Research Paper: A Comparative Study of Shear Bond Strength of Bulk-Fill Composites, Packable and Flowable, as Well as Conventional Light-Curing Composite

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ABSTRACT

Introduction: This study aimed to compare the Shear Bond Strength (SBS) of two bulk-fill composites versus a conventional resin composite.

Materials and Methods: In this study, 60 sound extracted human premolars were selected and sectioned horizontally from one-third of the coronal crown to expose dentin using a low-speed cutting saw. The dentin bonding agent was applied to all specimens, then they were randomly divided into three groups based on their corresponding composites: Group I: Bulk-fill packable (x-tra fil, Voco, Germany); Group II: Bulk-fill flowable (x-tra base, Voco, Germany); and Group III: Conventional (Grandio, Voco, Germany). Subsequently, composite samples with a diameter of 2.5 mm and height of 4 mm were prepared. Following thermocycling (1500 cycles, 5°C -55°C), SBS testing was performed by a universal testing machine. Then, the specimens were examined for the type of fracture (adhesive, cohesive, or mixed) under a stereomicroscope at 20X magnification. Data were analyzed using 1-way ANOVA and Tukey post-hoc test in SPSS.

Results: The highest bond strength was observed in group III (52.99±6.07) and the lowest bond strength was observed in group II (49.11±4.86). There was no statistically significant difference between the packable and flowable groups in terms of SBS (P=0.19). Statistically significant differences were detected between group I and group III (P=0.005) as well as group II and group III (P=0.000). The majority of the fractures observed in all three groups were of adhesive type.

Conclusion: Conventional composites produced significantly better results in comparison with bulk-fill composites as far as SBS was concerned. Therefore, it is advisable to continue the use of bulk-fill materials incrementally in dental treatment.

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1. Introduction

The growing demand for aesthetic dentistry as well as mercury-free and tooth-colored restorations has increased application of composites in dental treatments [1, 2]. Also, as a result of developments in conservative dentistry, certain minimally invasive procedures have emerged, that are conservative by definition, and yet present a blend of advantages and drawbacks [3]. The advantages that composites can provide include more conservative dental preparation and enhanced bonding to tooth structure [1]. Composite restorations promise improved aesthetic and mechanical qualities, and as a result, they have become a popular choice for direct restorations in anterior and posterior regions [4].

On the other hand, application of composites is technique-sensitive and requires complete polymerization along with incremental layering; that ensures reduced polymerization contraction, achieves greater polymerization, and allows adequate curing time [4, 5]. Incremental layering of composites (2 mm apart at maximum) results in enhanced light penetration and improved polymerization while reducing polymerization contraction stress [1, 6]. However, this technique is time-consuming and may cause gaps and voids in restorations [1, 7]. Incorrect implementation of the composite placement technique can lead to inadequate polymerization, causing incomplete cure of the material between the layers. This could, in turn, decrease restoration strength, and as a result an optimum seal will not be accomplished [8, 9].

As an attempt to deliver a more convenient, accelerated process of composite placement in posterior restorations, manufacturers have introduced particular materials known as bulk-fill composites, claiming that this material can be inserted into the cavity as a bulk placement (with 4-5 mm apart layers), resulting in minimal contraction stress while eliminating the need for incremental layering [10, 11].

A successful composite restoration requires adequate polymerization so as to ensure improved mechanical qualities, biocompatibility, and positive long-term prognosis [12]. It has been suggested that increased translucency of these materials can actually enhance the cure depth of bulk-fill composites since this quality increases light transmission, which is associated with augmented depth of cure [5, 13].

Optical properties of composites and their corresponding polymerization reaction, which is activated by light, are interdependent. In other words, with an increase in the yield of radiant exposure, the polymerization degree will rise as well. Light conduction is subject to the composition of the material. Dental fillers diffuse light and inhibit its conduction. This phenomenon is heavily affected by the size of the filler particles as well as the wavelength of the curing light [6].

A variety of bulk-fill composites are available, differing in terms of filler volume, resin matrix composition, and the type of photoinitiator. Some of these products possess greater flowable consistency while others have larger filler volume (packable type); each provides different mechanical properties [6, 14]. One type of photoinitiator that comes with such composites is a dibenzoyl germanium derivative branded as Ivocerin® [8], which is a byproduct of Tetric EvoCeram Bulk Fill (Ivoclar Vivadent, USA). It is a germanium-based photoinitiator that promises a higher degree of photocuring than camphorquinone, and can also absorb a greater amount of light energy within the 400-450 nanometer range.

Accordingly, another advantage of certain bulk-fill composites over conventional products is their different initiator, which leads to improved curing in thicker layers [15]. In view of the different opinions observed in the current literature with respect to Shear Bond Strength (SBS) of these materials [16-19], this study was designed to examine packable bulk-fill composite and flowable bulk-fill composite (from a single available manufacturer) in terms of their bond strength to dental tissues in comparison with conventional composite.

2. Materials and Methods

Collection and storage of specimens

A total of 60 sound human premolars (with no caries, cracks, or any type of defect), extracted already due to orthodontic treatment or periodontal problems, were entered into this study. After cleansing the debris, the teeth were immersed in a disinfecting solution, 0.5 chloramine-T (Fisher Chemical, Fair Lawn, NJ, USA) for 24 hours, and then stored in distilled water at room temperature until operation time.

Preparation of specimens

The teeth were sectioned horizontally (perpendicular to the longitudinal axis of the tooth) from one-third of the coronal crown using a water-cooled low-speed cutting saw (Isomet, Buehler Ltd, Evanston, IL, USA) in order to create a smooth dental surface with an exposed sound

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dentin in the center. Next, the specimens were processed to create a standard smear layer on the exposed smooth surface by means of a 600 grit silicon carbide abrasive paper (Snam Abrasives Pvt. Ltd., India), leaving a polished dental surface. Finally, the specimens were stored in distilled water at room temperature for another 24 hours.

Restoration of specimens

Table 1 presents the data concerning the manufacturer as well as the composition and application method of all materials used in this study. In order for the teeth to remain fixed in place while packing the composite resins, a wax mold was made so that the teeth could be secured perpendicular to the longitudinal axis. Then, the exposed dentin surface of the specimens was etched for 15 seconds using 37% phosphoric acid (Vococid, Voco, Germany). After 10-second rinsing, the excess moisture was dried off according to the blot dry method.

During the following stage, a 5th generation bonding agent, namely Solobond M (Voco, Cuxhaven, Germany), was applied to the dentin surface of all specimens in accordance with the manufacturer's instructions. This was followed by treating the applied layer employing a light-curing device (Bluedent LED smart, Bulgaria) for 20 seconds at 800 mW/cm^2 intensity, controlled by a radiometer (RD-7, Ecel Ind. E Com. Ltda, Ribeirão Preto/São Paulo, Brazil). Afterwards, a dental straw (height: 4 mm and diameter: 2.5 mm) was placed on the smooth dentin surface using sticky wax while the specimens were carefully isolated. At this point, the experimental specimens were randomly allocated to three groups of 15 each, based on their treated composite resin.

The first group was treated with a packable bulk-fill composite branded as x-tra fil (Voco, Cuxhaven, Germany) using a bulk placement technique for restoration, in compliance with the manufacturer's instructions. The procedure involved condensing the composite resin to 4 mm in a plastic mold and polymerization utilizing a light-curing device for 20 seconds at 800 mW/cm^2 intensity. After curing the specimens and following a 5-minute interval, the plastic dental straw was cut off using a scalpel and removed from the restoration site.

The second group received a flowable bulk-fill composite branded as x-tra base (Voco, Cuxhaven, Germany) using a bulk placement technique, according to the manufacturer's instructions. This procedure involved placing the tip of the composite injection syringe at the bottom of the plastic mold, followed by slow injection of the composite resin. During the injection, the syringe was slowly lifted upward to the top of the mold so that the tip remained floating in the composite material in order to prevent formation of any bubbles. Subsequently, these specimens were cured in accordance with the manufacturer's instructions.

As for the third group, a conventional nanohybrid composite resin was used, namely Grandio (Voco, Cuxhaven, Germany). The material was placed on the dentin surface using the incremental layering technique (each layer 2 mm) and then cured, performed in compliance with the manufacturer's instructions. To allow the aging process to take effect, all experimental specimens were stored in distilled water for a period of one week. Next, they were placed in a thermocycler machine and subjected to 1500 thermal cycles in baths of 5°C and 55°C with 30 seconds of dwell time for each bath and 10-15 seconds of transfer time.

Evaluation of shear bond strength

A universal testing machine (STM-20, SANTAM Design and Manufacturing Co., Iran) was employed to assess the bonding strength of the composite to the dentin. First, a dental acrylic base was made proportionate to the jaw of the machine. Then, the teeth were mounted on the molds. Next, the specimens were subjected to force at the tooth-composite interface, parallel to the bonded surface, utilizing a stainless steel rod with a sharp blade of 2.5 mm diameter at the speed of 0.5 mm/min until fracture occurred (Figure 1). Finally, using the STM controller software, bond strength value was determined in MPa.

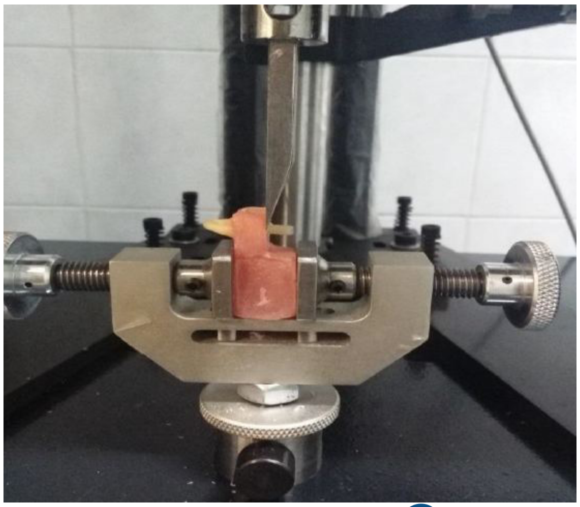

Figure 1. Evaluation of specimens in terms of type of the fracture

Table 1. Content, manufacturers, and application procedure of used materials

	Material	Content	Manufacturer	Application Procedure
Bonding agent	Solobond M	BisGMA, HEMA, BHT, acetone, organic acids	Voco, Cuxhaven, Germany	Etched with 37% phosphoric acid for 15 s, rinsed and air-dried, adhesive applied with a brush, let act for 30 s, adhesive dispersed with a faint air jet, light cured for 20 s
Composites	Grandio (conventional nanohybrid)	Inorganic fillers in a methacrylate matrix (BIS-GMA, TEDMA, UDMA)	Voco, Cuxhaven, Germany	Applying composite in 2-mm increments, light cured for 20 seconds
	x-tra base (bulk-fill flowable)	Inorganic fillers in a methacrylate matrix (aliphatic dimethacrylate)	Voco, Cuxhaven, Germany	Applying composite in 4-mm increments, light cured for 10 s at 800 mW/cm^2 or higher
	x-tra fil (bulk-fill packable)	Inorganic filler in a methacrylate matrix (Bis-GMA, UDMA, TEGDMA)	Voco, Cuxhaven, Germany	Applying composite in 4 mm increments, light cured for 10 s at 800 mW/cm^2 or higher

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Abbreviations: BisGMA: Bisphenol-A-Glycidyl Methacrylate; TEGDMA: Triethylene Glycol Dimethacrylate; UDMA: Urethane Dimethacrylate

All specimens were observed at 20X magnification under a stereomicroscope (OLYMPUS DF PLAPO 1X, JAPAN). The following types of fractures were observed: 1. Adhesive: when more than 90% of the bonded surface between the dentin and the composite resin was fractured; 2. Cohesive: when more than 90% of the fracture occurred in either the dentin or the composite resin; 3. Mix: when both adhesive and cohesive types of fracture occurred.

Statistical analysis

All data were analyzed using descriptive statistics of mean and standard deviation, 1-way ANOVA inferential test and Tukey post-hoc test in SPSS version 21.

3. Results

The mean SBS values are presented in Table 2. The mean (SD) value of SBS in the conventional composite group was equal to 57.99(6.07), which was greater than that of the packable bulk-fill composite group as 52.08(4.08) as well as that of the flowable bulk-fill composite group as 49.11(4.86). This difference was statistically significant (P=0.0001). However, there was no statistically significant difference between the packable bulk-fill composite group and the flowable bulk-fill composite group.

Pairwise comparison of SBS among groups are presented in Table 3. The information shows no statistically significant difference between the packable and flowable composites SBS (P=0.19), while there is a signif-

Table 2. Mean and standard deviation of bond strength values in study groups

Experimental Group	Shear Bond Strength	
	Mean	SD
Conventional	57.5416	5.91
Packable bulk fill	52.0836	4.083
Flowable bulk fill	49.1178	4.87

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Table 3. Pairwise comparison of shear bond strength among study groups (Tukey HSD analysis)

Group		Mean Difference	P*
Packable	Flowable	2.96578	0.190
	Conventional	-5.45802	0.005
Flowable	Packable	-2.96578	0.190
	Conventional	-8.42380	0.000
Conventional	Packable	5.45802	0.005
	Flowable	8.42380	0.000

* The mean difference is significant at the 0.05 level.

icant difference between the SBS of the conventional and the packable composites (P=0.005), as well as the significant difference was observed between the SBS of the conventional and flowable composites (P<0.001) Table 4 presents different types of fractures. Concerning the type of fracture, the most frequent type in all three groups was the adhesive type (76%).

4. Discussion

One of the greatest challenges in using composite-resin restorations is polymerization contraction and the resultant stress subjected to the cavity walls. This is an issue of paramount importance since it can lead to adverse complications, including post-treatment sensitivity, bond fracture resulting in gaps, microleakage, minute cracks, cuspal bending, the consequent pain, and finally, secondary caries [20, 21].

Bulk-fill composite resins are currently available in two types: packable and flowable. It has been claimed that they deliver decreased polymerization contraction stress and offer a deeper curing in similar layers compared to conventional composite resins. Therefore, manufacturers claim that these composite resins can be applied in 4-mm thick layers and cured without any negative effects on other properties. They have also introduced a number of strategies, such as increasing the translucency of the material using micro-fillers; utilizing particles with lower elastic modulus; employing modified resin compositions; and using different photo-initiator systems, in an attempt to justify the improved qualities of these composites versus conventional products [22].

Similar to the findings of some studies [18, 19], the findings of the present study suggest that bulk-fill composites showed significantly lower bonding strength in comparison with conventional composites. This finding indicates that, despite the technological advances in the production of bulk-fill composites, the restoration is still subjected to stresses caused by the polymerization contraction of the resin at the tooth-composite interface, reducing the strength of the bond.

Also, even though no statistically significant difference was observed between the two bulk-fill groups in terms of SBS, the flowable group showed a lower bonding strength which could be explained by the comparatively lower filler volume (75% of total weight), higher measure of polymerization contraction, as well as lower quality of other physical and mechanical properties compared to their packable counterparts with greater filler volume (86% of total weight).

Table 4. Fracture type

Fracture Type	Conventional	Packable Bulk Fill	Flowable Bulk Fill
Adhesive	14	14	14
Cohesive	1	0	0
Mixed	4	4	4

Caixeta et al. [18] designed a study to evaluate the bonding strength of bulk-fill composites and reported that x-tra fil bulk-fill composite resins showed lower bonding strength in comparison with two other composites (Filtek Z350 XT Flow and Filtek Z350 XT). This finding was in agreement with the result of Colack et al. study [19].

On the other hand, Van End et al. [23] reported that insertion of conventional composites into the cavity using the bulk-placement technique results in markedly decreased bonding strength, whereas the application of SDR flowable bulk-fill composite provides a desirable bonding strength, regardless of the filling technique and the depth of the cavity. This finding is totally inconsistent with the results of the present study, which might be due to the different procedures followed in the two studies. In the current study, the conventional composite resins were placed into the cavity using the incremental layering technique, while Van End et al. inserted the conventional composite resins into the cavity using the bulk-placement technique – which resulted in reduced bonding strength.

According to a study conducted by Yakushiji et al. [24], which involved evaluation of the microtensile bond strength of conventional versus bulk-fill composite resins using the incremental layering and bulk-placement techniques, SDR flowable bulk-fill composites showed the greatest measure of bonding strength compared to a conventional composite resin (Filtek Z350 XT, 3M ESPE) when following both incremental layering technique and bulk-placement approach. In addition, the incremental layering technique resulted in greater bonding strength compared to the bulk-placement approach, regardless of the type of composite resin used.

Although the present study did not find any statistically significant difference in terms of bonding strength between the two types of bulk-fill composites involved (packable and flowable), and that the findings indicated a considerable difference between the conventional and bulk-fill composites in terms of bonding strength, there are some other studies [25] that reported no marked difference between the conventional and bulk-fill composites in terms of bonding strength. According to Juloski et al. study [25], which evaluated the microtensile bond strength of low-shrinkage composites to the dentin, conventional and bulk-fill composite resins did not produce considerably different results in terms of bonding strength.

The observable difference in the findings of the aforementioned study versus the present study could be due to the different materials used (composites and bonding agents) as well as the different type of SBS testing.

5. Conclusion

Conventional composites produced significantly better results in comparison with experimental bulk-fill composites as far as SBS was concerned. Therefore, it is highly advisable to continue the application of bulk-fill materials in dental treatment due to their clinical success. Furthermore, the incremental layering technique remains the recommended choice for restoration of cavities, even though bulk-fill composite resins are available.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered about the samples.

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Conflict of interest

The authors declared no conflict of interest.

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