

Comparing Microleakage and the Layering Methods of Silorane-based Resin Composite in Wide Class II MOD Cavities

YH Bagis • IH Baltacioglu • S Kahyaogullari

Clinical Relevance

This *in vitro* study showed that the Silorane-based microhybrid resin composite system had no microleakage for wide Class II MOD restorations with oblique and vertical layering techniques.

SUMMARY

Objective: This *in vitro* study compared the effects of different layering techniques and different monomer-based composites on microleakage.

Method and Materials: Thirty-two freshly extracted caries-free human third molars were used. A wide mesio-occlusal-distal (MOD) cavity was prepared in each third molar, with the occlusal dimension being approximately two-thirds of the intercuspal dimension, and the cervical limit of one proximal box was stopped 1 mm below and the other 1 mm above the cementoenamel junction. The cavities were filled with a

methacrylate-based nanohybrid composite (Grandio, VoCo) and a silorane-based microhybrid composite (Filtek Silorane, 3M ESPE). All samples were subjected to 1000 thermal cycles of 5°C/55°C in water with a 30-second dwell time and, after the procedure, the teeth were immersed in a 0.5% basic fuchsin dye at 23°C for 24 hours. Sectioned samples were examined under a stereomicroscope (Leica MZ12, Leica Microsystems), and microleakage scores were statistically analyzed using the Kruskal-Wallis and the Mann-Whitney *U* tests.

Results: No microleakage was observed for silorane-based resin composite restorations. The nanohybrid-based resin composite restorations showed different levels of leakage. Statistical analysis of microleakage scores showed differences only at the enamel margins for nanohybrid material for both layering techniques ($p < 0.05$). The nanohybrid-based resin composite restorations showed better results with the vertical layering technique for enamel margins.

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INTRODUCTION

Many commercially available dental composites are based on methacrylate chemistry. Because of the free-radical polymerization of methacrylate-based composites, monomer molecules come closer to each other during the polymerization process, which results in volumetric shrinkage.¹ This volumetric shrinkage ranges from 2% to 5%²⁻⁵ and it develops stresses around the tooth–restoration interface.⁶⁻⁷ Polymerization contraction stress produces powerful forces that can separate the restoration from the tooth. Lack of sealing allows the occurrence of marginal microleakage. Microleakage is defined as the passage of bacteria, fluids or molecules between a cavity wall and the restorative material applied to it.⁸ Microleakage may cause hypersensitivity, recurrent caries and pulpal pathoses.⁹

Dentin margins have less mineral content than enamel, contain more moisture and show more leakage.¹⁰ In Class II MOD cavities, microleakage is common at the gingival margin of the proximal box.¹¹⁻¹³

In order to minimize microleakage, different incremental insertion techniques have been suggested as a way to improve composite curing in-depth and minimize the effect of confinement on contraction stress development.¹⁴⁻¹⁹ Instead of using a bulk technique, layering techniques may have some advantages, that is, the use of a small volume of material, a lower cavity configuration factor and minimal contact with the opposing cavity walls during polymerization.²⁰

By using nanotechnology, manufacturers can produce highly filled dental composites. Highly filled nanohybrid composites show less free linear shrinkage values than microhybrid composites, because of their lower monomer and higher filler content.²¹

One of the other strategies for controlling polymerization contraction stress is using a novel monomer system that has decreased polymerization shrinkage and an associated reduction in shrinkage stress.²² Silorane-containing resin monomers have been developed by 3M ESPE (St Paul, MN, USA) for the production of new dental composite materials. The term “silorane” is derived from the combination of siloxanes and oxiranes.²³⁻²⁴ These resins have better biocompatibility,²⁵⁻²⁶ marginal adaptation and less microleakage than methacrylate-based systems.²⁷⁻²⁸

The aim of the current study was to compare the effects of different layering techniques and different monomer systems on the microleakage of wide Class II MOD composite restorations. The null hypothesis tested was that vertical and oblique layering techniques and monomer systems would have no effect on microleakage for deep and wide composite restorations.

METHODS AND MATERIALS

Thirty-two extracted human third molars, free of cracks, caries and restorations, were stored in normal saline solution and used within two weeks after extraction. After removing residual tissue tags, the specimens were cleaned with pumice. A large mesial-occlusal-distal (MOD) cavity was prepared in each third molar, with the occlusal dimension being approximately two-thirds of the intercuspal dimension. Occlusal depth of the cavities was approximately 2 mm. In each specimen, the cervical limit of one proximal box was 1 mm below, while the other was 1 mm above the cemento-enamel junction. Each cavity was prepared with a new cylindrical diamond burr (KG Sorensen, São Paulo, Brazil) using a high-speed hand-piece with water-cooling. Digital calipers (Mitutoyo 500, Mitutoyo Corporation, Kanagawa, Japan) were used to measure the occlusal depth and width of cavities to ensure uniformity among preparations. Gingival margins were left as a butt joint.

Restorative Procedures

After the preparations were completed, the teeth were randomly assigned to four groups of eight teeth each. Prior to the experimental procedures, a restoration template was prepared. The acrylic teeth were embedded in self-cure acrylic resin individually implanted in heavy silicone material, alongside other teeth, and a screw was used to position the teeth into contact with each other (Figure 1).

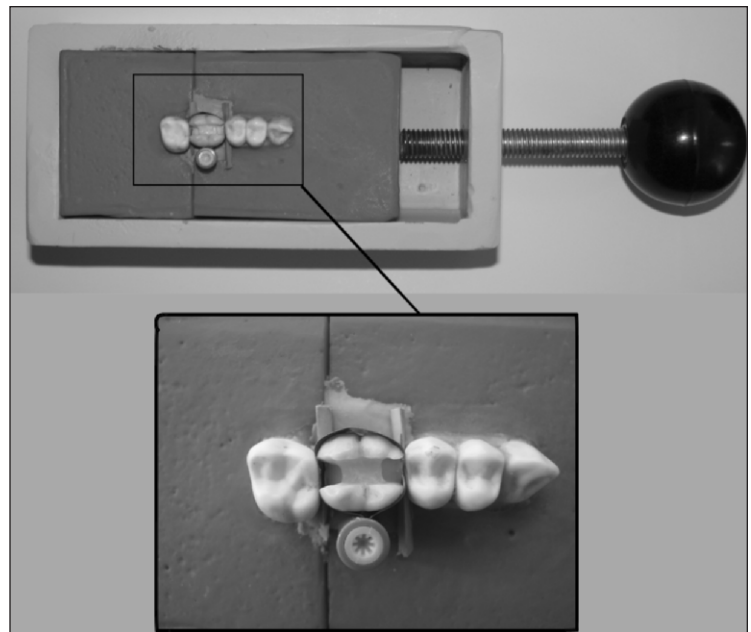


Figure 1. Restoration template.

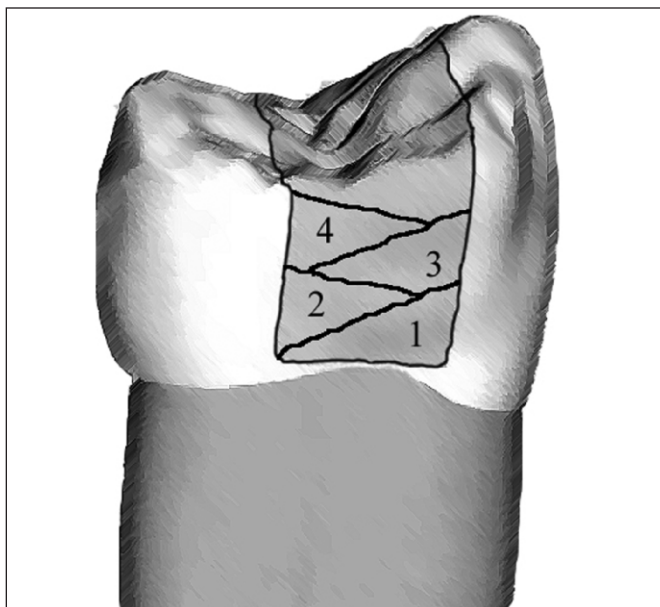


Figure 2. The oblique incremental technique.

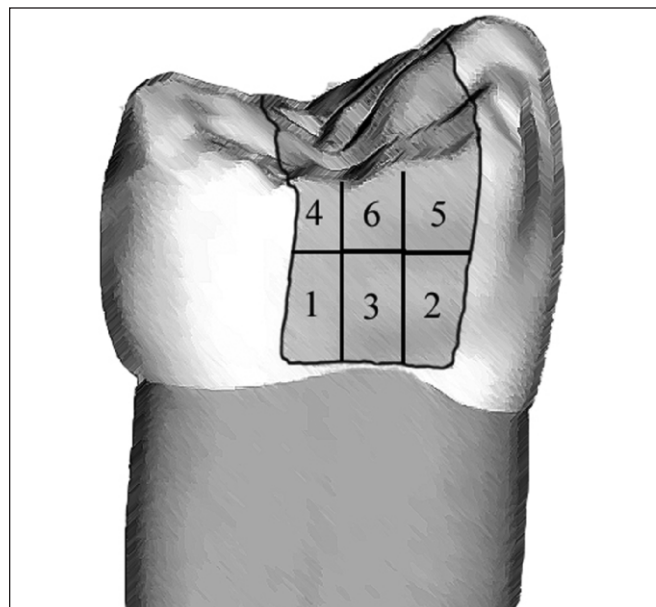


Figure 3. The vertical incremental technique.

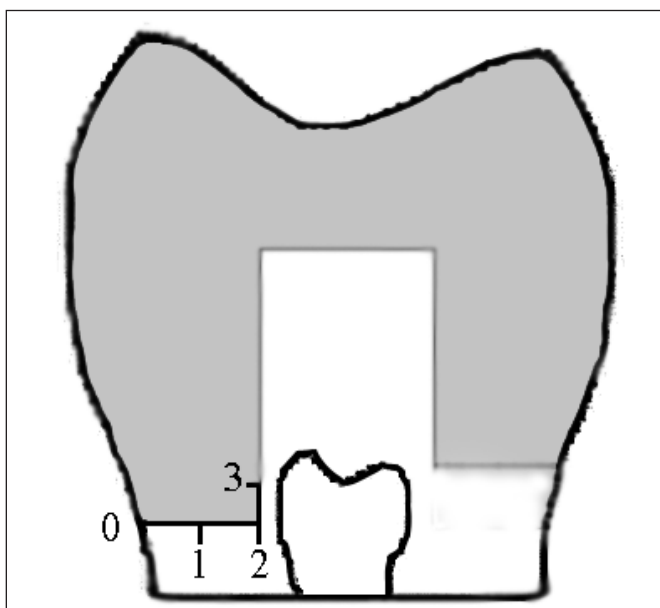


Figure 4. Diagram of microleakage evaluation criteria.

Group 1. Oblique Incremental Technique with Nanohybrid Composite

This group consisted of eight specimens obturated with a universal light-curing nanohybrid restorative material and its relevant adhesive (Grandio, shade A2, Solobond M, VoCo, Cuxhaven, Germany).

Metal matrix bands (Adapt SuperCap Matrix no 2182, Kerr-Hawe, Bioggio, Switzerland) and wooden wedges were seated. The enamel was etched for 30 seconds and the dentin for 15 seconds with 35% orthophosphoric acid (Vococid, VoCo), rinsed for five

seconds, then gently air dried, leaving the surface moist, according to manufacturer's directions. This procedure was followed by the application of bonding agent and, after waiting for 20 seconds, excess solvent was evaporated with a gentle air blast for 10 seconds. The bonding agent was cured for 20 seconds with a Hilux Ultra curing unit (Benlioglu Dental, Inc, Ankara, Turkey). Output power was periodically monitored with the radiometer of the curing unit to ensure an intensity at least 800 mW/cm². Two oblique layers of 2 mm resin composite were carefully placed (Figure 2) on both gingival (mesial and distal) floors, avoiding contact with the opposite wall. Each incremental layer was cured for 20 seconds. Second incremental layers were placed carefully on the opposite wall of the cavity and cured for 20 seconds. The remaining cavity was restored in the same way as described above.

Group 2. Vertical Incremental Technique with Nanohybrid Composite

Following the same procedures applied in Group 1, a vertical incremental technique (Figure 3) was used for this group. The resin composite material was inserted into the cavity using a vertical incremental technique. First, layers were placed vertically to one side of the approximal walls using a hand instrument to easily create and adapt vertical increments (OptraSculpt, Ivoclar Vivadent, Schaan, Liechtenstein) and were then cured for 20 seconds. Next, the second layers were vertically placed on opposite walls, and finally, resin composite was inserted onto gingival floors and cured.

Group 3. Oblique Incremental Technique with Silorane Composite

This group consisted of eight specimens obturated with a posterior silorane restorative material and its relevant adhesive (Filtek Silorane, shade A2, Silorane System Adhesive, 3M ESPE).

Silorane System Adhesive Self-Etch Primer was applied to the enamel and dentin surfaces. After waiting 20 seconds, excess solvent was evaporated with a gentle blast of air for 10 seconds, and the primer was light cured for 10 seconds. Bond was applied to all surfaces and light cured for 10 seconds. The oblique restorative technique used for Group 1 was used; however, the curing time was raised to 40 seconds according to the manufacturer's instructions.

Group 4. Vertical Incremental Technique with Silorane Composite

Following the same procedures as applied in Group 3, the vertical incremental technique that was used for Group 2 was used for Group 4.

Experimental Procedures

After storing for 24 hours in 37°C distilled water, all the specimens were subjected to 1000 thermal cycles of 5°C/55°C in water with a 30-second dwell time. After thermocycling, apices of the teeth were sealed with a layer of sticky wax, and all tooth surfaces were covered with two coats of fingernail polish, with the exception of 1 mm around the tooth-restoration interface. The teeth were then immersed in a 0.5% basic fuchsin dye at 23°C for 24 hours. Following immersion, the teeth were washed thoroughly with distilled water, embed-

ded in clear polyester material and sectioned mid-sagittally in the mesial-distal plane using a Micracut 175 (Metkon Instruments Ltd, Bursa, Turkey). The sectioned samples were examined under a stereomicroscope (Leica MZ 12; Leica Microsystems, Wetzlar, Germany) at 10x magnification to assess the extent of the cervical gingival microleakage. The scoring criteria outlined in Table 1 and Figure 4 were utilized to rank the degree of microleakage. Resultant cervical gingival microleakage scores were statistically analyzed using the Kruskal–Wallis test, followed by paired-group comparisons using the Mann–Whitney *U* test at a 95% significance level.

RESULTS

The microleakage scores for enamel and dentin margins are presented in Table 2 and representative figures are shown in Figures 5 and 6. There was no microleakage found in specimens restored with silorane-based composite, and this was significantly different from specimens restored with methacrylate-based composite ($p < 0.05$). When layering techniques were compared with methacrylate-based composite, there was no significant difference observed at the dentin margin ($p > 0.05$), and there was a significant difference at the enamel margins ($p < 0.05$).

DISCUSSION

The purpose of the microleakage test was to get information about the sealing ability of the restoration-adhesive complex. The results of *in vitro* microleakage studies are close to clinical reality, because human teeth and clinical protocols are used. Failure of the restoration to seal the tooth may contribute to marginal staining, adverse pulpal response, postoperative sensitivity and recurrent caries.¹⁰ Reducing microleakage at the tooth-restoration

Table 1: Microleakage Scoring Criteria

Microleakage Score	Description
0	No evidence of dye penetration
1	Dye penetration into half extension of the cervical wall
2	Dye penetration into complete extension of the cervical wall
3	Dye penetration into the cervical and axial walls toward the pulp

Table 2: Microleakage Score of Wide Class II MOD Restorations

	Enamel (above cemento-enamel junction)				Dentin (under cemento-enamel junction)			
	Score 0	Score 1	Score 2	Score 3	Score 0	Score 1	Score 2	Score 3
Group 1 VoCo Grandio Oblique incremental	2	3	3	–	2	3	3	
Group 2 VoCo Grandio Vertical incremental	3	4	1	–	2		3	3
Group 3 3M Silorane Oblique incremental	8				8			
Group 4 3M Silorane Vertical incremental	8				8			

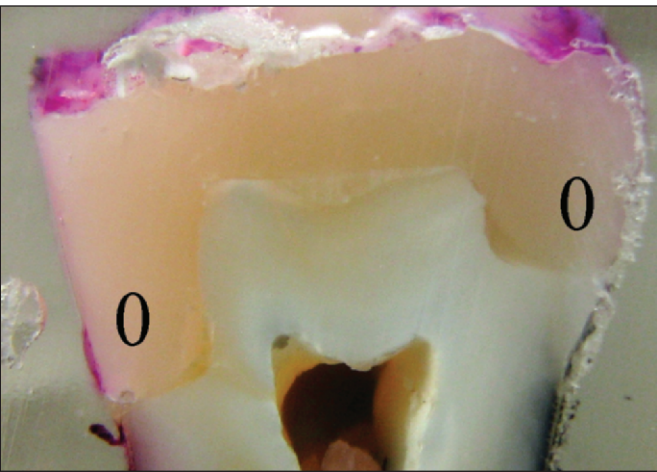


Figure 5. Representation of no dye penetration in Group 4.

interface is important for large Class II MOD restorations.

Different incremental layering techniques,^{11-12,15-17} C-factor analysis,²⁰ low-shrink materials^{18,28} and a combination of different restorative materials¹³ have been used in efforts to prevent this problem.

One approach to minimize the effects of curing shrinkage is the insertion of resin composite in increments, which lowers the configuration factor. The configuration factor (C-factor) is the ratio between the bonded and free surfaces of the cavity. High C-factor values can cause adhesion breakdown between the restorative system and the cavity wall.²⁹ The use of incremental techniques has been extensively studied.³⁰⁻³³ However, there is not a common agreement among authors. In the current study, the authors used oblique and vertical incremental techniques that have lower C-factor values to reduce shrinkage stress in wide MOD cavities.

Reis and others³⁴ found that oblique layering provided the lowest bond strength values in their study, which compared the bond strengths of different layering techniques. Ghavamnasiri and others¹⁵ compared two different incremental techniques on Class II cavities and found no difference with respect to marginal microleakage. Nikolaenko and others³⁵ compared the effects of horizontal, oblique and vertical layering techniques on microtensile bond strength to dentin, and they showed that, only when the first increment was

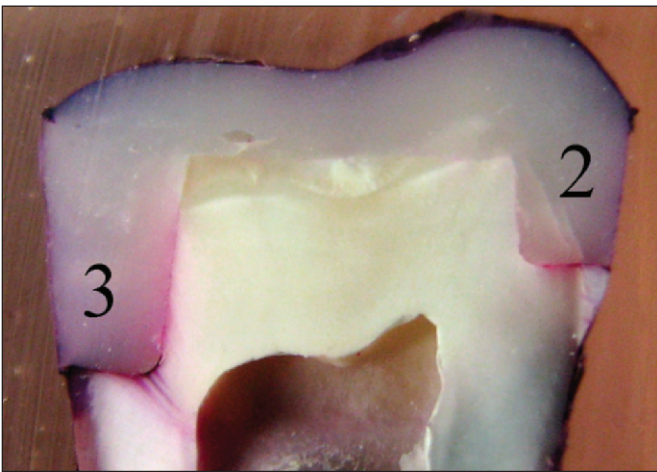


Figure 6. Representation of dye penetration at different levels in group.

bonded horizontally to the cavity floor, were acceptable bond strengths observed. Kuijs and others³⁶ compared the shrinkage stress of different restorative techniques used in a large cusp-replacing composite restoration to see which technique resulted in the lowest polymerization stresses. They found that locations of concentrated high stress resulting from polymerization shrinkage were similar for all the restorative procedures. Jedrychowski and others³⁷ examined the shrinkage stresses generated by resin composites in use in different incremental placement techniques. They found few differences in polymerization shrinkage stresses between incremental placement techniques; whereas, the bulk technique showed the lowest stresses. Versluis and others³⁸ used a permanent model and demonstrated that the highest cusp-deflection occurred with the horizontal placement technique, followed by the faciolingual, oblique and bulk techniques.

Grandio is a highly filled nanohybrid resin composite. Nano structures are used to produce composites with low shrinkage, high wear resistance and biocompatibility.³⁹ The inorganic filler loading is 87% by weight and 71.4% by volume. Its volumetric polymerization shrinkage is 1.57%. Filtek Silorane developed by 3M ESPE has a filler level of 76%, and its volumetric shrinkage is less than 1%.⁴⁰ The Silorane system uses ring-opening polymerization instead of free-radical polymerization of dimethacrylate monomers; therefore, a significantly lower polymerization shrinkage and lower stress development occurs.⁴¹ The marginal

Table 3: Statistical Analysis of Microleakage Scores of Wide Class II MOD Restorations by Using the Kruskal-Wallis Test Followed by the Mann-Whitney U Test						
	Group 1-2	Group 1-3	Group 1-4	Group 2-3	Group 2-4	Group 3-4
Enamel	(p:0.492) p<0.05*	(p:0.00) p<0.05*	(p:0.01) p<0.05*	(p:0.003) p<0.05*	(p:0.003) p<0.05*	(p:1) p>0.05
Dentin	(p:0.911) p>0.05	(p:0.01) p<0.05*	(p:0.00) p<0.05*	(p:0.003) p<0.05*	(p:0.003) p<0.05*	(p:1) p>0.05

integrity and microleakage of silorane-based restorative systems are reported to be superior to methacrylate-based systems.^{27-28,42}

Palin and others²⁸ used experimental silorane and an experimental silorane bonding system in their study. All tested MOD restorations exhibited microleakage in the Palin study; but, the microleakage of experimental silorane-based composite restorations was less than commercial methacrylate-based composite restorations. In the current study, no observable microleakage was found in the cavities restored with Filtek Silorane, independently of the oblique and vertical incremental layering technique. These contrary results may be attributed to a different chemistry between the experimental and commercial silorane systems. The experimental bonding agent was a one-step system, where etching, priming and bonding took place together. The commercial product that the authors of the current study used has a two-step bonding agent and it was special for Filtek Silorane. In the first step, self-etching primer is applied and light-cured for 10 seconds. This self-etch primer contains phosphorylated methacrylates, BisGMA, HEMA and water/ethanol as the solvent. This primer is rather hydrophilic and prepares the wet dentin/collagen surface for hydrophobic bonding resin. Then, bonding resin is applied and light-cured for 10 seconds. This adhesive bond contains hydrophobic bifunctional monomer in order to match the hydrophobic silorane resin. It may be speculated that this two-step procedure could have improved the quality of the tooth restoration interface.

In the current study, the authors used the methacrylate-based composite system with a two-step total-etch adhesive (Solobond M, VoCo) (priming and bonding takes place in the same step). Solobond M is composed of methacrylates, acetone, organic acid derivatives and an organic fluoride component. The application of total-etch adhesives has higher technical sensitivity than self-etch systems.⁴³ Also, polymerization shrinkage stresses of methacrylate-based restorative materials are higher than the silorane-based resin system.⁴⁴ Therefore, the microleakage of methacrylate-based composite might be explained by higher polymerization contraction forces and/or imperfect application of technique-sensitive total-etch adhesive.

In the current study, the two-step self-etch Silorane system adhesive has less technical sensitivity than the total-etch system and might have increased bonding quality and resulted in the absence of microleakage in the MOD cavities restored with silorane; also, no difference was found between the two insertion techniques used in the silorane restorations. The silorane system adhesive is essential for silorane restorative materials and is not recommended for use with methacrylate-based systems; therefore, the absence of microleakage in teeth restored with silorane-based

composite should not be solely attributed to adhesive; restorative systems and their adhesive systems should be considered together.

No observation of leakage in silorane specimens may depend on: 1) the ring opening chemistry of the silorane system, 2) the different nature of the silorane system adhesive and 3) the successful cooperation of silorane composite and its relevant adhesive system.

CONCLUSIONS

Based on the current study, the null hypothesis was rejected. Silorane-based material showed no leakage in enamel and dentin margins. With methacrylate-based composite, microleakage was observed in both cervical margins; therefore, different monomer compositions may affect microleakage of wide Class II MOD restorations. Vertical layering techniques reduced leakage values at the enamel margins for methacrylate-based composite in large Class II MOD cavity restorations. Additional research is required to determine the physical, chemical and biological properties of silorane-based materials. In order to reduce microleakage problems, silorane-based materials might be a better substitute for methacrylate-based composites.

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