Original Article

In-Vitro Evaluation of Microleakage of Class II Cavities Restored with Bulk-Fill Flowable Composite

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Abstract

Background and Aim: Composite placement poses many challenges, especially in the gingival floor with dentinal margins. Microleakage is one of the factors affecting the longevity of dental restorations. We aimed to compare the microleakage of cavities filled with bulk-fill composite at enamel and dentinal margins.
Materials and Methods: In this experimental study, a total of 102 sound human premolars were randomly divided into six groups. In groups 1, 3, and 5, Class II cavities were prepared with their gingival margins above the cementoenamel junction (CEJ). In groups 2, 4, and 6, standard Class II cavities were prepared with their gingival margins below the CEJ. In groups 1 and 2, cavities were incrementally filled with Filtek Z250. In groups 3 and 4, the gingival 2 mm of the cavity was filled with Filtek bulk-fill, and the rest of the cavity was restored with Filtek Z250. In groups 5 and 6, the gingival 4 mm of the cavity was restored with Filtek bulk-fill, and the remaining part was restored with Filtek Z250. The teeth were immersed in 2% basic fuchsine for 24 hours, sectioned mesiodistally, and evaluated under a stereomicroscope at ×40 magnification. Data were analyzed using Kruskal-Wallis test. Wilcoxon signed-rank test was used for intergroup comparisons ($\alpha=0.05$).
Results: No significant difference was noted in the microleakage scores of the gingival margins of the six groups ($P=0.168$). No microleakage was noted at enamel margins.
Conclusion: Neither Filtek bulk-fill nor Filtek Z250 could completely eliminate gingival microleakage. It seems that Filtek bulk-fill flowable composite can be safely and reliably used in 4-mm-thick increments.
Key Words: Filtek Bulk Fill, Composite Resins, Dental Leakage

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Introduction

Class II cavities rank second in terms of the prevalence among dental caries [1]. Considering the increasing demand for tooth-colored restorations, studies have focused on factors affecting the success of these restorations. Despite the advances in composite materials, restoration of Class II cavities is still challenging and time-consuming. For the successful restoration of a Class II cavity with light-cure composites, the clinician must overcome some common challenges such as forming a suitable contact with the adjacent tooth and establishing an acceptable marginal seal [2]. Development of postoperative secondary caries is among the most important complications of the restoration of posterior teeth with light-cure composites [3]. Secondary caries often occurs as a result of microleakage and inadequate marginal seal of restorations [3]. Bacterial toxins are responsible for the development of secondary caries and pulpal irritation. Microleakage allows the passage of bacteria through the tooth-restoration interface into dentinal tubules [3]. Microleakage results from alterations in the oral cond tions (i.e. occlusal forces and thermal changes) and the difference between the physical properties of teeth and restorative materials (such as polymerization shrinkage) [4]. Many researchers have attempted to eliminate or minimize microleakage; however, no restorative material or technique has been able to completely eliminate microleakage [4]. Microleakage is a major problem in restorations with gingival margins beneath the cementoenamel junction (CEJ). For tooth restoration with conventional light-cure composites, the composite resin must be applied in increments with a maximum of 2-mm thickness due to the limited depth of polymerization with visible light [5]. Incremental application of composite decreases polymerization shrinkage. Thus, composite restoration of teeth is often time-consuming. Due to high demands for shorter working time, the manufacturers attempted to synthesize composites that can be polymerized in thicker layers with no adverse effect on marginal microleakage of restorations [5]. A new generation of composites, referred to as bulk-fill, was introduced to meet the needs. Bulk-fill composites may be applied in up to 4-mm-thick layers. The manufacturers claim that this composite can be used for the restoration of all types of dental cavities [5]. In some special types, the manufacturer recommends filling-up the cavity with bulk-fill composite, but the occlusal 1 mm of the cavity must be restored with a conventional composite. However, in-vitro and clinical studies are still lacking in this regard [6]. A study on a commercial type of these composites showed that application of composite in 4-mm-thick layers had no negative effect on the quality of marginal seal [7]. Another study showed that use of bulk-fill flowable composite caused a significant reduction in cuspal deflection compared to the incremental application of composite in posterior teeth; however, it showed that use of bulk-fill composite did not decrease microleakage [8].

Considering the recent introduction of bulk-fill composites, a gap of information exists in this regard. Most previous studies have been conducted on Class V cavities restored with bulk-fill composites, and the obtained results have been mostly controversial [3]. Few studies have been conducted on the restoration of Class II cavities with bulk-fill composites [9]. Thus, this study sought to compare the microleakage of restorations with bulk-fill flowable composite in comparison with cavities incrementally filled with conventional Filtek Z250 microhybrid composite at enamel and dentinal margins.

Materials and Methods

This in-vitro experimental study was conducted on 102 human premolars with no caries, cracks, fractures or previous restoration. The teeth had been extracted in the past five months for orthodontic or periodontal reasons. The teeth were stored in distilled water until the experiment. The teeth were rinsed with water, and calculi and periodontal tissue appendages were removed using a scaler. The teeth were then cleaned with a prophylaxis brush and pumice paste. For disinfection, the teeth were immersed in 0.5% chloramine-T solution for one week at 4°C. Then, they were randomly divided into six groups of 17. Standard Class II cavities were prepared on the mesial surfaces of the teeth with a 4-mm buccolingual width and a 2-mm depth. The cavities were prepared 1 mm above the CEJ in groups 1, 3, and 5 and 1 mm below the CEJ in groups 2, 4, and 6. The cavities were prepared using a high-speed handpiece and a fissure diamond bur (d2/#8, Teezkavan Co., Tehran, Iran) under water and air spray. The bur was changed after the preparation of five cavities. During the experiment, the teeth were stored in distilled water at 37°C. The cavities were etched with 37% phosphoric acid (Ultradent Products Inc., South Jordan, UT, USA) for 15 seconds, rinsed with water spray for 10 seconds, and blot-dried. Next, Adper™ Single Bond2 (3M ESPE Dental Products, St. Paul, MN, USA) was applied to the enamel and dentinal surfaces in 2-3 layers using a microbrush for

15 seconds and was then spread with gentle air spray for 5 seconds and light-cured by Valo light-emitting diode (LED) curing unit (Ultradent Products Inc., South Jordan, UT, USA) with a light intensity of 1000 mW/cm^2 for 10 seconds. It should be noted that the Universal matrix system (Tofflemire; KerrHawe SA, Bioggio, Switzerland) was used for all cavities. Depending on the type of restoration, the study groups were prepared as follows:

Groups 1 and 2: The entire cavity was incrementally filled with oblique layers of Filtek Z250 composite (3M ESPE Dental Products, St. Paul, MN, USA). Each composite layer was light-cured with Valo LED curing unit with the light intensity of 1000 mW/cm^2.

Groups 3 and 4: The gingival 2-mm of the cavity was measured by a periodontal probe and bulk-filled with Filtek bulk-fill flowable composite (3M ESPE Dental Products, St. Paul, MN, USA). The rest of the cavity was incrementally restored with Filtek Z250.

Groups 5 and 6: The gingival 4-mm of the cavity was measured by a periodontal probe and bulk-filled with Filtek bulk-fill flowable composite. The rest of the cavity was incrementally restored with Filtek Z250 (Table 1).

Immediately after removal of the matrix band, the restorations were polished with coarse, medium, fine, and superfine aluminum oxide discs (Sof-Lex™; 3M ESPE, St. Paul, MN, USA). All samples were then immersed in distilled water and incubated (Kavooshmega Co., Tehran, Iran) at 37°C for 24 hours. The teeth were then subjected to 3000 thermal cycles in a water bath between 5-55°C with 15 seconds of dwell time and 30 seconds of transfer time. The samples were then dried, and the apices were sealed with sticky wax. The entire tooth surface, except for a 1-mm margin around the restoration, was covered with two layers of nail varnish. The teeth were then immersed in 2% basic fuchsine dye (Merck KGaA, 64271 Darmstadt, Germany) and incubated at 37°C for 24 hours. The teeth were then rinsed with water to remove excess fuchsine and dried with air spray. The teeth were mounted in clear polyester acrylic resin for sectioning. Then, they were mesiodistally sectioned at the center of the restoration by a cutting machine (Mecatome T201 A, Presi, France) using a double-blade diamond disc with a 0.3-mm thickness under water coolant. The sections were then evaluated under a stereomicroscope (Nikon, SMZ 800, Tokyo, Japan) at ×40 magnification (Figures 1 to 3). The enamel and dentinal margins of both halves of each tooth were evaluated by two blind observers. Microleakage was evaluated according to the following criteria [10]:

1. No evidence of dye penetration.
2. Dye penetration along the occlusal/gingival wall to less than half of the cavity depth.
3. Dye penetration along the occlusal/gingival wall to more than half of the cavity depth but not extending to the axial wall.
4. Dye penetration along the occlusal/gingival wall to the full cavity depth, extending to the axial wall.

The data were analyzed using SPSS software (version 22; SPSS Inc., Chicago, IL, USA) with the level of significance being set at P=0.05. Non-parametric Kruskal-Wallis test was applied to compare the six groups.

Results

In the gingival margins, there was no statistically significant difference between the levels of microleakage in the six experimental groups according to Table 2 (P=0.168). In the enamel (occlusal) margins, no microleakage was noted in any of the samples (Table 2). According to the statistical analyses, the intergroup microleakage differences were not significant; therefore, secondary tests were not performed.

Discussion

This study compared the microleakage of Filtek bulk-fill flowable composite in the enamel and dentinal margins of Class II cavities in 2- and 4-mm thicknesses compared to Z250 microhybrid composite. The results showed that the null hypothesis (no significant difference among the groups) of the study was accepted since no significant differences were noted in the microleakage of the study groups (with different composite thicknesses) in either of the enamel or dentinal margins.

Marginal integrity is a fundamental factor in determining the longevity and survival of restorations [10]. Microleakage due to polymerization

Table 1. Materials used in this study and their composition

Type	Material	Manufacturer	Composition	Application Procedure
Filtek Z250	Microhybrid methacrylate-based composite	3M ESPE Dental Products, St. Paul, MN, USA	Resin System: BisGMA, BisEMA, UDMA, TEGDMA Filler: Zirconia, Silica (particle size=0.01-3.5 μm)	Place in increments less than 2.5 mm. Light-cure each increment for 20 seconds.
Filtek Bulk-Fill Flowable	Flowable composite	3M ESPE Dental Products, St. Paul, MN, USA	Resin System: BisGMA, BisEMA, UDMA, Procrylate resin. Filler: Zirconia,Silica (particle size=0.01-3.5 μm), ytterbium trifluoride filler (particle size=0.1-5 μm)	Place in 4-5 mm increments. Light-cure each increment for 20 seconds.
Adper™ Single Bond2	Total-etch adhesive	3M ESPE Dental Products, St. Paul, MN, USA	BisGMA, HEMA, dimethacrylates, water, novel photoinitiator system, methacrylate functional copolymer of polyacrylic, polyitaconic acids	Apply 2-3 consecutive coats for 15 seconds. Gently air thin for 5 seconds. Light-cure for 10 seconds.

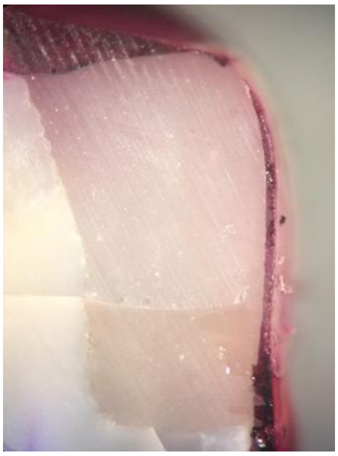

Figure 1. Scanning electron microscope (SEM) image (×40); score 0 in the gingival margin

Figure 2. Scanning electron microscope (SEM) image (×40); score 1 in the gingival margin

Figure 3. Scanning electron microscope (SEM) image (×40); score 3 in the gingival margin

shrinkage is among the most important causes of failure of direct posterior composite restorations since it leads to the loss of marginal integrity [10]. Microleakage is an important parameter for the assessment of the success of restorative materials. The passage of bacteria, fluids, and molecules through the tooth-restoration interface is often assessed for evaluation of microleakage [10]. Dye penetration is a well-recognized technique for in-vitro evaluation of marginal microleakage. It has been shown that fuchsine, silver nitrate, and methylene blue are not significantly different and can all be used as a dye in this technique [4,10]. The composites used in the current study were all manufactured by 3M ESPE. Filtek bulk-fill is a flowable composite with low polymerization shrinkage and Bis-GMA, Bis-EMA, UDMA, and Procrylate resin matrix. Filtek Z250 is a microhybrid composite with Bis-GMA, Bis-EMA, TEGDMA, and UDMA resin matrix [11,12]. Procrylate is a high-molecular-weight monomer similar to Bis-GMA with lower viscosity. The difference between Bis-GMA and Procrylate is the absence of hydroxyl groups which decreases the viscosity of this monomer. The type of filler in both composites is the same (zirconia/silica) but the filler volume percent (vol%) is different between the two (60 vol% in Filtek Z250 and 42.4 vol% in Filtek bulk-fill composite resin) [12,13]. Filtek Z250 composite must be applied in maximum 2-mm-thick increments, while Filtek bulk-fill flowable can be applied in 4-mm-thick increments and is perfectly polymerized at this thickness according to the manufacturer's claims [11]. The technique of application of composite is an important factor determining the polymerization stress [12]. Incremental application of composite has been recommended by almost all manufacturers. This technique is safe since it decreases the C-factor; however, it is time consuming.

Bulk-fill composites were introduced due to the high demand for composites with shorter application time [12]. Recent studies have shown that the polymerization rate is satisfactory shown that the polymerization rate is satisfactory at 4-mm depth of bulk-fill

Table 2. The frequency of microleakage scores in different groups

			Leakage		
			.00	**1.00**	**2.00**
Groups	**1. (Z250 a)**	**Count**	17	0	0
		(%) within group	100.0	0.0	0.0
	2. (Z250 b)	Count	12	4	1
		(%) within group	70.6	23.5	5.9
	3. (FB a 2)	Count	11	4	2
		(%) within group	64.7	23.5	11.8
	4. (FB b 2)	Count	12	2	3
		(%) within group	70.6	11.8	17.6
	5. (FB a 4)	Count	11	4	2
		(%) within group	64.7	23.5	11.8
	6. (FB b 4)	Count	11	4	2
		(%) within group	64.7	23.5	11.8
Total		Count	74	18	10
		(%) within group	72.5	17.6	9.8

FB= Filtek Bulk-Fill, a=enamel margin, b=dentin margin

composites [12]. Class II cavities with their walls in dentin and cementum have been evaluated in several studies. Since obtaining marginal seal is particularly important in such cavities, they were evaluated for microleakage assessment in the current study [12].
Acid-etching is the most reliable technique of surface preparation [14]. Thus, in the current study, surface preparation was done using the etch-and-rinse technique, and Adper Single Bond2 two-step bonding agent was applied according to the manufacturer's instructions to obtain a bond. As recommended by the manufacturer, a high-intensity (1000 mW/cm^2) light-curing unit was used for all cavities.
The results of the current study showed no significant difference in microleakage among the six groups (P=0.168). Comparison of microleakage in the occlusal and gingival walls revealed that gingival walls had greater microleakage than occlusal walls. These results are in line with those of Swapna et al [11] and Webber et al [13]. This finding is due to the fact that the gingival wall of Class II cavities is mainly composed of dentin and cementum when it is located close to the CEJ.
Bond to dentin is different from the bond to enamel due to morphological and histological differences in the mineral composition of enamel and dentin [14]. Enamel is more mineralized than dentin and has approximately 96 weight percent (wt%) mineral content; this rate is 70 wt% for dentin [14]. The organic phase of cementum contains collagen fibers coarser than those in dentin; for this reason, bond to cementum is weaker than that to dentin [14].
Another factor explaining different microleakage scores in the occlusal and gingival margins is the distance between the tip of the light-curing unit and the composite surface. When this distance exceeds 2 mm, the light intensity significantly decreases; consequently, adequate polymerization cannot be achieved [15]. In the current study, no significant difference was noted in the microleakage of gingival margins in different groups; this finding is in agreement with those of Moorthy et al [8] and Webber et al

[13]. None of the two materials used in the current study could completely prevent microleakage in the dentinal margins of the gingival wall. However, no significant differences in the microleakage of the gingival wall margins of bulk-fill flowable composites and high frequency of microleakage score zero in these groups justify their safe use [16]. Low polymerization shrinkage of bulk-fill flowable composites is partly due to their different resin content. The presence of Procrylate monomer in their resin composition controls polymerization shrinkage. Use of photoactive groups in Procrylate resins has increased the translucency of this group of composites and resulted in their more controlled polymerization kinetics [17]. Moreover, low modulus of elasticity of flowable composites decreases the polymerization stress [17].

Bulk-fill composite resins exhibit greater depth of curing and lower polymerization shrinkage compared to conventional composite resins; this is because of the polymerization modulators embedded into the chemical structure of the resin monomer, delaying the gel point [18]. In the pre-gel phase, the flexibility of polymer chains causes the material to flow from the free surface of the cavity; as a result, the internal stresses within the material are relaxed [18]. The time at which the substance cannot compensate the polymerization shrinkage determines the final tensions in the material [18]. Therefore, this type of composite resins behaves differently compared to conventional methacrylate-based materials [16].

It should be noted that no dye penetration occurred between the two layers of bulk-fill and microhybrid composites, which was expected since they were both manufactured by the same company. An important finding when assessing tooth sections was the presence of cracks in some enamel samples. It appears that the application of these composites in thick layers results in the creation of stress in the adjacent enamel. This phenomenon has also been reported by Ferracane [19]. Further research is required in this respect. Despite the relatively satisfactory results of bulk-fill flowable composites and lack of a significant difference in microleakage among the groups, the relatively high frequency of microleakage scores 1, 2, and 3 in the groups should not be overlooked and must be further scrutinized in future studies.

Conclusion

Under the limitations of this study, neither Filtek bulk-fill flowable nor Filtek Z250 could completely eliminate gingival wall microleakage. It seems that Filtek bulk-fill flowable composite can be safely and reliably used in 4-mm-thick increments.

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