



Effect of Different Application Techniques of Universal Bonding System on Microtensile Bond Strength of Bulk-Fill Composites to Primary and Permanent Dentin

Masoud Fallahinejad Ghajari¹, Mahsa Sheikholeslamian², Amir Ghasemi², Leila Simaei^{3*}

1. Dental Research Center, Research Institute of Dental Sciences, Department of Pediatric Dentistry, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran
2. Dental Research Center, Research Institute of Dental Sciences, Department of Restorative Dentistry, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran
3. Department of Pediatric Dentistry, Dental School, Kermanshah University of Medical Sciences, Kermanshah, Iran

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* Corresponding author:

Department of Pediatric Dentistry, Dental School, Kermanshah University of Medical Sciences, Kermanshah, Iran

Email: Leyla_Simaei@yahoo.com

ABSTRACT

Objectives: This study aimed to determine the microtensile bond strength (μ TBS) of a bulk-fill composite to permanent and primary coronal dentin using a universal adhesive in self-etch and total-etch modes.

Materials and Methods: This in-vitro study was performed on 52 occlusal dentinal surfaces of human primary and permanent teeth. The crowns were cut to the gingival level. The 48 prepared dentin sections were randomly assigned to the following groups (n=13): A: Primary/Total-etch, B: Primary/Self-etch, C: Permanent/Total-etch, and D: Permanent/Self-etch. In groups A and C, after etching for 15 seconds, two layers of a universal bonding (Futurabond U) were applied and cured for 10 seconds. All samples were filled with a bulk-fill composite (x-trafil; VOCO) and cured for 40 seconds. The samples were cut to a bar-shaped dentin block with the dimensions of $1 \times 1 \times 1$ mm³, and after 10,000 thermocycles, the μ TBS test was accomplished at a crosshead speed of 1 mm/minute. The mean and standard deviation (SD) of μ TBS were calculated, and the data were analyzed using two-way analysis of variance (ANOVA) and Fisher's exact test.

Results: The mean μ TBS was as follows: A: 15.03 ± 2.0279 , B: 11.11 ± 2.4423 , C: 23.50 ± 4.8165 , and D: 16.26 ± 6.3200 MPa. Futurabond U showed a higher μ TBS in the total-etch mode ($P < 0.001$). The permanent teeth had greater μ TBS than the primary teeth ($P < 0.001$). Similar percentages of failure modes were observed in the total-etch groups but in the self-etch groups, most failures were in the form of adhesive and mixed.

Conclusion: Greater μ TBS was observed in the permanent teeth with the total-etch technique.

Keywords: Dental Bonding; Dentin-Bonding Agents; Tensile Strength; Composite Resins; Permanent Dentition; Primary Teeth

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INTRODUCTION

Care and maintenance of the primary teeth are of great importance for the management of dental development in children. On the other hand, choosing the right dental material for pediatric dental treatment is very important [1,2].

Due to technological advances in recent years, the composition of resin composites has undergone significant changes. These advancements have led to the enhancement of optical properties, surface texture, integrity, aesthetics, and resistance. However, due to polymerization shrinkage, recurrent caries, plaque accumulation, and color instability, dentists are somewhat reluctant to use these materials [3-7].

The polymerization of dental composite resins occurs by the physical movement of the monomers using free radicals and chemical bonding. This reaction is followed by network volume reduction and composite shrinkage. At the early stages of polymerization, small chains can neutralize the shrinkage-induced stress, but due to polymer network enlargement and the inability of molecules to move freely, this stress applies force to the bulk of the composite, to the bonded surface of the tooth, and to the composite itself [8].

Using an incremental technique to reduce the intensity of polymerization-induced stress is an accepted method in large cavities. However, because of voids, contamination among the layers, and the time-consuming nature, this method has always been questioned. Bulk-fill composites were introduced to overcome these problems [9,10].

The main advantage of bulk-fill composites is their translucency, which increases the depth of polymerization from 1-1.5 mm to 3-5 mm [3,4] with a shorter working time [11,12].

The use of a new polymer called the SDR (stress decreasing resin) has greatly reduced the stress caused by the polymerization of resin composites over time [8].

The clinical success of composite restorations depends greatly on the adhesive system [1,2]. The bonding mechanism of adhesive systems essentially involves the replacement of

minerals removed from hard dental tissues by resin monomers; therefore, the polymer is micromechanically trapped in the dental substrate [13].

The universal bonding is the newest type of bonding that can be used in the total- and self-etching modes. The universal bonding can provide a suitable bond to wet and dry dentin with reduced postoperative sensitivity and appropriate marginal integrity. In a review of the dentin penetration and the microtensile bond strength (μ TBS) of a universal bonding to the dentin of permanent teeth using the self- and total-etching techniques, Wagner et al [14] found that additional etching steps did not affect the μ TBS; however, the level of adhesive penetration into the dentin indicated a significant increase [14]. In a three-year study, evaluating restorations of the posterior teeth using bulk-fill composites, van Dijken and Pallesen [15] concluded that the bulk-fill technique using a flowable resin-based composite (SDR) represents acceptable clinical success. In a review of the μ TBS of a new universal bonding for decayed and intact dentin of the primary teeth using both self- and total-etch techniques, Lenzi et al [16] found that the Scotchbond (the self-etch technique) had the lowest μ TBS in all groups, and no significant difference was observed among the groups of dentin with caries.

There are limited numbers of studies that focus on using a universal bonding and its physical and mechanical properties in combination with a bulk-fill composite in the primary dental system. This study aimed to evaluate the μ TBS of bulk-fill composites to the dentin of permanent and primary teeth using a universal bonding in self- and total-etching modes.

MATERIALS AND METHODS

This experimental study has been approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (code: 1396.466). Twenty-six extracted, caries-free, and unrestored primary first and second molars and 26 extracted, caries-free, and unrestored erupted permanent first and second premolars were used in this experimental study.

The teeth were disinfected in a 0.5% chloramine solution and placed in distilled water for up to one month. An IsoMet saw (Buehler Ltd., Lake Bluff, IL, USA) was used for exposing the dentin surface such that the space between the dentin surface and the dental pulp would be at least 2 mm. Then, to prevent light propagation in other directions, steel bands with a 4mm height were adapted to the exposed dentin surfaces and fixed using acrylic resin.

Fifty-two dentin samples were randomly divided into four groups of 13 samples each as follows:

A: Primary/Total-etch

B: Primary/Self-etch

C: Permanent/Total-etch

D: Permanent/Self-etch.

In groups A and C, the dentin was etched with 37% phosphoric acid (Scotchbond Etchant, 3M ESPE, St. Paul, MN, USA) for 15 seconds, rinsed with water for 15 seconds, and dried with air spray for 5 seconds. After the application of the dentin bonding agent (Futurabond U; VOCO GmbH, Cuxhaven, Germany) and curing for 20 seconds using a light-curing unit (Optilux 50, Demetron/Kerr, Danbury, CT, USA) at an intensity of 650 mW/cm², a bulk-fill resin composite (x-trafil; VOCO GmbH, Cuxhaven, Germany) was applied to the prepared dentin surfaces using a steel band with a height of 4mm, which was carefully attached to the prepared dentin surfaces. The composite resin was light-cured for 40 seconds using the halogen light-curing unit.

In groups B and D, after the application of the dentin bonding agent and curing for 20 seconds using the light-curing unit, the bulk-fill resin composite was applied to the prepared dentin surfaces using the steel band. The composite resin was light-cured for 40 seconds using the halogen light-curing unit.

After storage in distilled water at 37°C for 24 hours [17], the bonded samples were cross-sectioned (Accutom-50; Struers Gmbl, Copenhagen, Denmark) under water spray perpendicular to the adhesive interface into quadrangular bonded sticks. The sticks were measured using a digital caliper (1×1 mm²). Then, the roots were cut at 2 mm below the cemento-enamel junction (CEJ). The samples

were subjected to 10,000 thermocycles with a dwell time of 30 seconds and a transfer time of 10 seconds. After 24 hours, the sticks were individually attached to the microtensile testing jig with a cyanoacrylate adhesive, and the bond strength was evaluated using a universal testing machine (Bisco, Schaumburg, IL, USA) at a crosshead speed of 1 mm/minute. A tensile load was applied until failure. The load at the fracture point in Newtons (N) was divided by the surface area ($l \times b$) to obtain values in Megapascal (MPa). The fractured surfaces were inspected under an optical microscope (Leica, Heerbrugg, Switzerland) at ×40 magnification to determine failure modes, which were classified as (a) adhesive, (b) cohesive in dentin, (c) cohesive in the composite, and (d) mixed (failure at the resin/dentin interface including some cohesive patterns on the neighboring substrates). Two examiners crosschecked this observation and confirmed the findings. Two-way analysis of variance (ANOVA) was performed to examine the mean and standard deviation (SD) of the μ TBS of the bulk-fill composite to the dentin of primary and permanent teeth. Failure modes were analyzed using Fisher's exact test. All statistical tests were applied with a confidence level of 95%.

RESULTS

The two-way ANOVA showed that the type of bonding application had a significant effect on the μ TBS ($P < 0.001$). The dentin samples in the total-etch group showed a higher μ TBS compared to the self-etch group. Type of tooth also had a statistically significant effect on the μ TBS ($P < 0.001$; Table 1).

The permanent teeth showed a higher μ TBS than the primary teeth. There was no significant interaction effect between the bonding application mode and tooth type ($P = 0.169$). In both self-etch and total-etch modes, the μ TBS in the permanent teeth was higher than that in the primary teeth ($P < 0.001$ and < 0.005 , respectively). In both permanent and primary teeth, the μ TBS of the total-etch bonding was higher than that with the self-etch bonding ($P < 0.01$ and < 0.001 , respectively).

Fisher's exact test showed statistically significant differences in the four groups in

Table 1. Mean and standard deviation (SD) of microtensile bond strength (μ TBS; MPa) according to the type of bonding and tooth (N=13)

Bonding	Tooth	Mean	SD	Mode
Total-etch	Permanent	23.5	4.81	33.0-17.1
	Primary	15.03	2.02	19.2-12.5
Self-etch	Permanent	16.26	6.32	25.5-6
	Primary	11.11	2.44	14.5-6

terms of the fracture location ($P=0.046$). This means that while all types of fractures were observed in the permanent teeth with the total-etch technique, with roughly similar percentages, most fractures observed in the self-etch group of permanent teeth and the self-etch group of primary teeth were in adhesive and mixed forms (Table 2).

DISCUSSION

Today, resin-bonded restorations are considered as an integral part of restorative dentistry due to their acceptable aesthetics and the ability to replace dental tissues in a conservative manner [17,18]. The success of these restorations mostly depends on the properties of the bonding system [19].

Universal adhesives are relatively new materials that have been recently introduced to the market to simplify and accelerate the bonding procedure [20,21].

Due to the fast entry rate of these new materials into the world of dentistry, few studies have examined their characteristics.

To reduce stress intensity at the contact surfaces of teeth, the incremental technique

with 2mm layers is recommended for composite placement. However, this technique is time-consuming and may cause voids and contamination among the layers, which makes it more difficult and more complex to use in pediatric dentistry [9,10].

Due to high reactivity to the light, feasibility of the placement of composites in a 4mm-thick bulk, and less exposure time, the use of bulk-fill composites has been welcomed by dentists [22]. The x-trafil composite is a type of hybrid and radiopaque composite that, according to the manufacturer, is suitable for direct posterior restorations and deep cavities [23]. It can be used in a 4mm bulk with low exposure time. The multi-hybrid technology has been used in this type of composite, which decreases polymerization shrinkage in bulky masses with high wear resistance, making it a good choice for highly loaded restorations [23]. Since different types of monomers in bulk-fill composites give different mechanical properties and because of the better results obtained by using composite and bonding from one manufacturer, the x-trafil composite, which consists of Bis-GMA (Bisphenol A glycidyl methacrylate), UDMA (urethane dimethacrylate), and TEGDMA (triethylene glycol dimethacrylate) monomers with a high degree of conversion, is a reasonable choice. This composite has shown acceptable mechanical and structural properties in many previous studies [24]. Nowadays, different methods are used to evaluate the quality of bonding to enamel and dentin.

Table 2. Frequency of failure modes in the four study groups (N=13)

Bonding	Tooth	Failure mode N(%)			
		Mixed	Cohesive/Composite	Cohesive/Tooth	Adhesive
Total-etch	Permanent	4(30.8)	3(23.1)	3(23.1)	3(23.1)
	Primary	7(53.8)	2(15.4)	3(23.1)	1(7.7)
Self-etch	Permanent	5(38.5)	0(0)	0(0)	8(61.5)
	Primary	7(53.8)	2(15.4)	0(0)	4(30.8)

As one of the most important of these methods, we refer to the micro- or macro-bond strength test. The shear and tensile bond strength test is one of the most common methods.

For the first time, Sano et al introduced the μ TBS test to measure the elastic modulus of mineralized and non-mineralized dentin [25]. The advantages of this test include reducing the numbers of teeth for sample collection,

test variables reduction, and facilitated assessment by scanning electron microscopy and transmission electron microscopy (SEM/TEM). However, the μ TBS test has some disadvantages such as rapid dehydration of samples, the probability of damage to samples during restoration, and difficult measurement of forces less than 5 MPa [26].

Therefore, in the present study, this test was used according to the researchers' recommendations regarding the high importance of μ TBS. The new sample preparation design, bar-shaped instead of dumbbell-shaped [25], keeps the samples hydrated until the test is performed and reduces the time interval between sample preparations. Given that composite-dentin debonding force does not reach to lower than 5 MPa, using this test is not problematic.

Different studies have reported different bond strengths in the primary dentition. Generally, 6.2 to 18.2 MPa is the acceptable bond strength range in the primary teeth [27].

Based on the manufacturer's instructions, the bonding system used in the present study could be used in both self- and total-etching modes. The bond strength significantly increased with phosphoric acid etching (the total-etch samples). The results of this study were consistent with a study by Lee et al [28]. They showed that bond strength to the dentin with the Single-Bottle Bonding System in the self-etch mode was between 6.6 and 8.1 MPa, and in case of etching, it was between 20.6 and 21.1 MPa [28].

Van Landuyt et al (2006) [29], Sabatini (2013) [30], and Torri et al (2002) [31] reported a decrease in the bond strength of self-etch adhesives to the dentin of permanent teeth with the use of acid-etching due to the incomplete penetration of functional monomers to the demineralization depth. Hanabusa et al (2012) [32] evaluated the efficiency of a universal adhesive bonding to dentin and enamel. They noted that acid-etching significantly improves bonding to the enamel, but there was no significant difference in the μ TBS using two adhesive application methods (with or without additional acid-etching). However, they stated that despite the

difference in the μ TBS, according to the TEM estimates, the adhesive interface of the resin was porous, and the resin did not completely penetrate the collagen network [32]. In the valuation of a universal bonding following etch-and-rinse and self-etching, Muñoz et al (2013) [33] reported similar μ TBS for the dentin of permanent teeth. These conflicting results may be due to different types of substrate.

In the present study, the ANOVA results for the domain showed that type of bonding has a statistically significant effect on the tensile strength ($P < 0.001$). The total-etch bonding provided a higher tensile strength compared to the self-etch bonding.

Despite the acceptable bond strength to the enamel, bonding to the dentin is still considered as a clinical challenge [34]. This problem is more challenging in the primary teeth due to their particular structure. Characteristics such as small size, low enamel thickness, less dentin, and limited available surface for bonding, as well as their specific microstructural features, such as fewer and smaller dentinal tubules with less permeability, higher reactivity, and lower levels of calcium and phosphate in the intertubular and peritubular dentin, have caused the adhesives to have more effect on the dentin of primary teeth and to produce a thicker hybrid layer along with deeper demineralized intertubular dentin. This process results in incomplete penetration of adhesive resins, short resin tags, and finally, lower bond strength in the primary teeth. Compared to the permanent teeth, pulp chambers are wider in the primary teeth, reducing the bond strength [35].

The results of our study are in line with studies by Perdigão et al [36], Gateva and Dikov [37], and Yaseen and Subba Reddy [38]. Therefore, the correct execution of different bonding stages is much more important in the primary teeth due to their weaker bond strength.

In the current study, tooth type had a statistically significant effect on the tensile strength ($P < 0.001$). The permanent teeth had a higher μ TBS than the primary teeth. There was no significant interaction between

bonding type and tooth type ($P=0.169$). With both total-etch and self-etch bondings, the μ TBS in the permanent teeth was higher than that of the primary teeth ($P<0.001$ and <0.05 , respectively). Moreover, in both permanent and primary teeth, the μ TBS with the total-etch bonding was higher than that with the self-etch bonding ($P<0.01$ and $P<0.001$, respectively).

In 2014, van Dijken and Pallesen [15] evaluated the restoration of the posterior teeth using bulk-fill composites. They reported the bulk-filling technique as a successful method for the application of composites [15].

Because we always try to reduce chair time in pediatric dentistry and considering the demand for esthetic and durable restorations, the use of bulk-fill composites has been welcomed due to their useful characteristics. According to the findings of the present study, using bulk-fill composites in combination with a universal adhesive in the total-etch mode can be a good choice for pediatric dentists when dealing with uncooperative children. We did not consider any incrementally cured composite as a control group in this study; therefore, we cannot compare the results of bulk-fill composites with that of conventional types. Since similar studies have not been carried out on the efficiency of the universal bonding with bulk-fill composites in the primary dentition, more in-vitro studies and clinical research are required.

CONCLUSION

The μ TBS (Futurabond U) was higher in the total-etching mode than in the self-etching mode. The μ TBS (Futurabond U) was higher in the permanent teeth.

CONFLICT OF INTEREST STATEMENT

None declared.

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