Journal of Dental School 2016; 34(4): 225-34 Original Article

Microleakage of Bulk-Fill Composites at Two Different Time Points

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Abstract

***Objectives*:** Microleakage is the main concern in composite restorations. This study aimed to compare the microleakage of two bulk-fill and one conventional composite at two different time points.

***Methods*:** Class II cavities were prepared in 60 premolar teeth and divided into six groups of 20. Groups 1 and 4 were incrementally filled with Grandio composite. Groups 2 and 5 were filled with X-tra fil bulk-fill composite. Groups 3 and 6 were filled with Tetric-N-Ceram bulk-fill composite in one layer. The samples were thermocycled for 5000 cycles between 25-55°C. In groups 1-3, the samples were incubated for 24 hours and then immersed in 1% methylene blue dye. Groups 4-6 were incubated for three months and then immersed in dye. All samples were mesiodistally sectioned and degree of microleakage was scored under a light microscope. The data were analyzed using Mann Whitney and Kruskal-Wallis tests.

***Results*:** The results showed no significant difference among groups 1-5 and 6 in terms of microleakage ($P>0.05$) but a significant difference was noted between groups 1 and 4 in this regard ($P=0.01$). The microleakage in groups 4-6 was higher than that in groups 1-3 ($P=0.02$). Also, microleakage in gingival margins was greater than that in occlusal margins ($P=0.02$).

***Conclusion*:** The microleakage of bulk-fill composites is comparable to that of conventional composites both at 24 hours and three months after restoration.

***Key Words*:** Composite Resins; Dental Leakage; Time

How to cite:

Kianvash Rad N, Javid B, Panahandeh N, Ghasemi A, Kamali A, Mohammadi G. Microleakage of Bulk-Fill Composites at Two Different Time Points. J Dent Sch 2016; 34(4): 225-34.

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Received: 21.10.2016
Accepted: 17.12.2016

Introduction

The process of polymerization requires physical movement of monomers present in the formulation of composites in order to form chemical bonds mediated by free radicals. This process decreases the volume, which is referred to as polymerization shrinkage. This shrinkage creates stresses in tooth and composite structure. Thus, conventional composites are applied in thinner than 2mm increments in order to form a smaller polymer network and create subsequently lower polymerization stress.

Bulk-fill composites were introduced to dental market aiming to enhance extensive restorations of teeth in a shorter time (1). The main advantages of these composites include lower polymerization stress and higher depth of light curing by up to 4mm (2, 3). A new polymer has been added to the polymer network of bulk-fill composites, known as the stress decreasing resin (SDR),

which is a urethane-dimethacrylate resin. It significantly decreases the accumulation of stress in the polymer network over time. The SDR is composed of a combination of high molecular weight molecules and polymerization modulators, which are located between monomers. High molecular weight and flexibility of the polymer matrix around the modulators decrease the polymerization stress. Thus, according to the manufacturer's instructions, these composites can be applied in 4mm thick increments.

Polymerization shrinkage creates gap between the tooth and the restoration and enables leakage of bacteria and oral fluids (4,5). Microleakage causes tooth hypersensitivity, discoloration of restoration and eventual pulp irritation (6). Assessment of microleakage is an important indicator of the quality of restoration (7). Time affects microleakage as well. Several methods are available for assessment of microleakage, and dye penetration is among the most commonly used techniques (8). Easy use and low cost are among the advantages of this technique.

This in vitro study aimed to assess the microleakage of two bulk-fill and one conventional composite at two different time points.

Methods

This in vitro experimental study was conducted on 60 sound extracted human premolar teeth. In order to determine the 42% difference in microleakage between six groups, with 60% of samples in each group having zero microleakage and considering the P value less than 0.05 to be significant and study power of 80% (Power and Sample Size Calculation version 2.1.31), 20 samples were required in group and thus, 120 samples were required for the study.

The teeth were cleaned by pumice paste and hand scaler and immersed in 1% chloramine T solution for one week for disinfection. During the experiment, the teeth were stored in distilled water in an incubator at 37°C. The teeth were randomly divided into six groups of 10. Class II cavities were prepared in both the mesial and distal surfaces of each tooth using a high speed hand piece (NSK, Tokyo, Japan) and #10 fissure bur (Dia, Italy). Thus, six groups (n=20) were prepared. All cavities had the same dimensions (3mm buccolingual width, 2mm mesiodistal width and 4mm occlusogingival depth). The characteristics of composites used in this study are summarized in Table 1.

The samples were divided into six groups as follows:

Group one: Twenty cavities filled with Grandio composite and stored for 24 hours.

Group two: Twenty cavities filled with X-tra fil composite and stored for 24 hours.

Table 1- Characteristics of the composites used

Composite	Filler (%)	Light curing depth(mm)	Shade	Manufacturer	Batch number
Tetric N-Ceram	75-77	4	IVA	Ivoclarvivadent	644173AN
X-trafil	86	4	universal	voco	1242554
Grandio	87	2	A2	voco	1224390

Group three: Twenty cavities filled with Tetric N-Ceram composite and stored for 24 hours.

Group four: Twenty cavities filled with Grandio composite and stored for three months.

Group five: Twenty cavities filled with X-tra fil composite and stored for three months.

Group six: Twenty cavities filled with Tetric N-Ceram composite and stored for three months.

The cavities were etched with Vococid acid etching gel (35% etchant; Voco, Cuxhaven, Germany). The enamel was etched for 20 seconds and the dentin was etched for 15 seconds. After rinsing, excess moisture was dried using a dry cotton pellet. Care was taken not to over-dry the dentin and a wet cotton pellet was used for this purpose. Two layers of Solobond M (Voco, Cuxhaven, Germany) bonding agent was then applied. Each layer was air sprayed to improve its performance. The bonding agent was cured for 20 seconds by a light curing unit with a light intensity of 450 mW/cm^2 (Demetron, Kerr, Orange, CA, USA). The cavities were then filled with designated composite resins. Bulk-fill composites were applied as one layer and light cured. Grandio was applied in two horizontal increments each with 2mm thickness and light cured. Next, all restorations were finished and polished using composite polishing burs (Mani Inc., Utsunomiya, Japan). The samples were then immersed in distilled water for 24 hours and incubated at 37°C. To simulate oral clinical setting, all samples were subjected to thermocycling (P20, Dorsa, Tehran, Iran) between 25-55°C as 20 seconds in cold water bath, 10 seconds in air and 20 seconds in hot water bath for a total of 5000 cycles.

Afterwards, the samples in groups 1, 2 and 3 were stored in an incubator for 24 hours and were then dried. Two layers of nail varnish were applied on the samples except for the restoration and 1-1.5mm margin around it. To ensure a complete seal, bonding agent was applied to the apex and light cured. Nail varnish was applied on top of it and the area was covered with red dental wax. Groups 4, 5 and 6 were immersed in distilled water and incubated at 37°C for three months. After the completion of this time period, they were subjected to the same procedures as in groups 1-3. After applying nail varnish, the teeth were immersed in 1% methylene blue dye for 24 hours to detect microleakage.

All teeth were sectioned mesiodistally along their long axis and evaluated under a light stereomicroscope (SZX16, Olympus, Tokyo, Japan) at ×32 magnification. Degree of microleakage was scored by an operative dentist in occlusal and gingival margins. Four degrees were classified for microleakage at each of the occlusal and gingival margins (Table 2). Figure 1 shows the schematic view of this classification.

Table 2- Scale microleakage

	Leakage at the occlusal margin		Leakage at the gingival margin
0	No enamel leakage	1	No dentin leakage
1	Leakage in the enamel	2	Leakage extending to less than half the distance to pulp
2	Leakage in dentin	3	Leakage extending to more than half the distance to pulp
3	Leakage reaching pulp chamber	4	Leakage reaching pulp chamber

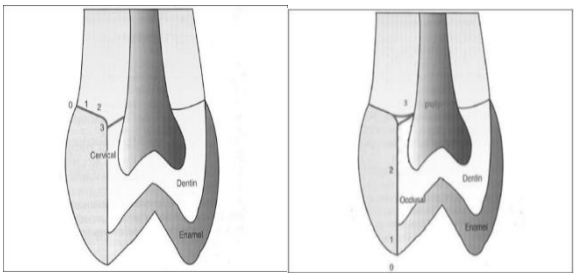

Figure 1- Scoring of microleakage at the gingival and occlusal margins

Results

The Mann Whitney and Kruskal-Wallis tests reported no significant difference in microleakage among the three groups of 1, 2 and 3. No significant difference was noted in microleakage among the groups 4, 5 and 6 either (P>0.05). The gingival microleakage in group 4 was greater than that in group 1 (P=0.01). No significant difference was noted in microleakage between groups 2 and 5 or between groups 3 and 6 (P>0.05). No significant difference was noted among the three composites in terms of occlusal or gingival microleakage at both time points (P=0.532). In samples stored for 24 hours, no significant difference was noted in occlusal and gingival microleakage (P=0.5). In samples stored for three months, a significant difference was noted between occlusal and gingival microleakage (P=0.01). The degree of microleakage in samples stored for three months was greater than that in samples stored for 24 hours (P=0.01) (Tables 3 and 4). Figures 2 to 5 show the microleakage of some samples under a stereomicroscope.

Table 3- Microleakage at the occlusal margin

		Group					
		1.Grandio 24h (%)	2. X-tra fil 24h (%)	3. Tetric 24h (%)	4.Grandio 3m (%)	5. X-tra fil 3m (%)	6. Tetric 3m (%)
Microleakage occlusal margin	None (0)	10 (8.3)	9 (7.5)	11 (9.2)	7 (5.8)	9 (7.5)	8 (6.7)
	Enamel (1)	8 (6.7)	7 (5.8)	8 (6.7)	9 (7.5)	8 (6.7)	9 (7.5)
	Dentin (2)	1 (0.8)	2 (1.7)	1 (0.8)	2 (1.7)	1 (8)	1 (8)
	Pulp (3)	1 (0.8)	2 (1.7)	0 0.0	2 (1.7)	2 (1.7)	2 (1.7)
Total		20 (16.7)	20 (16.7)	20 (16.7)	20 (16.7)	20 (16.7)	20 (16.7)

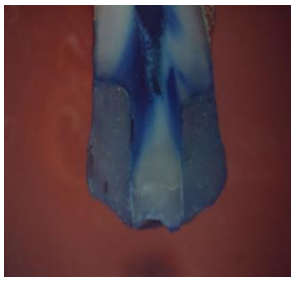

Figure 2 - Dye penetration in samples 3 and 4 in group 5

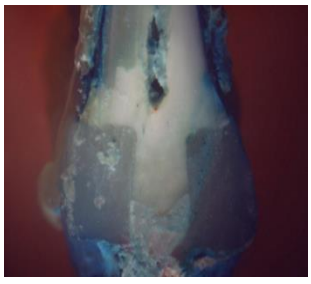

Figure 3 - No dye penetration in samples 1 and 2 in group 1

Table 4- Microleakage at the gingival margin

		Group					
		1.Grandio 24h (%)	2. X-tra fil 24h (%)	3. Tetric 24h (%)	4.Grandio 3m (%)	5. X-tra fil 3m (%)	6. Tetric 3m (%)
Microleakage gingival margin	None (0)	13 (10.8)	11 (9.2)	9 (7.5)	5 (4.2)	5 (4.2)	7 (5.8)
	Half axial (1)	3 (2.5)	5 (4.2)	8 (6.7)	1 (0.8)	2 (1.7)	4 (3.3)
	Axial (2)	4 (3.3)	1 (0.8)	2 (1.7)	3 (2.5)	0 (0.0)	2 (1.7)
	Pulp (3)	0 (0.0)	3 (2.5)	1 (0.8)	11 (9.2)	10 (8.3)	7 (5.8)
Total		20 (16.7)	20 (16.7)	20 (16.7)	20 (16.7)	20 (16.7)	20 (16.7)

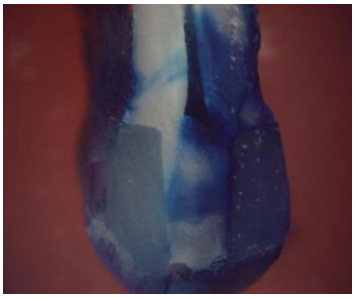

Figure 4 - Dye penetration in samples 5 and 6 in group 6

Figure 5 - Dye penetration in samples 3 and 4 in group 4

Discussion

Microleakage is an important parameter affecting the success rate of restorative materials. Considering the clinical significance of microleakage and introduction of bulk-fill composites to the market, we selected two types of bulk-fill composites in the current study, which have been less commonly assessed in the literature. Grandio conventional composite was used as the control since it has been extensively evaluated in previous studies (9). Availability of the selected three composites in the Iranian market and their lower price compared to their alternatives were among other reasons behind their selection for evaluation in the current study.

Considering the clinical importance of time passed since the restoration and the aging process, this parameter has been evaluated in many studies on restorative materials especially those focusing on microleakage in particular (10). Thus, we performed thermocycling for 5000 cycles and assessed microleakage at two time points to better simulate the clinical setting and further increase the value and generalizability of our findings.

Microleakage was assessed using dye penetration method in the current study, which is among the most commonly used techniques for assessment of microleakage at the tooth-restoration interface (8). In dye penetration technique, different dyes or tracers such as fuchsine, silver nitrate and methylene blue are used (11). Methylene blue is the most commonly used tracer for

different purposes (12). Although some authors believe that small size of methylene blue particles may overestimate the results of dye penetration and microleakage testing (13), use of this dye in adequate concentration can be suitable for scoring of microleakage (14).

In all six groups in our study, variable degrees of microleakage were noted along the occlusogingival surface. For instance, at the gingival margin, the prevalence of score 3 (dye penetration extending to the pulp chamber) ranged from 0% in group 1 (Grandio, 24 hours) to 55% in group 3 (Grandio, three months).

The Kruskal-Wallis test was used for comparison of several groups, which revealed a significant difference among the six groups in terms of gingival microleakage (P=0.01) but no significant difference was noted in terms of occlusal microleakage (P=0.4). In general, no significant difference was noted in terms of microleakage (at the occlusal and gingival margins) among the Tetric, X-tra fil and Grandio composites at the two time points. Similar results were also reported in another study (15). However, in a previous study, degree of microleakage was significantly variable among different types of composites (16). The superiority of bulk-fill to conventional composites in terms of dentinal microleakage has also been previously reported (17).

Several methods have been proposed to decrease polymerization shrinkage and microleakage in composite restorations including incremental application of composite, placement of self-cure composite beneath the light cure composite in the cavity and application of flowable composite beneath the light cure composite. Some studies have shown that incremental application of composite increases the degree of conversion of light cure composites and decreases the shrinkage stress in the tooth surface. However, the results of the current study revealed that use of technologies to control polymerization stress in bulk-fill composites resulted in absence of a significant difference in microleakage between their use as one layer and incremental application of conventional composites. Furness *et al*. (18) restored 4-mm deep class I cavities with bulk-fill composites and showed that number of gap-free margins around these restorations was not significantly different from that in cavities filled incrementally with conventional composite. However, Moorthy *et al*. (19) demonstrated that despite using eight oblique increments of GrandioSo composite, no significant difference was found in microleakage between this conventional and bulk-fill composites.

Load is applied to samples to simulate occlusal loads and assess the physical properties and behavior of composites under load application. Campos *et al*. (20) in 2014 assessed the marginal fit of class II cavities restored with several bulk-fill composites. Despite simulation of occlusal loads, bulk-fill composites showed adequate marginal fit, similar to standard composites. These results are in line with our current findings. However, some studies have questioned the physical and mechanical properties of bulk-fill composites. Leprince *et al*. (21) reported that many bulk-fill composites such as X-tra fil had poorer physicochemical properties

than the conventional composites. They warned clinicians about the use of bulk-fill composites in areas under high occlusal loads. However, Campos *et al*. (20) applied similar occlusal loads to bulk-fill and conventional composites and found no significant difference in microleakage between them.

A recent theory suggests that modulus of elasticity plays a more important role in stress concentration than the shrinkage. In other words, the greater the elasticity of the material in the cavity, the greater the reduction in polymerization shrinkage stresses. This may explain lack of a significant difference in microleakage of bulk-fill and conventional composites in our study. According to the information provided by the manufacturers in their websites, modulus of elasticity and filler percentage of Grandio composite are greater than those of bulk-fill composites used in the current study. It means that Grandio has lower elasticity. When polymerized, there is a possibility that bulk-fill composites show higher elasticity than Grandio and thus, reduction in polymerization shrinkage stresses occurs to a greater extent, preventing gap formation at the tooth-restoration interface in use of bulk-fill composites.

As reported earlier, no significant difference was noted in microleakage among groups 1, 2 and 3, which were stored for 24 hours. The difference among the groups stored for three months was not significant either. The difference in microleakage between the groups 2 and 5 and also 3 and 6 was not significant either while groups 1 and 4 were significantly different in terms of microleakage. Therefore, it seems that three months of water storage in an incubator was sufficiently long to cause differences in microleakage in Grandio (control) composite.

Considering the fact that the adhesive-tooth bond degrades over time, we expected to witness a significant increase in microleakage in bulk-fill composites similar to that in Grandio after three months; however, this did not occur, which is probably attributed to their structural differences. Moreover, according to the information provided by the manufacturers in their websites (Voco, Ivoclar Vivadent), the percentage of resin matrix in bulk-fill composites is greater than that in Grandio. Moreover, it has been shown that by an increase in resin content, water sorption increases as well. Thus, greater water sorption by bulk-fill composites compared to Grandio may result in their swelling and subsequent compensation of gap created by polymerization shrinkage; this probably explains no significant change in microleakage of these composites after three months of water storage. However, the expansion due to water sorption cannot completely compensate for the gap created by polymerization shrinkage.

Moreover, the current results showed that after three months of water storage (groups 4-6), irrespective of the type of composite, a significant difference was noted between occlusal and gingival microleakage (P=0.02). It should be mentioned that since the occlusogingival depth of the cavities was 4mm in our study, no enamel was present at the gingival floor in most samples. Many studies have reported greater gingival than

occlusal microleakage irrespective of the type of bonding system or composite used (22). This difference may be due to better adhesion and seal provided by the bond to enamel than to dentin. Furness *et al.* (18) in their study in 2012 on bulk-fill composites showed that number of gap-free margins (class I cavities) in the enamel was higher than that at the pulpal floor. In another study in 2014, Campos *et al*. (20) evaluated the marginal fit of class II cavities restored with bulk-fill composites and reported the worst results in dentin margins.

Use of pre-polymer shrinkage stress reliever technology and incorporation of Ivocerin photoinitiator and photosensitive fillers in Tetric N-Ceram have enabled its use in 4mm thick increments without compromising its physical properties. Moreover, Ivocerin is more lucent than the other two materials and allows for transmission of light to deeper areas.

Based on the information available in Voco website on X-tra fil, curing is well achieved by up to 4mm depth in all areas without compromising the stability of this composite. Thus, X-tra fil composite is well cured by up to 4mm depth and this explains the lack of a significant difference in microleakage between X-tra fil and Grandio composites in our study.

In a study by Alshali *et al.* (23) in 2013 on the degree of conversion of a number of bulk-fill composites, the degree of conversion of several bulk-fill composites was found to be comparable to that of a conventional (GrandioSo) composite. This finding can also explain the lack of a significant difference in microleakage between bulk-fill and conventional composites.

Conclusion

1. No significant difference existed in microleakage of Tetric N-Ceram, X-tra fil and Grandio composites at the two time points.
2. Time increased the overall microleakage as well as the gingival margin in comparison to occlusal margin.
3. Time did not increase the microleakage for samples restored with bulk-fill composites.

Acknowledgement

This paper is produced from the thesis No.3191 Dental School, Shahid Beheshti University of Medical Science.

Conflict of interest: "None Declared"

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