15) This composite showed 60 % less polymerization shrinkage. The main difference lies in a modulator (on the activated photoactive group) that is incorporated into a urethane-based dimethacrylate, which reduces polymerization stress, forming a more flexible polymer network.(16)

Regarding marginal integrity, the results of the present study showed a high percentage of gap-free margins, regardless of the restorative technique used, which is in accordance with previous data.(10,13,14) We hypothesize that the favorable sealing quality of restorations, which is independent of restorative technique, can be correlated to the preparation, adhesion technique, cementation, and finishing procedures adopted for the same operator. Thus, we accept the null hypothesis of the study.

The similar marginal integrity obtained with direct and indirect restorations should be considered when selecting a restorative material. In addition, the amount of dentin structure removed, the complexity of the technique, and the cost of treatment should also be taken into account; in this case, direct restoration is advantageous.

It is important to note that the current study did not use all of the commercially available bulk-fill materials. However, the results obtained in our study are in line with one recent 3-year clinical evaluations using posterior teeth. In that study, the authors compared the bulk-filling technique using Surefill SDR flow plus a capping layer made of conventional resin composite with a conventional resin composite applied in an incremental technique.(17)

The reduction of the required clinical procedure duration is very attractive for simplification; thus, the use of bulk-fill resin composites is an alternative for reducing procedural duration and cost when compared IRC restoration. However, more studies are still needed to clarify the stability of the restoration-dentine interface in the long term.

Conclusions

Based on the results of this study, it can be concluded that Surefill SDR flow plus a capping layer made of a conventional resin composite can be used to reduce procedure durations.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Compliance with ethical standards

Ethical standards: This research was carried out in accordance with the current Brazilian laws relating to human experiments with ex-vivo samples.