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Laboratory Research

Efficacy of Four Lining Materials in Sandwich Technique to Reduce Microleakage in Class II Composite Resin Restorations

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Clinical Relevance

The sandwich technique results in more microleakage than classically bonded composite resin restorations.

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SUMMARY

Objectives: The aim of the present study was to evaluate the effect of four different sandwich techniques on gingival microleakage of Class II direct composite resin restorations.

Materials and Methods: Fifty sound human premolars were selected and randomly divided into five groups (n=10). Class II box only cavities were prepared in one of the proximal surfaces of each tooth with a gingival margin located approximately 0.5 mm below the cemento-enamel junction. Group A (control) was restored incrementally with composite resin (Tetric Ceram). Groups B, C, D, and E were restored with the sandwich technique using a compomer (Compoglass F), flowable composite resin (Tetric Flow), self-cure composite resin (Degufill SC), or resin modified glass ionomer (Fuji II LC), respectively. After thermal-load cycling, the specimens were immersed in 0.5% basic fuschin for 24 hours. Dye penetration (10^{-1} mm) was detected using a sectioning technique. Data were analyzed with repeated measurements and Duncan test at α=0.05.

Results: The least amount of microleakage was detected in the incremental group (1.28 ±

0.98). The sandwich technique using resin modified glass ionomer (7.99 ± 9.57) or compomer (4.36 ± 1.78) resulted in significantly more leakage than did the sandwich technique using flowable (1.50 ± 1.97) or self-cure composite (2.26 ± 1.52).

Conclusion: **According to the results of this study, none of the four sandwich technique composite resin restorations used in this study could reduce gingival microleakage to a greater degree than the incremental technique.**

INTRODUCTION

Although composite resins are the most commonly used tooth-colored restorative materials, they still present several difficulties when used as posterior restorations. These materials undergo contraction during curing, and the resulting shrinkage causes debonding of the restoration from the tooth structure.[1,2] Therefore, marginal adaptation remains a problem for composite, especially at the dentinal gingival floor of Class II restorations.[3] Poor marginal sealing is associated with bacterial, liquid, and molecular penetration through the cavity-material interface, resulting in marginal staining, postoperative sensitivity, secondary caries, pulp pathosis, and, finally, restoration failure.[4]

These related problems have led to the development of open sandwich techniques. Crim and Chapman[6] and Aboushala and others[5] demonstrated that glass ionomer liners reduced marginal microleakage. The benefits of glass ionomers include similar thermal expansion to those of dental structures, bacteriostatic function, molecular bonding to dentin and enamel, and low setting shrinkage.[7]

Sandwich restorations with glass ionomer are less technique sensitive than is composite restoration.[8] However, despite good short-term clinical results, the problems associated with these materials over time comprise a noticeable concern.[9]

The authors of some studies[10,11] have suggested the use of a flowable composite between the floor of the box and the restorative material. These materials may exhibit a stress-reduction property.[11,12] Their lower modulus of elasticity can reduce marginal microleakage, which is thought to compensate for the polymerization contraction stresses of the final restoration.[13-15]

On the other hand, Fusayama[16] and Truffier-Boutry and others[17] have suggested the use of self-cured composites for deeper cavities or dentinal gingival margins because of their slower rate of polymerization, a lower polymerization contraction stress, and consequent lower microleakage.

The use of compomer material that has more mechanical strength and simplified usage than do resin modified glass ionomers (RMGIs) is considered in the sandwich technique.[18] Studies[19-23] pertaining to the microleakage associated with these techniques have given controversial results. The purposes of the present *in vitro* study were as follows:

1. To evaluate gingival microleakage below the cemento-enamel junction (CEJ) in Class II composite resin restorations with four different sandwich techniques using compomer, flowable composite, self-cure composite, or RMGI and to compare them with the microleakage associated with the incremental technique.
2. To determine if there was any difference in microleakage between the lateral and medial areas of the gingival floor.

MATERIALS AND METHODS

Fifty freshly extracted sound human premolars with similar size, stored in 0.2% sodium azide solution, were randomly divided into five groups of 10 samples each. The teeth were vertically embedded 2 mm below the CEJ in a cylindrical auto-polymerizing acrylic resin (Neocryl™, Bosworth Co., Skokie, Illinois, USA). A box cavity was prepared in one of the proximal areas of each tooth. The dimensions of the cavities measured 4 mm buccolingual in width and 2 mm in axial depth at the axiopulpal line angle. The gingival margin was located 0.5 mm below the CEJ with nearly 1.0 mm in depth. All preparations were accomplished with a new high-speed handpiece and #57 fissure burs (Brasseler USA Dental, Savannah, Georgia, USA) that were changed for each 10 cavity preparations. Tofflemire matrix and matrix holder were applied, and teeth in each group were restored as described in Table 1.

Group A (Control)

In this group, after washing and drying the cavity, dentin bonding agent (Syntac Single Component, Ivoclar/Vivadent, Schaan, Liechtenstein) was applied according to manufacturer's instructions (Table 1). The cavity was restored with a light-cured composite resin (Tetric Ceram, Ivoclar/Vivadent) by the gingivocclusal incremental technique. While the first increment was 1 mm thick, the others were placed parallel to the gingival floor up to 2 mm in thickness. Each increment was light-cured from the

Table 1: *Experimental Groups, Material, and the Restorative Procedures*

Group	Bonding System	Lining Material	Restoration Material	Restorative Procedures[a]
A	Syntac Single Component	No lining material (control)	Tetric Ceram	a, b, d
B	Syntac Single Component	Compoglass F	Tetric Ceram	a, b, c, d
C	Syntac Single Component	Tetric Flow	Tetric Ceram	a, b, c, d
D	Syntac Single Component	Degufill SC	Tetric Ceram	a, b, c, d
E	Syntac Single Component	Fuji II LC	Tetric Ceram	c, a, b, d

[a] *Procedure codes: a, etching with 35% phosphoric acid was done 30 seconds for enamel and 15 seconds for dentin, rinsed with water for 20 seconds, then air-dried gently to keep dentin slightly moist; b, bonding system was applied according to manufacturers' recommendations; c, liner material was placed onto the cavity floor and was light-cured per manufacturers' recommendations. Light-curing was not done for group D; d, composite resin was placed up to 2 mm and cured for 40 seconds at 400 mW/cm² incrementally.*

occlusal aspect for 40 seconds with a new QTH light-curing unit with 400 mW/cm^2 (Coltlux 50, Coltene/Whaledent AG, Altstatten, Switzerland). Soon after the removal of the metal matrix, the restorations received further light-curing from the buccal and lingual sides, each for 40 seconds. The accuracy of the light-cure unit was monitored with a radiometer (Radiometer, Coltene/Whaledent AG) after each five restorations.

The bonding step and the process for restoring the whole remaining mass of the cavities in groups B, C, D, and E are the same as described for group A, with the following sandwich material exceptions (Table 1).

Group B

A compomer (Compoglass F, Ivoclar/Vivadent), measuring 1 mm in thickness, was placed and light-cured from the occlusal for 40 seconds.

Group C

A flowable resin composite (Tetric Flow, Ivoclar/Vivadent), also 1 mm in thickness, was placed and light-cured from the occlusal for 40 seconds.

Group D

A self-cure composite resin (Degufill SC, Degussa AG, Hanau, Germany), measuring 1 mm in thickness, was placed and was given four minutes for initial setting.

Group E

RMGI (Fuji II LC Improved, GC Corporation, Tokyo, Japan), measuring 1 mm in thickness, was placed and light-cured for 20 seconds. Bonding system was applied and the rest of the cavity was restored as described for group A (Table 1).

All restorations were finished with diamond finishing burs (Drendel & Zweiling, Diamant GmbH, Kalletal, Germany) and polished with polishing disks (Soft-lex, 3M ESPE, St.Paul, Minnesota, USA). Then thermocycling was conducted between 5°C and 55°C (±2°C) for 1000 cycles. The immersion time for each bath and the interval time were 30 seconds. Then load cycling was done with a load of 14 N, which lasted 0.2 seconds at a frequency of 3 Hz for 250,000 cycles. The teeth were then coated with two coats of nail varnish 1 mm beyond the margins of the restorations and soaked in a solution of 0.5% basic fuchsin dye at 37°C for 24 hours. Roots were cut and the crowns were embedded in slow-cure epoxy resin (Araldit® , Ciba-Geigy AG, Aarberg, Switzerland). Two cuts were made in a mesio-distal direction along the long axes of the teeth with a 1.0-mm–thickness diamond disc cooled with water (Leitz 1600, Leitz Wetzlar GmbH, Wetzlar, Germany). The cuts were 0.5 mm away from the buccal and lingual sides of the gingival floor. Therefore, two cuts per tooth provided three sections with four surfaces for gingival microleakage evaluation (Figure 1).

Dye penetration was evaluated using a stereomicroscope (Zoom, Blue Light Industry USA Inc., La Habra, USA) at 40× magnification. For each surface, the dye penetration, measured in 10^{-1} mm, was recorded at the gingival floor by Asus Digital VCR software (Figure 2). Finally, the data were analyzed by repeated measures and Duncan (α=0.05) tests.

RESULTS

The results for dye penetration are presented in Table 2. All testing groups showed some degree of microleakage (10^{-1} mm) (Figures 3 and 4). Group E (Fuji II LC/Tetric Ceram) showed the highest amount of microleakage (7.99 ± 9.57), and group A (Tetric Ceram) revealed the lowest amount of microleakage (1.28 ± 0.98).

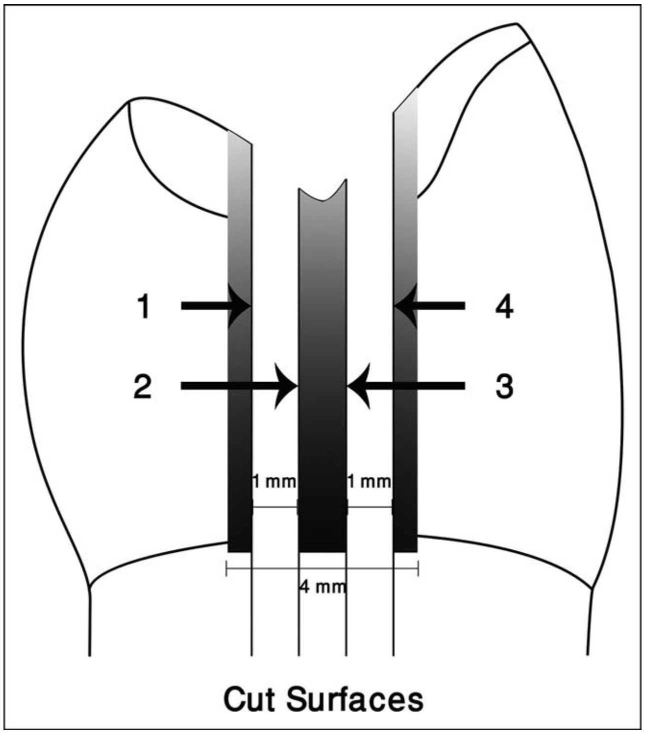

Figure 1. *Schematic illustration of two sectioning cuts made on four cut surfaces (1, 2, 3, and 4).*

There was a statistically significant difference in terms of total microleakage between the groups ($p<0.05$). However, group E (Fuji II LC/Tetric Ceram) showed significantly higher amounts of dye penetration compared to groups A (Tetric Ceram), C (Tetric Flow/Tetric Ceram), and D (Degufill SC/Tetric Ceram).

Repeated measurements were performed to detect the probable pattern of microleakage in the

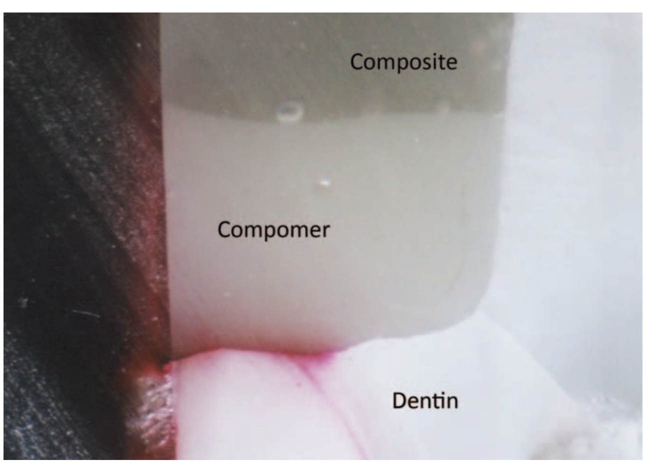

Figure 2. *Die penetration in one sample of group B (Compoglass F) at cut surface 2.*

Table 2: *Mean of Microleakage for Testing Groups*

Group	Lining Material	N	Mean ± SD,[a] 10^{-1} mm
A	No lining material (control)	10	1.28 ± 0.98 A
B	Compoglass F	10	4.36 ± 5.64 A,B
C	Tetric Flow	10	1.50 ± 1.97 A
D	Degufill SC	10	2.26 ± 1.52 A
E	Fuji II LC	10	7.99 ± 9.57 B

Abbreviation: SD, standard deviation.
[a] *Groups with different letters indicate statistical difference at $\alpha=0.05$.*

gingival floor of different cut surfaces in each group. There was no significant difference between the four cut surfaces of the restorations in each group ($p>0.05$).

DISCUSSION

Microleakage has been a major concern in operative dentistry. A variety of techniques have been described to evaluate microleakage and the sealing properties of restorations, such as air pressure, bacterial assessment, radioisotope studies, scanning electron microscopy, chemical identifiers, electrochemical studies, and measurement of dye penetration. Some studies have reported that different methods of microleakage evaluation do not differ in terms of the final results. Because of its long-term presence in the literature,[15,24,25] the dye penetration method, which is a semiquantitative method, was chosen in this study.

Gale and others[26] clearly demonstrated that microleakage is a three-dimensional phenomenon. Raskin and others[27] performed a study on three different sites of gingival wall to test how the number of sections affected the detection of the maximum depth of tracer penetration, and they inspected the influence of the number of sections on the reliability of *in vitro* microleakage evaluations. They found that the correlation coefficient increased as the number of sections increased up to three.[27] In the present study, two cuts per restoration allowed us to measure dye penetration in four locations at the gingival floor in order to find a pattern for gingival microleakage in each group (Figure 1).

It can be assumed that in light-cure dependent lining materials (groups A, B, and C) there would be better polymerization in the middle part of the gingival floor because of the conic pattern of light transmission. Therefore, less microleakage is expected to be observed in this part. On the other hand, in groups D and E, which are self- and dual-cured, no difference is expected among the four

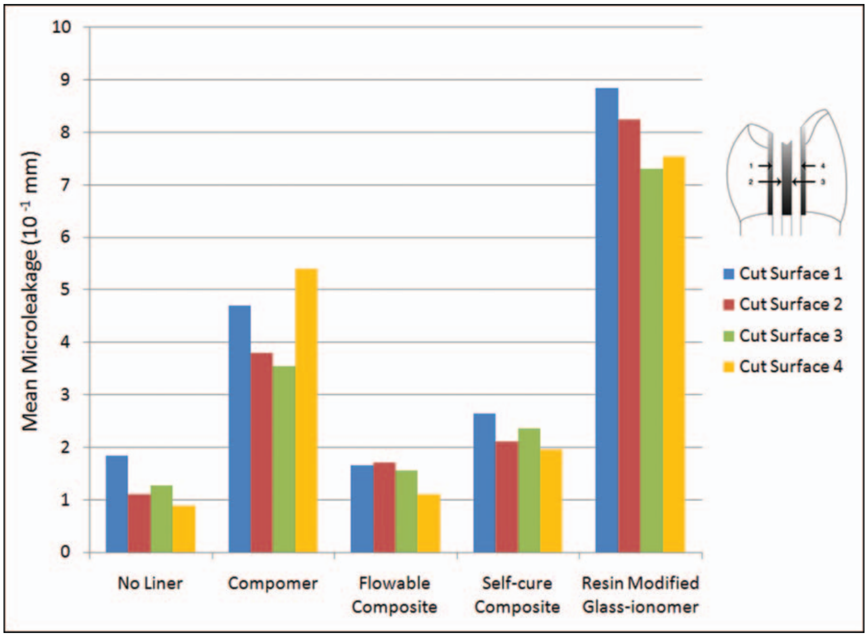

Figure 3. *Mean microleakage of each cut surface in different groups.*

surfaces. We believe that using four cut surfaces in this study in order to find the probable gingival floor microleakage pattern renders the dye penetration evaluation more quantitative in nature. However, this study does not reveal any significant difference in the microleakage values between different cut surfaces in each group ($p>0.05$).

In our study all testing groups showed some degree of microleakage, and there was no significant difference between groups A, B, C, and D. However, groups B and E showed significantly higher amounts of dye penetration or microleakage compared to groups A, C, and D (Table 2).

Some studies[11,12,28] have indicated that the use of flowable composite lining in Class II composite restorations reduced the gingival microleakage. However, other studies[29-31] indicate that it could not reduce microleakage.

The ability of flowable materials to improve marginal seal may be attributed to their composition and

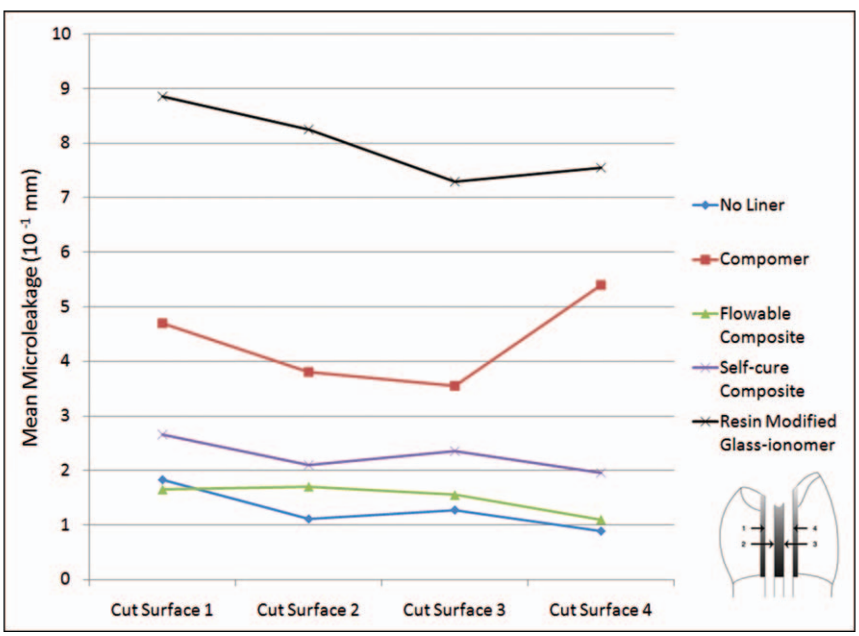

Figure 4. *Mean microleakage of each group in different cut surfaces.*

injectability. Flowable composite materials shrink more than traditional composites because of low filler loading. On the other hand, flowable composites exhibit a lower modulus of elasticity, resulting in more stress-buffering capacity than is offered by hybrid composite resins.[32] The interaction between parameters of polymerization contraction and modulus of elasticity consequently leads to an improved marginal seal of flowable composites. Chuang and others[12] demonstrated that it was advantageous to apply flowable composite in thinner layers.

In this study the microleakage of flowable composite-lined restorations was comparable to that of group A, which may be the result of the mentioned properties.[13,33]

Restorations lined with RMGI cement material presented inferior marginal sealing in group E. This is not in agreement with the findings of Chuang and others,[34] Dietrich and others,[35] and Kasraei and others,[36] who demonstrated that RMGIs improved the marginal seal and adaptation of direct Class II restorations with a sandwich technique. The controversy over sandwich restorations with glass ionomer can be related to the viscosity and application technique. An injection technique combined with a low-modulus material produced a more homogeneous restoration than resulted from use of a high-viscosity material.[37] It was demonstrated[38] that the injection technique, vs probe placement, could significantly reduce gingival microleakage in both opened and closed sandwich techniques with RMGI. The RMGI with higher viscosity and the probe placement technique used in this study could provide an explanation for the poor results noted in group E.

The thermal and load simulation of the clinical situation in the present study could be another reason for the inferior results associated with group E. Indeed, the better results for RMGI in other studies may be due to the fact that they use injection placement and low-viscosity glass ionomer with no simulation of thermal and mechanical loading. Therefore, when samples are load-cycled to simulate the clinical situation, there is no longer an advantage to glass ionomer.

Andersson-Wenckert and others[39] indicated that a noticeable distortion of RMGI occurred after years. Opdam and others[23] reported that posterior composite restorations (PCRs) with RMGI lining showed more frequent failure than did PCRs placed with the total bond technique.

The use of compomer materials for sandwich restorations has been investigated by some researchers,[35,40] and they showed that it can reduce microleakage. This finding is not in agreement with the results of this study, in which relatively higher amounts of microleakage were observed in group B (Figure 3). This finding is confirmed with another study,[41] in which Compoglass F was demonstrated to have the greatest overall microleakage. Our finding may be the result of the lower modulus of elasticity and dentinal bond strength than are associated with flowable composites.[18]

The gingival floor of Class II cavity preparations yields the greatest distance to the light source, which could decrease the degree of polymerization, leading to greater leakage values. Therefore, the use of a material with which curing is not dependent on light may be beneficial in deep cavity areas, which are far from the light source. A layer of chemically cured resin composite for the gingival floor of a proximal cavity has been suggested in order to solve this problem and improve marginal adaptation.[16,22,42,43]

The other rationales for suggesting the usage of a self-cured composite in the proximal box are its potential tendency to shrink toward the center of the mass. The mode of curing also has vectors directed toward the cavity walls. This curing “toward the tooth” is enhanced by the tendency of chemically cured composites to begin polymerizing in the warmest area of the preparation.[43] Therefore, we assume that the vectors toward the tooth could neutralize the vectors toward the mass, to some extent. In addition, the rate of polymerization allows better chances for bond formation. Some degree of stress relief could be attributed to the free surfaces offered by the porosity of chemically cured composites.[44] This can justify the lack of any significant difference between groups A and D.

The adhesive used in the present study was Syntac Single Component, which contains acidic elements, and this may explain the relatively greater-than-expected microleakage. Adverse chemical interaction between acidic resin monomers from the oxygen inhibition layer of polymerized adhesive and the tertiary amine catalyst in the self-cured composite were thought to be responsible for the incompatibility.[45,46] The other reason for incompatibility is the increase in permeability with the polymerized adhesive layer that allows time-dependent water movement through the polymerized adhesive. This can result in water blisters along the adhesive/composite interface, which is adversely affected by such an adhesive.[47-49] We used extracted teeth that had no pulpal pressure or dentinal fluid; therefore, the formation of water blisters was improbable.

The reliability of *in vitro* research depends on the extent of simulation of the oral cavity conditions. The current study used thermocycling associated with mechanical loading to offer more simulation that can accelerate adhesive and/or cohesive failures. It can increase interface gap formation and dye penetration, which means we have greater certainty in applying the results to clinical conditions.[18]

CONCLUSION

According to the results of this study, none of the four sandwich techniques used could reduce gingival microleakage more than the incremental technique.

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Conflict of Interest
The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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