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Original Article

Investigating the Effect of C-Factor and the Method of Bulk-Fill and Nanohybrid Composites Placement on Their Microtensile Bond Strength to Dentin

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Abstract

Statement of Problem: Bulk-fill composites have recently been introduced. There are few studies conducted on them.

Objectives: Therefore, the aim of this study is to ascertain the effect of C-factor and the method of bulk-fill and nanohybrid composites placement on their microtensile bond strength to dentin.

Materials and Method: In this study, 40 extracted third human molars with no caries were collected. The specimens were disinfected and mounted on plaster blocks. Some rectangular cavities (5*3 mm^2) were carved on the occlusal level of teeth in the depths of 2 and 4 millimeters. The molars were equally divided into eight study groups at random. After the carving was done, cavities were restored with universal (Tetric N-ceram/Ivoclar vivdent) and bulk-fill (Tetric N-ceram BulkFill/Ivoclar vivdent) composites with incremental and bulky techniques. Then they were stored in distilled water for one week. After that, they were cut into halves from the middle of the restoration spot at the buccolingual direction to turn them into rectangles. Then the microtensile bond strength test was carried out on them to record the failure resistance. The data were analyzed by conducting an ANOVA, a post hoc test, and a T-test. The failure mode was evaluated with a stereomicroscope.

Results: Using bulk-fill and nanohybrid composites in cavities filled massively in a 4-mm depth showed a significantly lower level of microtensile bond strength compared with other groups (p= 0.000). Failure was often adhesive in these groups.

Conclusion: Considering the research constraints of this laboratory study, bulk-fill composites can be cured well in a 4-mm depth. However, it is advised to use the incremental method in cavities with high C-factors due to the high stress caused by the polymerization shrinkage.

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Introduction

With the growing demands for beauty and advancements in bonding techniques, nowadays composites are regarded as one of the materials selected for the restoration of posterior teeth. Despite many benefits, there are some constraints on the use of such composites such as more abrasion compared with metal restoration, a chance of dental allergy, changes in color, and difficult working conditions for dentist [1]. The main problems of composites are their polymerization shrinkage and the stress they cause. This stress is imposed on the distance between a tooth and the restoration. It results in some concerns about direct composite restorations [2].

An incremental composite placement technique has been used as a standard to prevent gaps caused by polymerization stress and obtain the sufficient bond between composites and teeth [3-5]. However, bulk-fill composites have recently been introduced to reduce the time and cost of restoration [2].

Bulk-fill composites are claimed to be used in 4 to 6 millimeters of thickness with fewer layers in one phase [2, 6].

According to what the manufacturing factory claimed in addition to some studies, bulk-fill composites can adjust to the walls of a cavity very well. They can reduce the cuspal deflection [7]. However, one of the potential problems of these composites is a high C-factor due to the high thickness of each layer which may increase the stress caused by the polymerization shrinkage resulting in de-bonding, leakage, and post-restoration pains [1, 8-10].

Few studies have been conducted on the investigation of how to use the cavity restoration technique with bulk-fill composites in one phase in deep and narrow cavities [2, 4-5, 11]. The results have been contradictory due to the variety of composites, bonding, and curing intensity. It has not been clarified very well what effect the C-factor has on the bond strength. Thus, composite bonding and curing intensity are different in this study conducted to ascertain the effect of C-factor. Such cavities are characterized by a high C-factor. Moreover, stress cannot be released easily in bulk-fill composites. Therefore, the shrinkage stress force may exceed the bond strength.

The aim of this study is to compare the microtensile bond strengths of bulk-fill composites with nanohybrid composites in cavities with different C-factors and placement methods.

The null hypothesis is that the microtensile bond strength to dentin does not depend of the C-factor and the composite type.

Materials and Methods

In this study, 40 extracted third human molars with no cracks and caries were collected. The specimens were disinfected and stored in the chloramine solution 0.5% T (Merk-Germany) [2-3]. Then they were put in a physiology serum.

The number of teeth was determined according to a similar study. All of the teeth were mounted in plaster blocks for the ease of use. Before carving them, the surfaces of all cusps were smoothed with a diamond disk (Dian fong/China) to create a homogenous reference point. An 0.8-mm fissure device (Teeskavan/Iran) and a turbine with water and air were used to carve the teeth. Some box-looking cavities were carved in 5*3 mm^2 in the center of occlusal surfaces of teeth. Half of the teeth were randomly carved in a depth of 2 millimeters. The rest of them were carved in a depth of 4 millimeters. Then the rectangular cavities of Class 1 were carved in the desired dimensions. Half of them were carved in a depth of 2 millimeters, and others were carved in a depth of 4 millimeters from the occlusal surface (the C-factors of these cavities were 3.13=(3×5)+2(3×4)+2(5×4)÷3×5 and 5.26=(3×5)+2(3×4)+2(5×4)÷3×5, respectively). The depth of 2 millimeters was selected due to the maximum depth proposed by the manufacturing company of nanohybrid composites. The features were investigated with the probe periodontal (UNC15/America). After every five carves, a new fissure device was used to make cavities. Then the cavities were washed in normal water, then they were dried. Finally, the teeth were equally divided in 8 groups randomly for restoration and cure.

The microtensile bond strengths in different research groups (megapascal):

G1: the teeth restored with the universal composite (Table 1) using the bulky method in a depth of 2 mil

Table 1: Features of Composites

Type	Tetric N-ceram	Tetic N-ceram Bulkfill
Manufacturing Factory	Ivoclar vivadent-italy	Ivoclar vivadent-italy
LOT#	T24404	T29061
Matrix	Dimethacrylate	Dimethacrylate
Filler	Baiumglass, Ytterbium, tiflouride, mixed oxid & co polymer	Bariumglass, Ytterbium, triflouride, prepolymer & mixed oxide
Filler Size (%)	55-57	53-55
Filler Weight (%)	80-81	75-77

limeters

G2: the teeth restored with the universal composite using the bulky method in a depth of 4 millimeters

G3: the teeth restored with the universal composite using the incremental method in a depth of 2 millimeters

G4: the teeth restored with the universal composite using the incremental method in a depth of 4 millimeters

G5: the teeth restored with the bulk-fill composite (Table 1) using the bulky method in a depth of 2 millimeters

G6: the teeth restored with the bulk-fill composite using the bulky method in a depth of 4 millimeters

G7 the teeth restored with the bulk-fill composite using the incremental method in a depth of 2 millimeters

G8: the teeth restored with the bulk-fill composite using the incremental method in a depth of 4 millimeters

In restoration phases, the teeth (N- etch/Ivoclar vivadent Italy) were washed and dried according to the instructions provided by the manufacturing factory. Then the bonding (Tetric N-bond Total-Etch/Ivoclar vivadent Italy) was applied on the surface with light air for 10 seconds according to the instructions. Then they were cured for 10 seconds [12]. It should be mentioned that the tip of the light-cure device was kept in the minimum distance from the surfaces of teeth. In total, 10 teeth were restored with an IVA bulk-fill composite (Tetric N-ceram BulkFill/Ivoclar vivadent Italy) in a depth of 2 millimeters, and 10 other teeth were restored in the same way in a depth of 4 millimeters. Then other teeth were restored with a universal composite in A2 (Tetric N-ceram/Ivoclar vivadent Italy) (Table 1). In the restoration method for each composite, half of 2-mm or 4-mm cavities were restored and cured using the bulky method, and other cavities were restored and cured using the incremental method in 1-mm layers. The incremental filling method decreases the C-factor by 1.86 for each layer. The composites were cured using a light cure LED device (Woodpecker/China) in a light intensity of 500 mW/cm^2 using the soft start lighting method (5 seconds) for 20 seconds [12]. In addition, the light intensity of the light cure device was controlled before each restoration by using a radiometer device (Litex/Bulgarian). After storing the specimens in an incubator for one week at 37 degrees of Centigrade [2], the teeth were sectioned vertically in half by using a 0.3-mm diamond disk at a buccolingual direction. Then rectangular specimens of 2×1 millimeters were provided to test the microtensile bond strength. After that, they were turned into rectangles having 1-mm cross sections and connected to a plus universal testing machine (MTD-500/Germany). They were put under the tensile stress at a crosshead speed of one millimeter per minute. The microtensile bond strength was reported in MPA by applying a pre-force of 150 N. The statistical analyses were done in SPSS 10 (SPSS Inc., Chicago, Il, USA). Given the small size of specimens in each group, the Kolmogorov-Smirnov test was conducted to investigate the microtensile bond strength first. The results showed that the distribution of data was normal. Therefore, a post hoc test and a t-test were carried out to analyze data at a 0.05 level of significance. Moreover, the failure mode was evaluated by using a stereo microscope (Nikon/Japan) in 40 times of magnification.

Results

In this study, there were eight groups including five teeth each. In each group, nine specimens were evaluated with a cross section of one millimeter. The highest and lowest levels of microtensile bond strength were observed in G8 (24.170 MPA) and G2 (1.214 MPA), respectively. Therefore, they were significantly

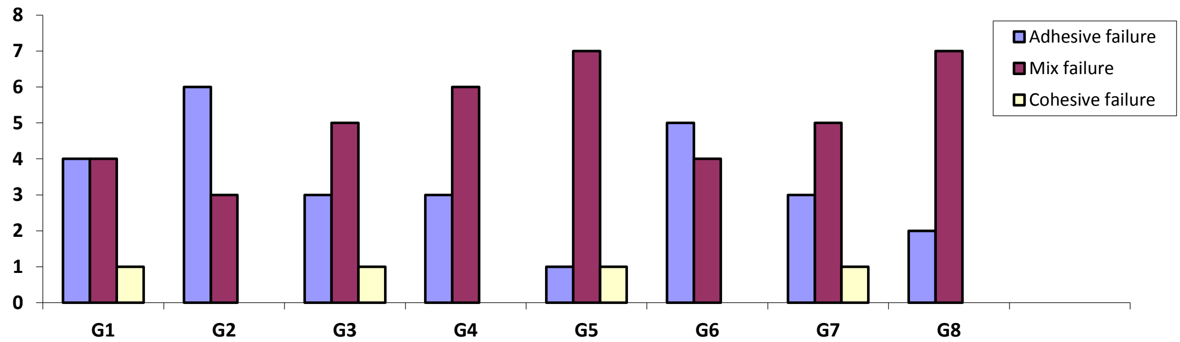

Figure 1: Distribution and Frequency of Failures in the Research Specimens

different.

The microtensile bond strength was analyzed using the ANOVA and a multivariate post hoc comparison (Table 2) at a 0.05 level of significance. There were significant differences in(g2g3) *p*= 0.044(g2g5) *p*= 0.002 (g2g7) *p* =0.005 (g2g8) *p*=0.006 (g5g6) *p*=0.013 (g6g7) *p*= 0.30 (g6g8) *p* = 0.33.

Then a stereomicroscope was used to investigate the failure mode. The results showed that most of failures were of the mix type. Moreover, there were mostly adhesive failures in G2 and G6 (Figure 1).

Table 2: Distribution and Frequency of Failures in the Research Specimens

Research Groups	Mean (MPA) + SD
G1	10.46+3.73
G2	5.15+3.98
G3	12.74+3.94
G4	11.29+5.86
G5	14.90+5.77
G6	6.39+4.97
G7	14.27+4.42
G8	14.20+5.71

Discussion

Nowadays the bulky restoration method is becoming more popular because it is time-saving and cost-effective. However, there are some concerns about the stress caused by polymerization shrinkage in this method [2].

Regarding the technological advances in composites of low shrinkage, bulk-fill composites have recently been introduced by using the bulky technique. These composites can be placed and cured in a 4-mm thickness with one layer [13-14].

In this study, the microtensile bond strength to dentin was evaluated in cavities with different C-factors and different placement methods by suing Tetric N-Ceram bulk-fill composites. In addition, the results were compared with the Tetric N-Ceram nanohybrid composites.

Since there were significant results between the means of pair research groups, the null hypothesis should be rejected. The results showed the dependency of C-factor on the type of composites and layering methods.

Generally, there are different factors affecting the microtensile bond strength: the type of adhesive, maintenance time and conditions, the type of composite, the curing method, and the layering technique [2, 6].

When there were two composites placed incrementally in different depths, no significant differences were observed in their microtensile bond strengths despite the presence of a satisfactory bond and a high level of microtensile bond strength in the bulk-fill composite. These findings are consistent with the studies conducted by Annelies [2] and Nicolaenka [4].

This finding can prove again that the incremental solution method is a standard method for posterior restorations.

When cavities were restored using the incremental method, a decrease was observed in the composite size and C-factor (this method decreases the C-factor by 1.86 for each layer) [2]. Both of these parameters can reduce the shrinkage stress applied to the common surface of adhesive on the bottom of a cavity [2].

The chemical structures of filler and matrix can have significant effects on light absorption and the bond as a result. In the combination of Tetric N-Ceram bulk-fill composite, pre-polymerized fillers were used because they contain minerals such as glass barium and silica. According to other studies [10, 15-17], the use of such fillers increases the size percentage and decreases the filler load in the matrix structure of dental composites by maintaining the appropriate contact surface between mineral fillers and the matrix. They also have positive effects on the ability to absorb radiative energy and polymerization through composites.

Nowadays optical launchers such as ivocerin and benzoyl germanium are used in the ppf structures of bulk-fill composites in a common way like camhorquinon [18-20].

The higher capacity of such materials in the production of free radicals for each unit of molecules can improve the light sensitivity of composites [21-22]. These changes have positive effects on the ability to absorb light and polymerization shrinkage in such composites. As a result, the microtensile bond strength is improved [2, 6].

When 2-mm cavities were restored in the bulky technique, the C-factor was increased to 3.13; furthermore, the size composite increased. However, the distance between the light cure device and the deep composite decreased.

Nevertheless, there were no significant differences in the microtensile bond strengths of bulk-fill composites in the incremental technique. However, the nanohybrid composite strength decreased, something which is inconsistent with the recommendation of the manufacturing factory for placing the maximum thickness of 2 millimeters in this composite.

When the 4-mm cavities were restored using the bulky technique, the increased pressure in such narrow cavities increased the stress caused by polymerization shrinkage. Then C-factor increased to 5.26 [2]. Therefore, the adhesive common surface became unstable. These observations resulted in a significant relationship in the bond strength compared with the incremental restoration. These findings are inconsistent with the studies conducted by Annelies [2] and Flury [11]. Annelies used flowable composites in a study. The bulk-fill (SDR) type of this composite was restored using a bulky technique in a depth of 4 millimeters. It resulted in a high bond strength which was due to the higher translucency of SDR improving the permeability of light providing enough curability in four more millimeters of depth. Flury achieved a high bond strength in the bulky restoration in 4 millimeters of depth despite the sameness of bulk-fill composite. However, a one thousand intensity was used for curing composites.

The forms of 4-mm cavities are not only due to the high C-factor, but also because of the reduction in maximum curing caused by increasing the depth of nanohybrid composites. The high C-factor increases the induction of polymerization stress [2].

In addition, the results of studies conducted on absorption and dispersion through the placement of composites, the light intensity is adversely disrupted in the bottom of a 4-mm cavity [2].

Therefore, both bulk-fill and nanohybrid composites showed significant differences in the microtensile bond strengths in a 4-mm depth in comparison with the incremental method conducted in a 2-mm depth (p =0.004).

Although the harmful effects of configuration factor and increased light attenuation are observed less often on the generality of sticky surfaces through multilevel adhesives, a single-level total etch adhesive (made by the composite-manufacturing factory) was finally used. It was also easy to use and implement. Different adhesives were used in various studies. For instance, Annelies [2] used the self-etch (Gaenial bond) adhesive based on water. The Tetric N-Ceram adhesive is one of the alcohol-based systems. The alcohol helps the adhesive penetrate into the collapsed collagen network [20]. Apparently, it can create the higher microtensile bond strength. After using the adhesive, an airy warhead was employed. This technique is easy to achieve a homogeneous and thick layer of adhesive [12]. The extension of adhesive was limited on the bottom of cavities of the first class, and it is not possible to avoid creating more variable and thicker layers and creating an adhesive pool in the corners of a cavity. This additional adhesive can have negative effects on the bond strength [2].

The microtensile test is the most recent test designed to evaluate the bond strength. It was introduced by Sano [1]. In such tests, the bond level decreases to a great extent and reaches nearly 1 mm^2 because the large size of a bond interphase area can cause more faults resulting in an uneven surface. As a result, it may cause an inappropriate distribution of forces and the early collapse of bond [23].

Price [24] and Flury [11] used the cutoff bond strength. The results of Price are consistent with this study; however, the results of Flury are inconsistent with bulk-fill composites. The reason was addressed earlier in this text.

It has been clarified that a 1-mm cross section is critical for this test. Therefore, the specimens were close to this cross section [25].

Collecting specimens to evaluate the microtensile bond strength can be done by trimming or without trimming them. The non-trim techniques are easier. They do need shorter preparation time. The trim phases cause dumbbell-looking or hourglass specimens by trimming in an interstitial level. Although this technique improves the accumulation of stress in the interface, it was complicated to collect the specimens, something which depends on the method of an operator. Accordingly, the specimens were non-trim rectangular in this study [1].

The analysis of failures indicated that the bond strength was more related to a mix or cohesive failure. On the contrary, the lower bond can often emerge as an adhesive in a common interface. These findings are consistent with the results of Annelies [2]. The inconsistency with the results of Flury [11] can be due to:

- Errors in adjusting the position of a specimen in line with the axis of a testing device
- Micro cracks while cutting and restoring specimens which are regarded as a cohesive failure in those areas.
- An observer's errors in observations

Conclusion

Considering the research constraints on this laboratory study, bulk-fill composites can be cured very well in a depth of 4 millimeters. However, it is advised to use the incremental method in cavities of high C-factors due to the high stress caused by polymerization shrinkage.

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Conflict of Interest: None declared.

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