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The Effect of Incorporation of Polyethylene and Glass Fiber on the Microleakage of Silorane-based and Methacrylate-based Composites in Class II Restorations: An in Vitro Study

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Abstract

Statement of Problem: Microleakage is one of the most important problems in composite restorations. One way to reduce the microleakage is decreasing the total amount of resin by insertion of fibers in composite restorations.

Objectives: This study aimed to compare the microleakage of Silorane and methacrylate-based composites (a nanohybrid) in Class II restorations with gingival margins on the root surface, with or without placing glass and polyethylene fiber.

Materials and Methods: 60 extracted sound third mandibular molars were disinfected. Class II slot cavities were provided on both proximal sides of each tooth. Based on application of composites and fibers, the teeth were randomly divided into 6 groups (n=20). group1: Z350; group2: Z350 + polyethylene fiber; group3: Z350 + glass fiber; group4: P90; group5: P90 + polyethylene fiber; and group6: P90 + glass fiber. The specimens were thermocycled, immersed in 2% basic fuchsine dye solution, and then sectioned to assess dye penetration under stereomicroscope (40X). Results were statically analyzed by Kruskal-Wallis and Mann-Witney tests at a significance level of $p<0.05$.

Results: There was a significant decrease in microleakage in Silorane composite when compared to nanohybrid composite ($p<0.001$). There was not any significant difference among groups with or without fiber inserts.

Conclusions: The use of Silorane composite reduces the microleakage in comparison with nanohybrid composite and fiber insertion had no effect on the microleakage in class II silorane and nanohybrid composite restorations with gingival margins below the CEJ.

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Introduction

Dental resin composites are the most common and greatly used direct restorative material in dentistry due to their aesthetic properties, good adhesion to the tooth structures, and more conservative cavity preparations [1,2]. There are still two major problems related to composites: low mechanical strength and polymerization shrinkage [3]. Composite polymerization shrinkage of 2.6% -7.1% creates stress between the tooth and the filling material, causing the seal loss and marginal microleakage [2,4]. Marginal microleakage leads to entry of the microorganisms, bacteria, saliva and other fluids in the mouth to the space between the teeth and filling material, so it causes sensitivity after dental work, marginal discoloration, recurrent caries, pulp damage, and ultimately failure [5,6].

Many studies have been performed to develop methods to decrease microleakage by using incremental placement technique, using low shrinkage composites and fiber [2,7]. Incremental technique has been suggested for placement of the composite. In this technique, by applying a small volume of composite, cure is done more efficiently in depth and residual stresses between the tooth and material surface are decreased [4,5].

Recently, resin composite technology is conducting to improve the properties of composites, their adhesion to the dental structure, and marginal adaptation. One of these advances is the application of nanoparticle in the composite resin [8]. Nanohybrid composite has proved to have the same properties as, or sometimes better than, hybrid composite and greatly better than microfilled composites [9]. This composite contains nanoceramic and conventional fillers and has a good polishability, great wear resistance, high tensile strength, and compressive strength to fracture [9-10].

A new composite, silorane, is introduced in dentistry that contains a cationic ring-opening hybrid monomer system. This monomer is achieved by reaction between siloxane and oxirane [11]. Silorane composite has similar, or even better, mechanical and physical properties than conventional composite [12]. These properties include low polymerization shrinkage due to opening and extending the oxirane rings during polymerization and compensating the volume reduction. This causes less cuspal deflection, hydrophobicity due to siloxane, low water sorbtion, favorable biocompatibility, good color stability over time due to its hydrophobic nature, high wear resistance, and good flexural strength [2,9,12,13].

Fibers insertion can improve the quality of the marginal zone by two procedures. The fibers reduce volumetric reduction of the composite by decreasing the total amount of composite; they also improve the resistance of the first composite increment against pull-away from the gingival margin toward the light source [9]. However, some studies showed that fibers had little or no noticeable improvement on reducing the microleakage at the gingival margin [5,9].

Polyethylene fibers show positive impact on the interfacial stresses generated at the etched enamel and resin boundary due to its high modulus of elasticity and low flexural modulus [5]. Glass fiber has the ability to withstand tensile stress and prevent the propagation of cracks in composite restoration. Application of glass fiber would lessen or eliminate the accumulation of stress at the dentin/composite interface and consequently can decrease gap formation and microleakage [14].

In one research on the visible difference between the glass fiber and polyethylene fiber, it has been observed that glass fiber had a greater role in decreasing the gingival microleakage [15]. However, some studies did not find much difference between the two fibers [1,16]. Since there is little information about the effectiveness of the use of polyethylene and glass fiber, and the effect of the fibers present in nanohybrid and silorane composite restorations on microleakage, the current study aimed to evaluate and compare the effect of glass and polyethylene fiber insertion. Moreover, the effect of two types of composite, Silorane and Nanohybrid, in reducing gingival microleakage in Class II cavities with gingival margins below the CEJ was evaluated.

Materials and Methods

In this experimental study, 60 extracted third mandibular molars, without any defect, were cleaned and kept in 0.5% chloramine T (Applichem, Germany) solution for one month. Then, the teeth were mounted vertically in acrylic resin (Acropars, Iran) (dimension: 2x2x2 cm) up to 2mm apical to the CEJ. Class II slot cavities were prepared on both proximal sides of each tooth by using fissure diamond burs (Tizkavan, Iran) in a water-cooled high speed air-turbine handpiece (NSK,Japan). The burs were changed after every 8 preparations. Gingival margin of the cavities was placed at least 1mm below the CEJ. The dimensions of slot cavity were 3mm bucco-lingually, 1.5mm in the axial depth and 6mm proximal box height [17]. There was not any bevel at the margins of the cavity [2]. The dimension of the cavities was measured with UNC15 periodontal probe. Based on the application types of fibers and composites, the teeth were randomly divided into 6 groups of 10 and each teeth was evaluated for 2 proximal cavities (n=20).

One operator prepared all cavities, and another measured the cavities before restoration to confirm the dimensions. Each cavity was cleaned with water spray and air-dried. A universal retainer (Toffelmire, USA) with matrix band (ARNEL, USA) was placed around each tooth and was supported externally by using low-fusing compound (Kerr, Italy) to keep fixing the retainer around the cavity margins.

In group1: The teeth were restored with nanohybrid composite, Z350 (3M ESPE, USA). First, etching gel (35% Phosphoric Acid; 3M ESPE, USA) was applied for 15 seconds, and the cavity was rinsed and gentle air dried for 10 seconds. Adper single bond II (3M ESPE, USA) was used twice to moisten the whole cavity surfaces for 20 seconds. The cavity was gently air dried for 5 seconds to evaporate the solvent carrier and then cured for 10 seconds with a halogen light-curing unit (600 mW/cm2, Coltolux 50, Swiss). The composite was placed into the cavity in 2mm incremental layers; every layer was cured 40 seconds and cavities restored with 3 layers. The band was then removed and the composite was cured from all the sides again for 40 seconds.In group2: The teeth were restored with Z350 and polyethylene fiber (NSI, Australia) inserted in proximal box. Acid-etch and bonding were applied, like group 1. Then, the composite was placed in 1mm increment layer on the gingival floor. After that, polyethylene fiber was cut by a blade (Novacut, China) 1mm less than the bucco-lingual dimension of the cavity and impregnated with Resist (Unfilled resin-HEMA free, Australia) in a dark bottle without light exposure for 5 minutes. Then, it was condensed into the 1mm composite resin and cured for 40 seconds. The next layer was 1mm and cured; then, the rest of the cavity was restored with 2 layers of (2mm increments) composite like group1 and cured.

In group3: The teeth were restored with Z350 and Glass fiber (Henan Jiyuan Glass Fiber CO.,Ltd). The steps were performed similar to group 2.

In group4: The teeth were restored with Silorane-based composite, P90 system adhesive self-etch primer+P90 system adhesive bond+FiltekP90 (3M ESPE, USA). P90 system adhesive self-etch primer was applied to the whole cavity for 15 seconds, dispersed bygentle air and cured for 10 seconds. P90system adhesive bond was applied to moisten all surfaces of the cavity; then it was dispersed by gentle air and cured for 10 seconds. FiltekP90 composite resin was placed into the cavity in 2mm increments similarly to that of nanohybrid composite in group1.

In group5: The teeth were restored with P90 system adhesive self-etch primer+P90 system adhesive bond+FiltekP90 and poly ethylene fiber. Self-etch primer and adhesive bond were applied similarly as in group 4. Then, the composite was placed in 1mm increment layer on the gingival floor and polyethylene fiber was inserted at the gingival floor similar to that in group 2. And FiltekP90 composite resin was placed into the cavity in 2mm increments, as in group2.

In group 6: The teeth were restored with P90 system adhesive self-etch primer+P90 system adhesive bond+FiltekP90 and Glass fiber. The steps were performed as in group 5.

All restorations were finished with 30-bladed tungsten carbide bur (H 135 UF, H 379 UF. H 246 LUF; Brasseler, USA) in a high-speed handpiece with water cooling and polished by an aluminum oxide point (Jiffy points; Ultradent). After that, the teeth were thermocycled (TC-300, Vafaee, Iran) for 500 cycles at 5`c-55`c with 30 seconds dwell time [2]. Then teeth were covered with two layers of nail varnish (Dalior, France) except for an 1mm-area around the gingival surface margin of the restorations.

The teeth were immersed in 2% basic fuchsine dye solution (Merck, Germany) for 24 hours in room temperature, washed, and dried. All the teeth were sectioned mesio-distally from the center of the restoration with a high-speed saw (Isomet; buchler, USA); then, the specimens were cut from acrylic base (Figure1).

Dye penetration was examined at the gingival margin with a stereomicroscope (Motic Microscopes, China) at 40X magnification (Figure 2), and the microleakage was scored based on the six-point scale used [17] and described as follows:

0. No dye penetration

1. Dye penetration extending to the outer half of the gingival floor

2. Dye penetration extending to the inner half of the gingival floor

3. Dye penetration extending through the gingival floor up to one-third of the axial wall

4. Dye penetration extending through the gingival

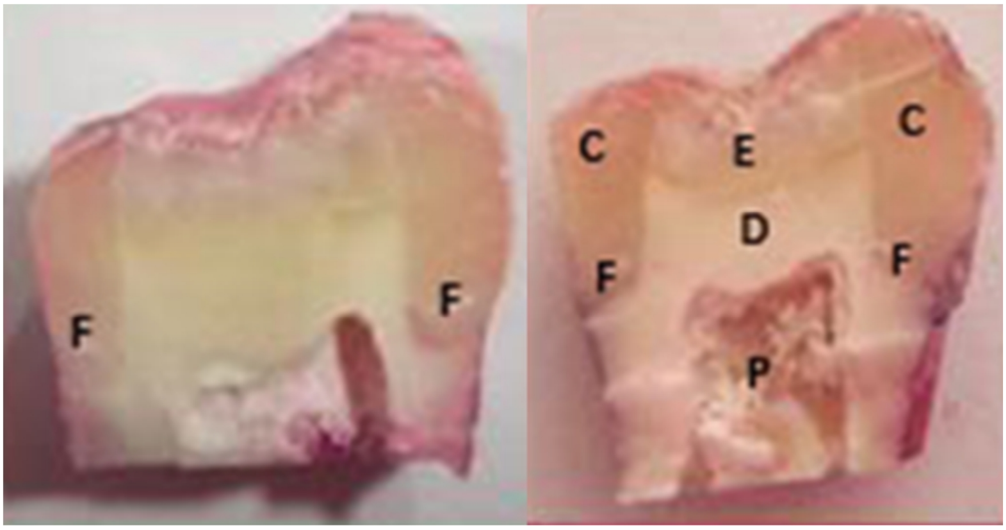

Figure 1: Representative sectioned specimen (F: Fiber, C: Composite, D: Dentin, E: Enamel, P: Pulp)

floor up to two-third of the axial walls

5. Dye penetration extending through the gingival floor up to full length of the axial wall

The median of the scores was subjected to statistical analysis using the nonparametric Kruskal-Wallis analysis of variance test and the Mann-Whitney tests (p<0.05). Statistical analysis was done using the SPSS 17.0 program.

Results

The results of Karuskal-Wallis revealed a highly significant difference (p<0.001) between Silorane-based and Nanohybrid composite with less microleakage for Silorane-base (Table 1, Figure 3). Mann-Whitney test showed there were no significant difference between 2 types of fiber in fiber containing groups, which were groups 2 & 3 (p=0.637) and groups 5& 6 (p= 0.906). Also Mann-Whitney test showed no significant differences between with or without fiber insert groups. There were no significant differences between groups 1 & 2 (p=0.901) and groups 1&3 (p=0.716). The same test showed, no significant difference between groups 4 & 5 (p=0.814) and 4 & 6 (0.880).

Discussion

Gingival microleakage is one the problems that occurs in composite restoration [8]; this happens due to the polymerization shrinkage, fatigue-cycling, and thermal changes in oral cavity [18]. Previous research has shown that microleakage occurred at the gingival margin more than the occlusal margins [17,19]. For this reason, this study aimed to evaluate the microlea-

Figure 2: Representative specimen, (left) showing a slot cavity restored with a glass fiber insert and score 0, and (right) showing slot cavity restored with a polyethylene fiber insert and score 1. (F: Fiber)

Table 1: Microleakage Scores Distribution among the Test Groups with Mean-Rank and Median

Groups	Scores	Mean rank(Median)
	0 1 2 3 4 5	
1: Z350	2 5 5 6 2 0	82.00(2.00)[A]
2: Z350+Polyethylene fiber	3 4 5 4 4 0	81.40(2.00)[A]
3: Z350 +Glass fiber	3 7 1 7 2 0	77.70(1.50)[A]
4: P90	14 3 1 0 1 1	43.55(0.00)[B]
5: P90+ Polyethylene	14 5 1 0 0 0	38.25(0.00)[B]
6:P90+ Glass fiber	14 4 1 1 0 0	40.10.(0.00)[B]

Different letters show significant differences between groups (using Mann-Whitney).The significant level was adjusted regarding the number of comparisons (α = 0.0033).

kage at the gingival margins.

There are different methods that assess the microleakage, such as using scanning electron microscopy, electro-chemical studies, radioactive isotopes, the air pressure method, and dye penetration method [20-22]. Some studies have reported no difference between these methods in evaluation of microleakage [23,24]. Dye penetration was employed in the current study since this method does not need any sophisticated equipment and does not have any adverse effects on specimens [2]. Basic fuchsine dye was used in the current study because it can be simply applied and is a useful quantitative method [25]. Also, basic fuchsine dye has a good contrast with the tooth structure; hence, it make it easy to determine the scores of microleakage at the stereomicroscope. For thermocycling, the temperature range of 5`C-55`C with a dwell time of 30 seconds for 500 cycle was used. This thermocycling temperature is clinically similar to the situation that may happen on the surfaces of the molar teeth in the oral cavity [2].

The results of our study revealed that using silorane-based composite had a great effect on decreasing the microleakage in the gingival margin compared to nanohybrid composite. Differences between two composites may be due to the difference in filler loading, filler size or volumetric polymerization shrinkage. P90 is a Silorane-based composite and has cationic ring opening. Polymerization in this composite has slow rates due to reactive particle. This particle does not allow the polymerization as quickly as the free radicals in methacrylate-based resins, and causes stress relaxations during polymerization, so it decreases the polymerization shrinkage. Volumetric shrinkage in P90 is less than 1% but in a Nanocomposite, Z350, it is about 1.7%. Also, it has been reported that Silorane composite can withstand fatigue at composite/dentin interface better than microfilled and nanofilled composites. In addition, filler loads of P90 and

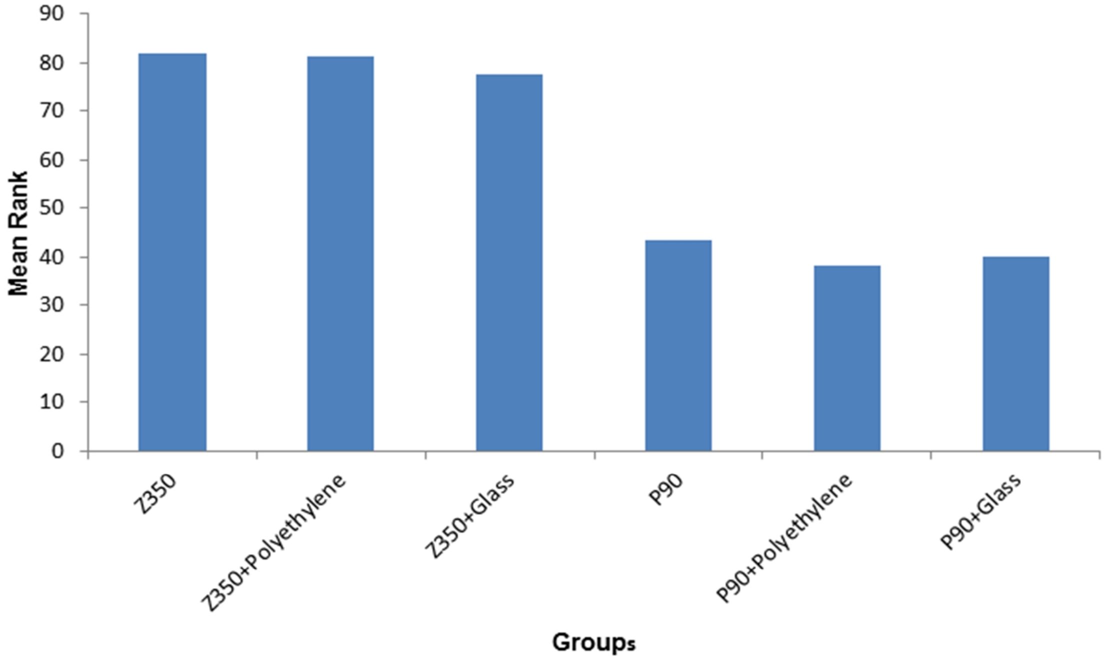

Figure 3: Mean Rank of Microleakage

Z350 are 76% and 78.6%, respectively. The filler load has a positive effect on reducing polymerization shrinkage due to reduction of matrix resin, but unfortunately it affects polymerization shrinkage strain negatively which can explain the higher microleakage observed with Z350 [10]. Previous studies confirmed the results of the present study [2,4,9,26,27].

Also, another reason for less leakage in P90 than Z350 may be the different adhesive systems used. We used two-step self-etch system for P90 and etch-rinse system for Z350. Studies have shown two-step self-etch produces less microleakage [17,28]. Bonding to dental tissue in self-etch is both micromechanical and chemical but in the etch and rinse adhesives the bonding is just micromechanical due to the elimination of the smear layer after rinsing [29].

However, this finding is inconsistent with the result of the study performed by Ernst *et al*. [30] who demonstrated that microleakage of Silorane is similar to methacrylate composites. They used one-step self-etch (Hermes bond) while we used the new bonding agent produced with silorane, i.e. two-step self-etch. These results may be attributed to the difference in generation of bonding agent of silorane composite and the new bonding agent may improve the properties of silorane. The study conducted by Hosaka *et al*. [31] revealed that one-step self-etch system had poor performance.

The effect of fiber insertion on reinforcement composite depends on some factors, such as the resin used, adhesion of fiber in the resin matrix, length of the fiber, form of the fiber, and impregnation of the fiber with the resin [3]. In our study, the results of glass and polyethylene fiber inserts showed no significant effect on the microleakage at the gingival margins; this is similar to the results of pervious investigations [5,9,32,33].

However, our results are different from the study that showed glass and polyethylene fiber insertion significantly reduced microleakage in composite restorations [34]. This difference can be due to the application of flowable composite on the gingival floor, the fibers placed on flowable composite, and then cavities restored with nanofilled composite. Application of flowable composite may cause better adaptation of the fiber to the cavity. Also, another study showed that application of flowable composite could improve the flexibility of the bonded assembly and during polymerization shrinkage of the resin composite it had a role like shock absorber and reduced the stress [35].

Moreover, the outcomes of some studies about fiber insert are contrary to the result of the present study [1,2,17]. It may be due to the type of the composite. Some researchers assessed the P60 but in this study P90 was tested. P90 is a low shrinkage composite and insertion of fiber may not have a significant effect on reducing the microleakage in this composite.

The volume of the fiber used in those studies was more than that used in our study. 1x2mm fiber did not reduce enough volume of the composite. It is possible to state that a little volume of the fiber does not have any significant effect on the microleakage.

Furthermore, this difference may be due to the different procedures of application of fiber. Some of the procedures used silanized and plasma treated system and some others used prime and bond NT for impregnation of fibers before applying and some cured the fiber after the impregnation and then placed it on the gingival floor. This procedure may have enhanced the bonding with resin, but in the present study we just impregnated the fibers in Resist (unfilled resin-HEMA free) without curing. Although we found that the types of composite had a greater role in decreasing the mikcroleakage than the fiber insertion, further studies are required to assess the characteristics of the fibers, such as fiber size and the technique of impregnation.

Conclusions

Based on the results of this study, silorane-based composite significantly reduces microleakage compared to the mathacrylate-based (nanohybrid) composite in class II restorations with gingival margins below the CEJ. The use of glass and polyethylene fiber inserts had no significant effect on the microleakage in classII resin composite restorations with gingival margins on the root surface.

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