In Vitro Comparison of Microleakage of Posterior Resin Composites With and Without Liner Using Two-Step Etch-and-Rinse and Self-etch Dentin Adhesive Systems

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Clinical Relevance

The use of resin-modified glass ionomers as cavity liners in the closed-sandwich technique reduced microleakage in Class II composite restorations.

SUMMARY

Background and aims: Composite restorations frequently have gingival margins apical to the cemento-enamel junction (CEJ). Microleakage at the cementodentinal margins is one of the most important causes of failure in these restorations. The current study evaluated micro-leakage at the occlusal and gingival margins of Class II packable composite restorations using resin-modified glass ionomer and flowable composite as liners, using the two-step etch-and-rinse and self-etch dentin-bonding systems.

Materials and methods: This in vitro study was carried out on 48 intact human premolars. Class II preparations were made with the gingival margins placed 1.0 mm apical to the CEJ. The teeth were randomly assigned to six groups of 16 boxes and restored using the following techniques: Group 1: Single Bond (3M ESPE) + Filtek P60 (3M ESPE); Group 2: Clearfil SE Bond (Kuraray) + Filtek P60; Group 3: Single Bond + Filtek Flow (3M ESPE) + Filtek P60; Group 4: Clearfil SE Bond + Filtek Flow + Filtek P60. Group 5: Single Bond + Fuji II LC

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(GC) + Filtek P60; Group 6: Clearfil SE Bond + Fuji II LC + Filtek P60. The restorations were thermocycled for 1000 cycles at 5{degree sign}C and 55°C, soaked in 2% methylene blue for 48 hours, then sectioned mesiodistally and viewed under a stereomicroscope for leakage at the gingival margin. The data were statistically analyzed using the Kruskal-Wallis, two-way ANOVA and Mann-Whitney U-tests.

Results: The resin-modified glass-ionomer liner demonstrated significantly less leakage than flowable composite (p<0.05). There was no difference between restorations with flowable resin composite liners and those without the liner; in addition, no significant difference was observed between the two kinds of adhesive systems.

Conclusions: The current study supports the use of resin-modified glass ionomer as a liner in closed-sandwich technique to decrease microleakage of Class II packable composite restorations, applying either the two-step etch-and-rinse or the self-etch dentin adhesive system.

INTRODUCTION

Although resin composites were first introduced in the early 1960s,[1] they were not appropriate for restoring posterior teeth[1] because of their inadequate wear resistance, leakage, polymerization contraction, adhesion to placement instruments, and lack of appropriate proximal contacts.[1-6]

Several manufacturers have introduced packable composites as alternatives to amalgam,[4,7,8] claiming they have better physical properties, particularly in the restoration of posterior teeth.[2,7,9] The average annual wear of these resin composites may be equal to amalgam; nevertheless, marginal leakage still seems to be a problem.[1] Packable resin composites with high viscosity have presented greater problems related to voids and cavity wall adaptation, particularly at the gingival portion of Class II restorations.[4,8-10]

Marginal microleakage of restorations and the transmission of bacteria, liquids, and molecules between the cavity surface and the restorative material results in hypersensitivity, secondary caries, pulp stimulation, and marginal discoloration.[5,8,11,12]

In posterior composite restorations, if the restoration margins finish on enamel, the bond will be efficient and the adhesive mechanisms to etched enamel will provide constant and acceptable solidity.[13] However, if the cavity extends below the cemento-enamel junction (CEJ) with the margins in dentin, microleakage, gap formation, and inappropriate adhesion to dentin remain considerable problems, as mentioned previously.[6] The natural structure of dentin, such as high organic material content, the presence of liquid and odontoblastic branches in dentin, and the formation of the smear layer, are factors preventing acquisition of a strong and rigid bond.[12,14] Therefore, during evaluation of the clinical success of composite restorations, microleakage should be considered a significant parameter.[15]

The use of lower viscosity and lower modulus lining materials, such as glass ionomers, flowable resin liners, or some kinds of dentin-bonding agents, has been proposed to improve the marginal integrity of a composite restoration.[5-6,8,16-18] The benefits of glass ionomers include thermal expansion similar to that of dental structures, bacteriostatic function, molecular bonding to dentin and enamel, and low setting shrinkage.[19] Flowable composites have lower physical properties compared with standard restorative composites and are not recommended for use in stress-bearing areas.[20] However, if they are used as an intermediate layer in restorations, their lower modulus of elasticity can reduce marginal microleakage, which is thought to compensate for the polymerization contraction stresses of the final restoration.[1,4,8] The use of any of these intermediate layers prior to placement of a packable resin composite may effectively reduce microleakage, overcoming a major obstacle to the long-term success of direct posterior composites.

Some studies report that flowable composite liners do not reduce microleakage in Class II cavities,[8,18,21-23] while other studies indicate that flowable composites as liners in Class II cavities could reduce microleakage.[5,6,9] These conflicting results might be attributed to the physical and mechanical characteristics of different flowable composites having different effects on marginal sealing. On one hand, the high fluidity of flowable composites would increase the wetting of resin, resulting in better coverage of surface irregularities. In addition, liners with lower elastic modulus better absorb stresses caused by composite polymerization. As a result, both stress in the tooth-restoration interface and, consequently, microleakage would decrease. On the other hand, flowable composites have low filler content and high percentages of low-molecular-weight monomers, which result in greater polymer-

ization contraction and high levels of stress transfer to the underlying adhesive layer.[4,24]

The type of adhesive system used in the bonding of restorative material is another factor contributing to marginal microleakage.[23] To obtain adequate bonding, the smear layer, which is formed during cavity preparation, must be treated or removed by adhesives.[25] However, the effects of different adhesive systems vary widely both on the smear layer and in bonding quality.[22,26,27] Biologically and technically, bonding mechanisms are different in etch-and-rinse and self-etch systems.[25] In etch-and-rinse systems, the bonding mechanism is micromechanical and is based on the formation of a hybrid layer. In addition to micromechanical adhesion, diffusion and infiltration of resin within etched collagen fibrils are also effective in bonding to dentin.[25,28] In self-etch systems that are easy to use, the bonding mechanism occurs by dissolving the smear layer and through penetration of acidic monomers into dentin to create a hybrid layer.[25]

Although numerous studies have been carried out on the different adhesive systems, on flowable composites, and resin-modified glass ionomers in the closed sandwich technique, few studies have compared the combination of all these factors.

The current study 1) evaluated the potential effects of a flowable composite liner and light-cured resin-modified glass ionomer on microleakage in Class II packable resin composite restorations and 2) compared the effects of two-step etch-and-rinse and self-etch dentin-bonding systems with and without liner on the microleakage of posterior resin composite restorations.

METHODS AND MATERIALS

Forty-eight sound (noncarious and nonrestored) human maxillary premolars extracted for orthodontic reasons were selected for the current study. The teeth were cleaned using scalers to remove calculus and any remaining tissue tags and then polished with a slurry of pumice and water using a low-speed handpiece. The teeth were then stored in distilled water until use.

Two Class II box-only cavities with a buccolingual width of 3.0 mm, an occlusogingival height of approximately 6.0 mm, and an axial depth of 1.5 mm at the cervical floor were prepared on the mesial and distal surfaces of each tooth. The proximal box margins were placed 1.0 mm below the CEJ. All dimensions of the preparation were confirmed with a periodontal probe. The buccal and lingual walls of the preparations were approximately parallel and connected to the gingival wall with rounded line angles. No bevels were used in the cavity preparations (Figure 1).

These preparations were completed using diamond burs (Drendel+Zweiling, 111.534.012, Diamant GmbH, Berlin, Germany) in a high-speed handpiece with water coolant. Once the preparations in each group were completed, a new bur was used. A periodontal probe was used as a guide to place the gingival margin 1.0 mm below the CEJ. Table 1 shows the product profiles and materials in this study. A single operator performed all the cavity preparations and restorations.

The teeth were randomly divided into six groups of 16 boxes. The prepared teeth in each group were restored as follows.

Group 1—The cavity surfaces were etched with 35% phosphoric acid gel for 15 seconds, rinsed for 10 seconds, and blot dried. The Single Bond adhesive system (3M ESPE, St Paul, MN, USA) was applied to the cavity walls according to the manufacturer's instructions and light cured with the Soft Start technique for 10 seconds using an LED (Demi LED Light Curing System, Kerr Corp, Orange, CA, USA) light-curing unit with a light intensity of 800 mW/cm^2 when measured with a radiometer. The curing procedure began with a light intensity of 200 mW/cm^2; it increased 200 mW/cm^2 every two seconds until 800 mW/cm^2 was reached after four steps and remained fixed until completion of the curing. A second layer of Single Bond was applied in the same manner.
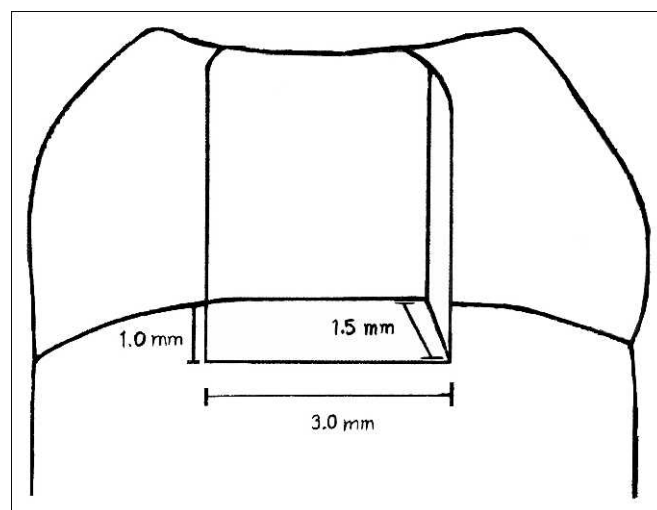

Figure 1. *Schematic view of the tooth preparation.*

Table 1: *Products Used in the Study*

Product	Components	Batch No.	Manufacturer
Filtek P60	Triethylenglycol dimethacrylate, urethane dimethacrylate, silica, zirconium bisphenylethylmethacrylate 84.5%, 0.6 mm)	9 AJ	3M ESPE Dental Products
Fuji II LC	Flouroaminosilicate glass, polyacrylic acid, HEMA	090823GC	GC
Flow 3M	Triethylenglycol dimethacrylate, TEGDMA, bisphenyl ethylmethacrylate	44-007-4337-5-A	3M ESPE Dental Products
Single Bond	Etching gel: phosphoric acid (35%), colloidal silica thickener, color, water	19991123	3M ESPE Dental Products
	Adhesive: polyalkenoic acid, hydroxyethylmethacrylate, bisphenol A diglycidyl ether dimethacrylate, dimethacrylate copolymer, ethanol, water		
Clearfil SE Bond	Primer: hydroxyethylmethacrylate, methacryloyloxydecyl dihydrogenphosphate, hydrophilic dimethacrylate, DL-camphorquinone, N, N-diethanol-p-toluidine, water	00101A	3M ESPE Kuraray, Umeda
	Adhesive: hydroxyethylmethacrylate, bisphenyl glycidylmethacrylate, methacryloyloxydecyl dihydrogen phosphate, hydrophilic dimethacrylate, DL-camphorquinone, N, N-diethanol-p-toluidine, silinated colloidal silica (10%, microthin)		

Group 2—Clearfil SE Bond (Kuraray Co Ltd, Tokyo, Japan) was used. First, the self-etching primer was applied for 20 seconds and dried with a mild flow of air, then bonding agent was applied and dried with a mild air flow and cured for 10 seconds, as described in group 1.

Group 3—The bonding steps were the same as in group 1. Prior to restoration with the resin composite, a 0.6- to 0.8-mm-thick flowable composite (Filtek Flow, 3M ESPE) was applied using the closed sandwich technique in an axiogingival line angle onto the gingival floor (0.7 mm to 0.9 mm away from the cavosurface margin, measuring with a periodontal probe); its thickness was tapered to zero on the axial wall midway from the axiogingival line angle to the dentoenamel junction (Figure 2), then it was light-cured as described above.

Group 4—The bonding procedure was the same as in group 2. The lining steps were performed in the same way as described in group 3.

Group 5—The bonding steps were the same as in group 1. The cavity lining was performed with a resin-modified glass ionomer (Fuji II LC, GC Corporation, Tokyo, Japan) in the same way as in group 3.

Group 6—The bonding procedure was the same as group 2. The cavity lining was performed with a resin-modified glass ionomer (Fuji II LC, GC Corporation) in the same way as in group 3.
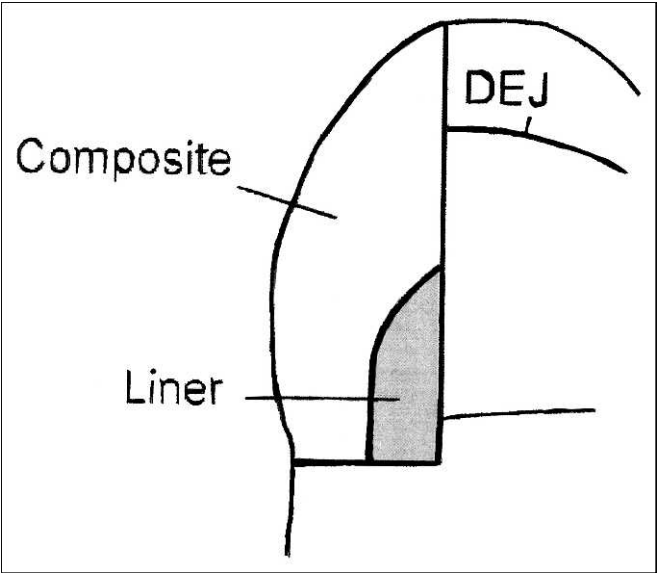

Figure 2. *Schematic view of liner placement for the closed sandwich technique.*

Following this step, a Tofflemire matrix retainer and soft metal band were placed on the tooth. The matrix was tightened and held by finger pressure against the gingival margin of the cavity, so that the restorations would not be overfilled at the gingival margin. Resin composite was placed in four layers using an incremental technique. To help adaptation, the first 1-mm layer was placed horizontally and adapted by a condensing instrument to the proximal box and cured for 40 seconds. The remaining three layers were applied obliquely in approximately 2-mm thicknesses and cured separately for 40 seconds.

The matrix was removed after both restorations were completed. A series of Sof-Lex extra thin discs (Sof-Lex, 3M ESPE) were used to finish the margins, which would be clinically accessible. The gingival margins were not finished with discs. Following restoration, the teeth from all the groups were stored in deionized water in a sealed container at 37°C for one day (24 hours).

The teeth were then thermocycled at 5°C-55°C for 1000 cycles with a dwell time of 30 seconds. Two coats of fingernail varnish were then applied to all parts of the specimen, extending 1 mm beyond the margins of the restoration, and the apex was sealed with utility wax. The teeth were then immersed in 2% methylene blue at 37°C for 48 hours. Upon removal from the dye, the teeth were rinsed thoroughly, cleaned with a bristle brush to remove surface dye, and returned to deionized water prior to sectioning.

In the vertical plane, each tooth was sectioned mesiodistally across the center of the restorations using a double-face diamond disk in a cutting machine (Meccatom, T201A, Presi Co, France).

The sectioned teeth were observed under a stereomicroscope at 40× (PZO, Warsaw, Poland) attached to a computer and scored for the degree of dye penetration.

The operator assessing the specimens had no information as to which group the teeth belonged. The scoring scales for marginal adaptation are shown in Figure 3:

0 = no leakage
1 = leakage extending to half of the cervical wall (slight)
2 = leakage to the full extent of the cervical wall but not including the axial wall (moderate)
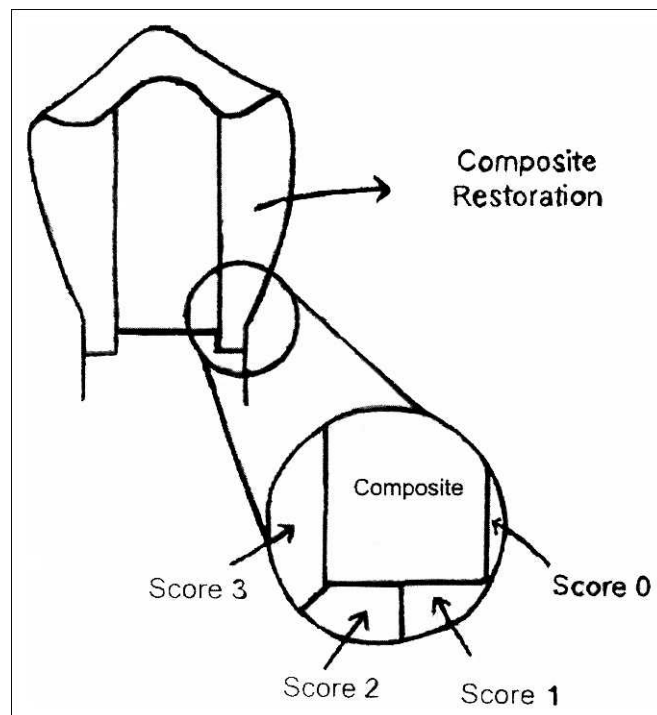3 = leakage to the full extent of the cervical wall, including the axial wall (severe)

Figure 3. *Schematic view of the scoring scale for microleakage.*

Scoring was repeated 24 hours later by the same examiner, again without any knowledge of the previous scores. The scores were then tabulated, and the final data were compiled from each scoring of the specimens using the worst score for each interface.

Statistical Analysis

The groups were compared for differences in microleakage ratings. Because the data were on an ordinal scale, the Kruskal-Wallis test was used to assess differences within the groups. If there was evidence of a difference from the global Kruskal-Wallis test, the Mann-Whitney U-test was used to investigate the pairwise differences among the different groups of filling materials. Two-way analysis of variance (ANOVA) was used to evaluate the combined effect of liner and adhesive system.

RESULTS

Table 2 shows the number of teeth in each microleakage rating category. In Class II P60 composite restorations, resin-modified glass-ionomer liner had a significantly lower leakage rating than flowable composite liner ($p<0.01$) and teeth with no liner.

Table 2: *Microleakage Scores Obtained From Gingival Margins*					
Microleakage Groups		**No Leakage, (%) Number**	**Score (1), (%) Number**	**Score (2), (%) Number**	**Score (3), (%) Number**
Adhesive System	**Liner Groups**				
Single Bond	No liner (1)	(5.37) 6	(8.18) 3	(5.12) 2	(3.31) 5
	Flowable liner (3)	(5.37) 6	(5.12) 2	(8.18) 3	(3.31) 5
	GI LC liner (5)	(5.62) 10	(8.18) 3	(8.18) 3	(0) 0
SE Bond	No liner (2)	(5.37) 6	(25) 4	(3.6) 1	(3.31) 5
	Flowable liner (4)	(5.37) 6	(1.18) 2	(25) 4	(8.18) 3
	GI LC liner (6)	(5.68) 11	(25) 4	(3.6) 1	(0) 0
GI: Glass-ionomer, LC: Light-cure					

The Kruskal-Wallis test showed significant differences among leakage scores of the restorative materials used (p=0.04).

Table 3 shows the Mann-Whitney U-test results reflecting significant differences in pairwise comparisons in the groups (p<0.05).

Two-way ANOVA showed that the effect of liner was significant (p=0.002), the effect of the adhesive system was not significant (p=0.527), and the effect of the adhesive system and liner together was not significant (p=0.96).

DISCUSSION

The evaluation of microleakage is performed by different methods, such as air pressure, bacterial assessment, radioisotope studies, scanning electron microscopy, chemical identifiers, electrochemical studies, and measurement of dye penetration.[4,12,29] In the current study, the authors used the dye penetration technique, which is a semiquantitative method. Some studies have reported that different methods of microleakage evaluation do not differ in the final results.[8] Packable composites are rigid materials; thus, the adhesive layer sustains a high level of stress in the tooth-restoration interface. As a result, if bonding does not have sufficient solidity and strength, debonding would occur, resulting in microleakage.[21,28] In addition, it is suggested that an elastic layer under restorations could act as a stress-absorbing layer and can play a key role in decreasing microleakage.[9,21] The adhesives in the current study included an etch-and-rinse one-bottle system and a mild self-etch primer system; both are different in the hybrid layer formation and bonding mechanism. The demineralization of dentin and enamel in mild self-etch adhesives occurs using acidic primers, so that some hydroxyapatite crystals exposed to acidic monomers remain around collagen fibrils in dentin. It is suggested that these remaining crystals have a chemical reaction with functional monomers and can

Table 3: *Comparison of Microleakage Between the Groups*		
Groups	**Groups**	***p* Value[a]**
Single Bond and RMGI liner	SE Bond and flowable liner	0.029
Single Bond and RMGI liner	SE Bond and no liner	0.027
SE Bond and RMGI liner	Single Bond and flowable liner	0.018
SE Bond and RMGI liner	SE Bond and flowable liner	0.026
SE Bond and RMGI liner	Single Bond and no liner	0.02
SE Bond and RMGI liner	SE Bond and no liner	0.03
RMGI: Resin-modified glass-ionomer [a] Mann-Whitney U–tests.		

prevent marginal microleakage.[25,28] Some researchers have shown differences in the sealing ability of restoration margins between these adhesives.[30,31] The results of the current study are consistent with studies carried out by Mitsui and others[30] and Pradelle and others[31]; both researchers stated that etch-and-rinse and self-etch systems do not differ in dentin margin microleakage. Moreover, one of the factors involved in microleakage is bond strength. Different studies have shown that these two types of adhesive systems have nearly similar bond strengths.[21,28]

The authors compared the microleakage of packable composite restorations with light-cured glass ionomer, flowable composite liner, and no liner; they concluded that resin-modified glass-ionomer (RMGI) liner can significantly decrease microleakage ($p<0.05$). The sandwich technique, wherein glass ionomer or other materials are used as liners, is a method used to decrease microleakage.[32] Application of the adhesive on prepared dentin results in the formation of a thin adhesive layer on the dentin surface, which allows little capacity for absorption of composite shrinkage stress.[18] This might further explain microleakage in groups without a liner, because a liner with a low elastic modulus can act as a stress-absorbing layer.[18] On the other hand, regardless of the type of material used as a liner, one of the reasons for reduced microleakage is a decrease in the total volume of resin composite as a result of less dimensional changes that occur during polymerization.[33] Considering the major drawbacks of the open-sandwich technique, including high solubility of RMGI exposed to the oral environment, the higher wear rate, and lower physical properties compared with resin composite and more interfaces created in this technique, the authors used the closed-sandwich technique, which has greater clinical success.[32,34] With pairwise comparisons of the study groups, it was observed that only light-cured glass-ionomer liner under the composite restoration had the ability to decrease microleakage in the dentin margins of restorations ($p<0.05$).

A clinically important point to note in the current study is that groups restored with RMGI liner + Filtek P60 (3M ESPE) composite did not show microleakage with a score of 3. Studies conducted by Aboushala and others[35] and Swift and others[12] concur with the current study, demonstrating that RMGI used as a liner under composite restorations has a high capacity for decreasing microleakage. The effect of glass ionomer in reducing microleakage has been well documented.[32,34] Since the setting reaction of RMGI is slow, it can have some flow, resulting in reduced stress transfer to the bond and less microleakage.[36] In addition, RMGI establishes chemical bonds to tooth structure; water penetration into these bonds is less than bonds that are established between resin composite and tooth structure.[19,32]

In the current study, the glass-ionomer liner had many zero scores compared with the other techniques. According to a study by Arora and others,[37] the bond between glass ionomer and resin composite is very weak; therefore, the interface between glass ionomer and resin can almost be considered an unbounded wall, resulting in less polymerization shrinkage stress being transferred to the bond between composite and dentin in the gingival floor. This may better explain the number of zero scores in restorations with RMGI liner.

In 2007, Stockton reported using Clearfil-SE Bond (3M ESPE) in the closed-sandwich technique with RMGI, resulting in decreased microleakage in restorations with dentin margins. Stockton's research reported that the chemical bonding mechanism of glass ionomer to dentin and the high solidity and bond strength of self-etch adhesives are the reasons for creating the combined effect of liner and adhesives on decreasing microleakage. However, in the current study, the combined effect of liner and dentin adhesive systems on reducing microleakage was not significant ($p>0.05$), which might be attributed to differences in the number of samples and methods of restoring cavities between the two studies.[32]

As mentioned earlier, the current research showed no differences in microleakage between groups with flowable liner and groups without liner ($p>0.05$). It is probable that the polymerization contraction of flowable composite liner results in greater microleakage in these groups, similar to groups without liner. Further studies with different types of flowable composite liners might be helpful in this regard.

CONCLUSIONS

Based on the results of the current study, although none of the techniques used fully prevented microleakage at the restoration-cavity interface, microleakage with a score of 3 was not seen in samples with a glass ionomer liner. RMGI liner was useful in decreasing microleakage compared with flowable composite liner and samples with no liner. There were no significant differences between the two different adhesives used.

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