



Influence of Cavity Dimensions on Microleakage of Two Bulk-Fill Composite Resins

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Abstract

Objective: To evaluate the effect of cavity dimensions on the amount of microleakage in two different types of bulk-fill composite resins. **Material and Methods:** Forty class II cavities were prepared in the mesial and distal surfaces of human molars without any carious lesions. The samples were divided into 4 groups (n=10): Group 1: cavities with 3 mm of buccolingual width (known as the smaller cavity), filled with Tetric N-Ceram Bulk Fill composite resin; Group 2: cavities with 6 mm of buccolingual width (larger cavity), filled with Tetric N-Ceram Bulk Fill composite resin; Group 3: cavities with 3 mm of buccolingual width, filled with X-Tra Base composite resin; and Group 4: cavities with 6 mm of buccolingual width, filled with X-Tra Base composite. After the specimens were thermocycled for 500 cycles at 5/55°C, they were immersed in 1% methylene blue for 24 hours, and then cut into sections mesiodistally in the longitudinal axis of each tooth. Then, the samples were scored regarding the amount of dye penetration in two occlusal and gingival areas under a stereomicroscope (x32). Data was submitted to Kruskal-Wallis and Mann-Whitney tests. **Results:** The highest degrees of microleakage in larger cavities filled with X-Tra Base among the four groups. There was a significant statistic difference (p=0.012) between large and small cavities filled with X-Tra Base (Groups 3 and 4); however, there was no significant difference between the two cavity sizes of Tetric N-Ceram Bulk-filled groups. **Conclusion:** Microleakage of composite resins depends on the dimension of the cavity and the type of composite resin used.

Keywords: Dental Cavity Preparation; Dental Leakage; Composite Resins.

Introduction

Today, composite resins are widely used due to improved mechanical properties, good aesthetic and strong bonding to the tooth structure [1]. However, some of the limitations of their function such as stress polymerization shrinkage and the resultant microleakage are still a major concern [2]. Microleakage will pave the way for secondary caries, enamel cracks, staining of restoration and postoperative sensitivity [3-5]. Polymerization-induced stress can be caused by various factors such as the type of material, the techniques used or the cavity preparation [2,6].

On the other hand, manufacturers always try to solve these problems and provide better products. In this regard, bulk-fill composite resins have been introduced to overcome some of the shortcomings of light-cure composite resins and facilitate restoration of large cavities in shorter times [7]. These materials are suitable for insertion in a 4-mm bulk placement due to their reduced polymerization stress and their reactivity to light-curing. These composite resins also reduce many possible disadvantages of using the incremental placement technique such as the risk of contamination or void formation between the layers [8]. The higher depth of cure of these materials is due to the presence of different photo-initiators that are more translucent and allow transmission of light to deeper layers [9].

Several studies have been conducted on the microleakage and marginal integrity of this new generation of composite resins. Some have shown no significant difference between a number of bulk-fill materials compared to conventional resin-based composite (RBC) [10,11], whereas some literature suggests that there is an improvement in the marginal seal with bulk-fill materials compared with conventional layering [12]. It was reported that higher viscosity of bulk-fill RBCs results in greater marginal gap formation [13].

This in vitro study aimed to evaluate the microleakage of two bulk-fill composite resins at two different sizes of cavities.

Material and Methods

In the present experimental study, 20 extracted human third molar teeth were used. To remove surface plaque and periodontal fibers, the specimens were cleaned with pumice paste and manual dental scaling instruments. Then, the teeth were immersed in 1% chloramine solution for a week for disinfection. In addition, during the experiment, to avoid dehydration, the teeth were stored in distilled water in an incubator at 37°C.

The teeth were randomly divided into 4 groups of 5, based on composite resin types and dimensions of the cavities. The characteristics of composite resins used in this study are summarized in Table 1.

Two cavities were prepared on each tooth on the mesial and distal surfaces; as a result, four groups with 10 samples in each were provided (n=10). The cavities were prepared using a high-speed handpiece (NSK Ltd., Tokyo, Japan) and a #010 fissure diamond bur (Intensiv SA, Montagnola, Switzerland) under air and water spray in two different dimensions.

Table 1. Characteristics of the composite resins used.

Composite	Filler (%)	Light-Curing Depth (mm)	Shade	Manufacturer
Tetric N-Ceram	75-77	4	Universal A2	Ivoclar Vivadent AG, Schaan, Liechtenstein
X-Tra Base Bulk Fill	86	4	Universal A2	Voco GmbH, Cuxhaven, Germany
GrandioSO	87	2	A2	Voco GmbH, Cuxhaven, Germany

The four groups were as the following: G1: Tetric N-Ceram Bulk Fill composite resin was used in the cavity with a buccolingual width of 3 mm × occlusogingival height of 6 mm × axial depth of 2 mm; G2: Tetric N-Ceram Bulk Fill composite resin was used in the cavity with a buccolingual width of 6 mm × occlusogingival height of 6 mm × axial depth of 2 mm; G3: X-Tra Base composite resin was used in the cavity with a buccolingual width of 3 mm × occlusogingival height of 6 mm × axial depth of 2 mm; and G4: X-Tra Base composite resin was used in the cavity with a buccolingual width of 6 mm × occlusogingival height of 6 mm × axial depth of 2 mm.

It should be noted that the dimensions of each cavity were determined separately for each tooth using standard calipers, and assessment of the interior angles and surface flatness of each cavity were confirmed under a Nikon SMZ1000 Zoom stereomicroscope (Nikon Corp., Tokyo, Japan).

To restore the cavities, first, self-etch bonding agent (Futura Bond DC, Voco GmbH, Cuxhaven, Germany) was applied several times on enamel and dentin surfaces for 20 seconds, air-dried for 5 seconds and light-cured with a light-curing unit at a light intensity of 500 mW/cm² (Demetron, Kerr Corp., Orange, CA, USA) for 10 seconds. The cavities were then filled with the designated composite resins. As the maximum depth of exposure of Tetric N-Ceram Bulk Fill has been determined as 4 mm, the 6-mm depth of the cavity was filled in two steps; the first time with a thickness of 4 mm and the second time with a thickness of 2 mm. The time of exposure was 20 seconds according to the power of the machine. In the case of X-Tra Base composite resin, the most appropriate thickness for exposure of composite resin has been reported to be 4 mm by the manufacturer, and posterior composite resin GrandioSO (Voco GmbH, Cuxhaven, Germany) has been recommended for the occlusal layer. The 4-mm depth of the cavity was filled with X-Tra Base for 20 seconds of exposure. In addition, the 2-mm surface of cavity was filled by GrandioSO for 20 seconds of exposure. Then the restoration surfaces were polished with polishing burs (JOTA AG Rotary Instruments, Rüthi, Switzerland).

The samples were then immersed in distilled water for 24 hours and incubated at 37°C (Mani Inc., Utsunomiya, Japan). To simulate oral clinical setting, all the samples were subjected to thermocycling (P20, Dorsa, Tehran, Iran) at 25/55°C (20 seconds in cold water bath, 10 seconds for transfer and 20 seconds in hot water bath) for a total of 5000 cycles.

After thermocycling and drying the samples, to prepare teeth for staining, two layers of nail varnish were applied on the teeth except for the restoration and 1-1.5 mm margin around it. In addition, to ensure a complete seal of the area, the bonding agent was applied to the apex and light-cured; then it was covered with red wax following the application of the nail varnish on it.

In the next step, to detect the areas with microleakage, the teeth were immersed in 1% methylene-blue for 24 hours. Then, all the teeth were sectioned along the longitudinal axis in a mesiodistal direction. In addition, they were observed and scored under a stereomicroscope (Nikon SMZ1000, Nikon Corp., Tokyo, Japan) at a magnification of x32.

The microleakage scores were classified in 2 separate occlusal and gingival axes (Table 2). Three groups of scores were considered for occlusal and 4 distinct groups were considered for the gingival area.

Table 2. The microleakage scores were classified in 2 separate occlusal and gingival axes.

Occlusal Area		Gingival Area	
0 - Lack of Enamel Leakage		0 - Lack of Dentin Leakage	
1 - Leakage in Enamel		1 - Leakage in Less Than Half of the Distance to the Pulp	
2 - Leakage in Dentin		2 - Leakage in More Than Half of the Distance to the Pulp	
		3 - Leakage to the Pulp	

Data Analysis

Data were analyzed using IBM SPSS Statistics for Windows Software, version 18 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to calculate the absolute and relative frequencies. Kruskal-Wallis and Mann-Whitney tests were used. Statistical significance was defined at $p < 0.05$.

Ethical Aspects

The ethical approval was obtained from the Ethical Review Board of the Zanjan University of Medical Science.

Results

The relative frequency and distribution of microleakage degrees in 2 occlusal and gingival levels of restored teeth, in all 4 groups, have been represented in Tables 3 and 4. Regarding occlusal scores, G4 presented the highest frequency of scores 2.

Table 3. Occlusal microleakage scores.

Microleakage Scores	G1		G2		G3		G4	
	N	%	N	%	N	%	N	%
0	5	50.0	1	10.0	3	30.0	1	10.0
1	5	50.0	7	70.0	6	60.0	3	30.0
2	0	0.0	2	20.0	1	10.0	6	60.0

Table 4. Gingival microleakage scores.

Microleakage Scores	G1		G2		G3		G4	
	N	%	N	%	N	%	N	%
0	4	40.0	6	60.0	6	60.0	1	10.0
1	1	10.0	0	0.0	2	20.0	0	0.0
2	3	30.0	1	10.0	0	0.0	3	30.0
3	2	20.0	3	30.0	2	20.0	6	60.0

Statistical analysis shows that regarding occlusal microleakage in scores of 0 and 1, Tetric N-Ceram Bulk Fill resin composite has allocated the highest percentage to itself (30% and 60%, respectively, in comparison with 20% and 45%), and in score 2, X-Tra Base resin composite has allocated the highest percentage to itself (35% in comparison with 10%). In addition, regarding gingival microleakage, in score 0, Tetric N-Ceram Bulk Fill (50% compared to 35%) and in the score 3, X-Tra Base resin composite (40% compared to 25%) have allocated the highest percentages to themselves. Kruskal-Wallis test showed that, there is a significant difference among all 4 groups regarding both occlusal ($p=0.011$) and gingival microleakage ($p=0.046$).

In Mann-Whitney test, and pairwise comparisons among 4 groups, a significant difference was observed among groups 3 and 4 in occlusal and gingival area and there was not any significant difference observed among other groups. In addition, a significant difference was obtained among all microleakages of 3-mm cavities and all microleakages of 6-mm cavities in enamel but there was not a significant difference in dentin (the comparison was done regardless of composite type).

Discussion

The technique involved in placing posterior composite resins presents many challenges [14]. To facilitate placement of direct composite resins in deeper cavities, bulk-fill composite resins have been introduced. The mechanical stability of fillings in stress-bearing areas restored with bulk-fill composite resins is still open to question since long-term clinical studies are not available [15] so far; thus, the aim of this study was to evaluate and compare the effects of different cavity dimensions on the microleakage of bulk-fill composite resins.

Based on statistical analyses, microleakage was observed at all the occlusal and gingival surfaces in all the 4 study groups, ranging from mild to severe, with significant differences between all the samples ($p=0.046$); the greatest amount of microleakage was detected in group 4 on the gingival surface X-Tra Base composite resin, 6-mm cavity). The difference in microleakage between groups 3 and 4 was significant: however, the difference between groups 1 and 2 was not significant.

Microleakage depends on multiple factors, with some related to resin composite resins and others related to specific cavity and restorative procedures. Factors related to composite resins are of key importance for gap formation, polymerization shrinkage and elastic modulus [16,17].

According to Hook's law, polymerization stress is the product of elastic modulus and strain [18], implying that composite resins with a combination of high polymerization shrinkage and high elastic modulus result in the highest polymerization stresses. Both polymerization shrinkage and elastic modulus highly depend on the filler content. In this context, lower filler contents give rise to greater shrinkage stresses [19]. Considering the statistical data on the websites of the manufacturer of each composite resin studied in the present study, Tetric N-Ceram Bulk Fill composite resin has high viscosity, with a nanofilled filler content of 79-81 wt%, a volumetric shrinkage of 1.74% and a shrinkage stress of 1.1 MPa, whereas X-Tra Base is a low-viscosity composite resin, with a filler content of 75 wt%, a volumetric shrinkage of 2.54% and a shrinkage stress of 5.9 MPa. X-Tra Base

composite resin exhibits higher flow rate and better adaptation with the cavity walls [20] and some studies have reported it as a flowable bulk-fill composite resin [21]. In a previous study flowable composite resins exhibited greater gingival microleakage [22]. In addition it was reported that flowable composite resins exhibited very high microleakage compared to other composite resins, consistent with the results of the present study [23].

Previous authors compared microleakage of flowable bulk-fill composite resins with that of conventional composite resins and reported less microleakage with the use of flowable bulk-fill composite resins, which was attributed to higher degree of conversion of flowable bulk-fill composite resins compared to conventional composite resins [24]. In addition, two separate studies showed proper performance of Tetric N-Ceram Bulk Fill composite resin in relation to microleakage [25,26].

In the present study, GrandioSO composite resin was placed on X-Tra Base composite resin as a cap according to manufacturer's instructions. Several studies have shown that due to some reasons, including greater shrinkage and other poor mechanical properties, when only flowable composite resin is used in the whole cavity, unfavorable results are achieved [27,28]. Therefore, packable composite resin should be used on the occlusal aspect of the cavity on flowable composite resin.

A possible theory to explain gingival microleakage of X-Tra Base composite resin in large cavities (6 mm) is that in composite resins with greater polymerization shrinkage it can be expected that increases in cavity dimensions resulting in increased C-factor, in the mass volume of composite resin and in shrinkage stresses in the composite resin mass will result in a significant increase in microleakage. In this context, composite resins with low shrinkage (Tetric N-Ceram Bulk Fill) might not exhibit such an increase in microleakage in large cavities or even they might not be affected by such shrinkage stresses.

A previous study evaluated the effect of cavity dimensions on cuspal flexure by determining microleakage and showed that there was a significant relationship between the cavity size and shrinkage, with greater microleakage in cavities with larger sizes [25]. Other researchers evaluated the effect of changes in cavity dimensions on microleakage of Class V cavities and reported that a change in the type of the bonding agent was significant only in large cavities and the bonding agent variable did not exhibit its effect in small cavities [29]. A direct and significant relationship between microleakage and composite resin volume and cavity dimensions was observed [30]. Based on the results of all the studies above, the greater microleakage in group 4 can be explained.

In addition, the occlusal microleakage of cavities was less than that in the gingival area. In many studies, gingival microleakage has been higher than the occlusal microleakage, irrespective of the bonding system or composite resin type used [31-34].

The presence of less dye penetration and better marginal seal on enamel is attributed to the low organic content of enamel compared to dentin. Dentin has a complex structure rich in organic molecules, making adhesion to dentin more variable and difficult [32]. Considering the structure of

enamel-dentin complex, another reason for the differences might be the good efficacy of etching and bonding to enamel, stability of enamel mineral content and limitations in the formation of proper resin tags in dentin.

Conclusion

Microleakage of composite resins depends on the dimension of the cavity and the type of composite resin used.

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