Scanning Electron Microscope Analysis of Internal Adaptation of Materials Used for Pulp Protection under Composite Resin Restorations

MARIA INEZ LEMOS PELIZ, DDS, MS, PHD*
SILLAS DUARTE JR, DDS, MS, PHD†
WELLINGTON DINELLI, DDS, MS, PHD‡

ABSTRACT

Purpose: The aim of this study was to evaluate the interfacial microgap with different materials used for pulp protection. The null hypothesis tested was that the combination of calcium hydroxide, resin-modified glass ionomer, and dentin adhesive used as pulp protection in composite restorations would not result in a greater axial gap than that obtained with hybridization only.

Materials and Methods: Standardized Class V preparations were performed in buccal and lingual surfaces of 60 caries-free, extracted human third molars. The prepared teeth were randomly assessed in six groups: (1) Single Bond (SB) (3M ESPE, St. Paul, MN, USA); (2) Life (LF) (Kerr Co., Romulus, MI, USA) + SB; (3) LF + Vitrebond (VT) (3M ESPE) + SB; (4) VT + SB; (5) SB + VT; (6) SB + VT + SB. They were restored with microhybrid composite resin Filtek Z250 (3M ESPE), according to the manufacturer's instructions. However, to groups 5 and 6, the dentin bonding adhesive was applied prior to the resin-modified glass ionomer. The specimens were then thermocycled, cross-sectioned through the center of the restoration, fixed, and processed for scanning electron microscopy. The specimens were mounted on stubs and sputter coated. The internal adaptation of the materials to the axial wall was analyzed under SEM with ×1,000 magnification.

Results: The data obtained were analyzed with nonparametric tests (Kruskal-Wallis, $p \leq .05$). The null hypothesis was rejected. Calcium hydroxide and resin-modified glass ionomer applied alone or in conjunction with each other ($p < .001$) resulted in statistically wider microgaps than occurred when the dentin was only hybridized prior to the restoration.

CLINICAL SIGNIFICANCE

Dentin hybridization provides superior sealing of the dentin-restoration interface than does calcium hydroxide or resin-modified glass ionomer.

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The placement of bases and liners under restorations was a routine procedure in restorative dentistry for many years.[1,2] With the evolution of dentin adhesive materials and the inclination for esthetic restorations, other treatment alternatives became available.[1,3–6] However, polymerization shrinkage of adhesive materials and the difference in physical behavior between tooth structure and restorative materials have been indicated as major factors in gap formation at the composite resin–dentin interface.[7]

*Associate professor, Department of Prevention and Oral Rehabilitation, Federal University of Goiás, Goiânia, Brazil
†Associate professor, Department of Restorative Dentistry at Araraquara School of Dentistry, University of São Paulo State (UNESP), Araraquara, São Paulo, Brazil; formerly visiting professor, Department of Restorative Sciences, University of Minnesota, Minneapolis, MN, USA
‡Formerly associate professor, Department of Restorative Dentistry, UNESP, Araraquara, São Paulo, Brazil

The presence of gaps at the composite resin–dentin interface may lead to marginal microleakage, which allows the passage of saliva, fluids, and bacteria, which may be responsible for alterations in the dental pulp.[8] Ideally, the materials used for pulp protection should obstruct the penetration of fluids and bacteria through the gaps formed; nonetheless, they might not achieve these objectives.[6,8,9] Despite the evolution of the adhesive systems, total elimination of microleakage and microgaps, especially in the areas that do not possess enamel, has yet to be reported.

The aim of the present study was to examine under scanning electron microscope (SEM) the interfaces between the dentin, adhesive system, and lining material with regard to the formation of axial microgaps in Class V restorations. The null hypothesis tested was that the combination of calcium hydroxide, resin-modified glass ionomer, and dentin adhesive used as pulp protection in composite restorations would not result in a greater axial gap than that obtained by hybridization only.

MATERIALS AND METHODS

Sixty freshly extracted third molars were used in this research. Immediately after extraction, the teeth were cleaned with periodontal curettes and polished with a pumice/water slurry and a soft rubber cup with a slow-speed handpiece. They were examined under ×10 magnification (Carl Zeiss, Oberkochen, West Germany, model no. 475200/9901) to ensure that the teeth were free of cracks, defects, and caries. The selected teeth were stored in a solution of 0.5% chloramine at 4°C. Standardized Class V preparations were made on the buccal and lingual surfaces with a high-speed handpiece under copious water irrigation (Figure 1A and B). The preparations were circular (6.0 mm diameter, 3.0 mm depth), and the cavity walls converged at an angle similar to that of the no. 245 carbide bur (KG Sorensen, Barueri, SP, Brazil). The bur's active tip was previously limited to 2.0 mm and 0.5 mm with an acrylic resin stop to allow for three different depths to the pulpal floor (Figure 1C), simulating the differences in depth that occur in real situations. The cervical margins of the preparations were located approximately 1.0 mm below the cementoenamel junction. No cavosurface bevel was placed. After being used to create five cavity preparations, the burs were replaced with new ones. The preparation dimensions were measured with a digital caliper for width (model 599-571-3, Brown & Sharpe Mfg. Co., North Kingstown, RI, USA) and a periodontal probe for depth. The

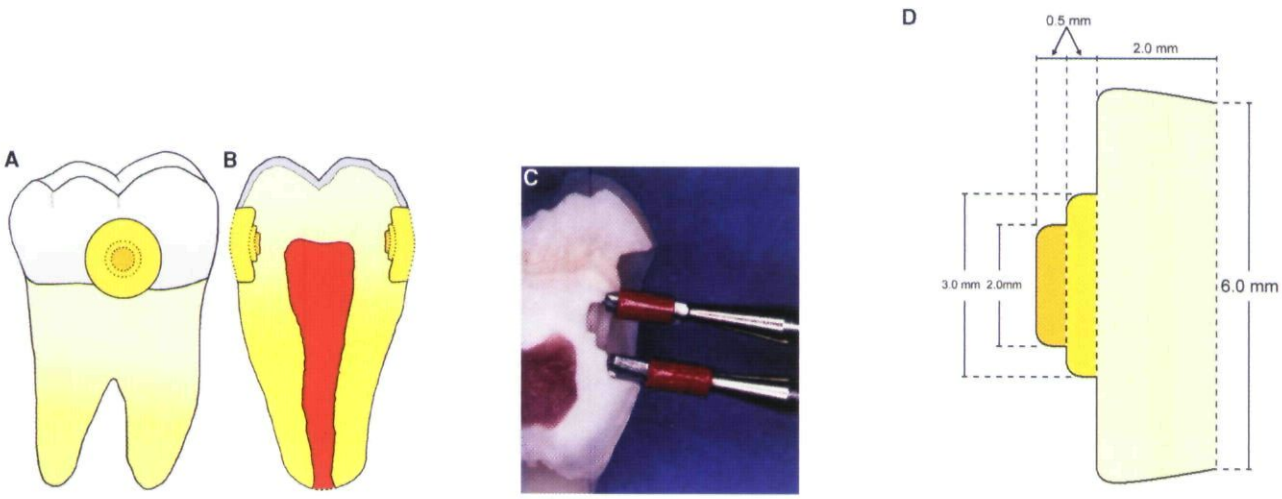

Figure 1. Cavity design: A, *buccal view;* B, *proximal section view;* C, *depth measurement corresponding with the bur; and* D, *cavity dimensions.*

final dimensions are indicated in Figure 1D. The prepared teeth were randomly assigned to one of six groups (n = 20 preparations) and restored with the materials listed in Table 1. The experimental groups involved a combination of the materials, as indicated in Table 2. All materials were used according to the manufacturers' instructions, except in groups 5 and 6.

Single Bond

Enamel and dentin were etched for 15 seconds with 35% phosphoric acid gel (Scotchbond Etchant, 3M ESPE) and rinsed with a water spray for 30 seconds; excess moisture was blotted dry with a cotton pellet. The ethanol- and water-based adhesive (Single Bond) was applied in two consecutive coats, gently air dried to evaporate the solvent, and light cured for 10 seconds.

Life

Equal amounts of Life base and catalyst were mixed for 10 seconds and applied immediately into the deepest area (2.0 mm diameter and 0.5 mm deep) of the cavity floor by means of a liner-placement instrument (Duflex, SS White Ltda, Rio de Janeiro, RJ, Brazil). It was rapidly inserted in one application to avoid air bubbles and to obtain a smooth surface and a uniform thickness. This cement was untouched for 4 minutes. After setting, the etchant was applied to the enamel and dentin walls, with care to not touch the calcium hydroxide cement.

Vitrebond

As per the manufacturer's instructions, no dentin pretreatment was done. One scoop of Vitrebond powder was mixed with one drop of liquid on a mixing pad for 10 to 15 seconds. The resin-modified glass ionomer was inserted into the preparation with a liner-placement instrument (Duflex) and light cured for 20 seconds. The etchant was applied only to the enamel and dentin walls with a needle syringe tip, avoiding contact with the resin-modified glass ionomer.

Restoration

Depending on the group, the two deepest levels were filled with uniform layers of composite resin (Filtek Z250, shade A2) or with lining materials. Three horizontal increments of composite resin of not more than 2.0 mm were sequentially inserted from cervical to occlusal thirds.[10] Each increment was light cured for 20 seconds with a soft-start halogen visible light-curing device with a gradual increase of light intensity from 80 to 540 mW/cm^2 (KM 200 R, DCM Equipamento Ltda, São Carlos, SP, Brazil).

The restored teeth were finished with sequential abrasive disks (Sof-Lex Pop-on, 3M ESPE) and stored in distilled water at 37°C for 24 hours. The specimens were then thermocycled (5°C/55°C, 500 cycles, 30 seconds dwell time) and sectioned mesiodistally in two halves

TABLE 1. RESTORATIVE MATERIALS USED.

Manufacturer	Material	Composition
Kerr Co., Romulus, MI, USA	Life Lot. 29674	Base: calcium oxide, zinc oxide Catalyst: resin disalicylate and trisalicyate, methyl salicylate
3M ESPE, St. Paul, MN, USA	Vitrebond Lot. 7510	Powder: fluoro-aluminosilicate glass Liquid: acrylic acid copolymer containing pendant methacryloxy groups, HEMA
	Single Bond Lot. 1105	BIS-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, initiator, water, ethanol
	Filtek Z250 Shade A2 Lot. 1LG	BIS-GMA, UDMA, BIS-EMA, zirconium/silica

BIS-GMA = bisphenol A diglycidyl ether dimethacrylate; BIS-EMA = bisphenol A polyethylene glycol diether dimethacrylate; HEMA = 2-hydroxyethyl methacrylate; UDMA = urethane dimethacrylate.

TABLE 2. EXPERIMENTAL GROUPS TESTED.

	Sequence of Application				
Groups	Adhesive	Calcium Hydroxide	Resin-Modified Glass Ionomer	Adhesive	Composite Resin
1	SB	—	—	—	Z250
2	—	LF	—	SB	
3	—	LF	VT	SB	
4	—	VT	—	SB	
5	SB	—	VT	—	
6	SB	—	VT	SB	

LF = Life; SB = Single Bond; VT = Vitrebond.

with a water-cooled diamond blade in a precision saw machine (Isomet 1000, Buehler Ltd, Lake Bluff, IL, USA). Subsequently, each half was sectioned along the longitudinal axis through the center of the restorations to obtain a slice of 2.0 mm thickness. The sectioned specimens were examined under stereoscopic microscope at ×20 magnification to ensure the absence of any defect that could compromise the gap analysis. The specimens were immediately fixed in 2.5% glutaraldehyde in 0.1 M sodium cacodylate buffer (Electron Microscopy Sciences, Fort Washington, PA, USA) at pH 7.4 for 12 hours at 4°C.[11,12] After fixation they were rinsed with 0.2 M sodium cacodylate buffer solution at pH 7.4 for 1 hour with three changes, followed by distilled water for 1 minute.[11,12] The specimens were then dehydrated in ascending grades of ethanol (25% for 20 min, 50% for 20 min, 75% for 20 min, 95% for 30 min, and 100% for 60 min).[11,12] The specimens were dried by immersion in hexamethyldisilazane (Electron Microscopy Sciences) for 10 minutes, placed on a paper filter inside a covered glass vial, and air dried at room temperature.[11,12]

The specimens were embedded in epoxy resin, and the exposed tissue was metallurgically polished with wet silicon carbide papers of decreasing abrasiveness (600, 800, and 1,200 grit) and with diamond suspensions of 2.0 and 1.0 μm (Electron Microscopy Sciences) for 10 seconds each. After polishing, the specimens were ultrasonicated in absolute ethanol for 10 minutes,[11,12] etched with a silica-free semigel 10% phosphoric acid (All-Etch, Bisco Dental Products, Itasca, IL, USA) for 5 seconds, and rinsed for 10 seconds. The specimens were mounted on aluminum stubs, sputter coated (SCD 050 Sputter Coater, Bal-Tec S/A, Tokyo, Japan) with gold palladium, and examined with an SEM (model JSM–T 330 A, JEOL LTD., Tokyo, Japan). The restored interfaces were examined for microgaps between the liners, between the liners and dentin, and between the liners and overlaying composite. Photomicrographs were taken with ×1,000 magnification in the area of largest microgap width. The photomicrographs were digitally transferred to Image Tool 2.00 program (San Antonio University, San Antonio, TX, USA) to obtain the mean gap width. The data obtained (interfacial gap mean rank) were analyzed with nonparametric tests (Kruskal-Wallis, $p \leq .05$) and graphic methods.

RESULTS

Figures 2 and 3 summarize the two sets of results. Figure 2 represents interfacial gaps that occur without the application of adhesive first, and Figure 3 represents interfacial gaps that occur with the application of the adhesive first. It is evident in Figure 3 that the gap measurement has neither a normal nor a symmetric distribution around the average rank. The same evaluation might be done for Figure 2, despite the fact that the evidence was not clear.

In the first set of results (see Figure 2), the gaps were consistently seen in practically all specimens. It was shown that the microgaps were similar in distribution in the interfaces between LF-dentin and VT-dentin (see Figure 2), being larger at the LF-VT interface ($p < .001$). The Kruskal-Wallis nonparametric test

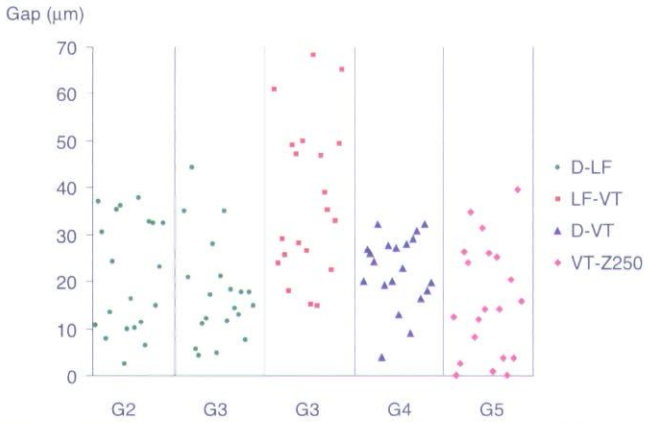

Figure 2. Gap measurements at interfaces without an adhesive system between the dentin (D) and the materials Life (LF) or Vitrebond (VT), between these two materials, and between the resin-modified glass ionomer and Filtek Z250 (Z250) in groups (G) 2, 3, 4, and 5.

(H = 23.0) of the interfacial gaps that occur without application of adhesive resulted in $p < .001$—highly significant. The interfacial gaps in specimens without the application of adhesive were compared with Dunn's test (Bonferroni method, $p \leq .05$), resulting in the values shown in Table 3. The results confirmed that the interfaces between LF and VT produced substantially larger microgaps compared with the other interfaces.

In the second set of results (see Figure 3), the restorations produced were either gap free or had only minimal gaps. One would not expect gaps at the interface with the composite and adhesive in group 1 as well as group 2. In groups 3, 4, and 5, the gaps were similar to all of the interfaces containing the adhesive. The gaps reached relatively high values (see Figure 3) but were lower than those obtained at the interfaces without application of the adhesives first in those same groups (see Figure 2). In group 6, however, in spite of fewer gaps, some specimens achieved high values in the interfaces without an adhesive layer. The Kruskal-Wallis nonparametric test was applied to evaluate whether statistically significant differences between gaps at interfaces occurred where adhesive was used. A Kruskal-Wallis value of 4.0 was obtained, which corresponds to $p = .5525$; therefore, no statistical evidence of a difference among the interfaces was observed. The use of adhesive reduced the possibility of microgap formation between the bonded interface and different materials used.

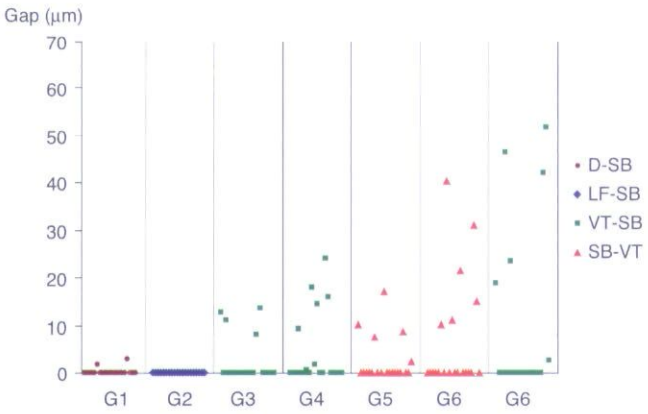

Figure 3. Gap measurements at the interfaces with the Single Bond (SB) and the materials Life (LF) or Vitrebond (VT), and dentin (D), in groups (G) 1 through 6.

DISCUSSION

The application of an intermediate layer of a bonding agent or a lining material has been shown to reduce polymerization contraction stress and improve marginal adaptation.[13] However, gap formation was observed in the lining materials.[13] If adhesive failure occurs at the restoration margin, the internal gap allows penetration of bacteria and fluids between the liners and dentin toward the pulp.[14,15] The results presented in this report confirm the importance of these considerations, although in the present study, the

TABLE 3. MULTIPLE COMPARISONS OF MICROGAPS IN INTERFACES AMONG EXPERIMENTAL GROUPS.

			p Value for Group/Interface			
Group	Interface	Sum of Ranks	2/D-LF	3/D-LF	3/LF-VT	4/D-VT
2	D-LF	48.7				
3	D-LF	39.7	.327			
3	LF-VT	75.6	.003*	<.001*		
4	D-VT	52.8	.651	.152	.013*	
5	VT-Z250	35.9	.163	.679	<.001*	.065

D = dentin; LF = Life; VT = Vitrebond; Z250 = Filtek Z250.
*Significant at $p < .05$.

lining materials used did not contribute to reduction of internal gap formation. Thus, the results require rejection of the null hypothesis that the use of calcium hydroxide or resin-modified glass ionomer liner does not result in larger gaps than those seen using adhesive resins as liners.

To minimize the effects of resin shrinkage, the Class V preparations, which exhibited a high configuration factor (C-factor),[16,17] were filled using the incremental placement technique. Three horizontal layers not more than 2.0 mm thick were used for resin placement.[10] The placement of small increments and thin layers favors the curing contraction in only one direction, and the opposite increment surface allows for stress relaxation.[17,18] In addition, the strong bond at the dentin-resin interface achieved by newer-generation dentin bonding systems may affect the direction of polymerization shrinkage. The shrinkage flow will be directed toward the bonded interface rather than toward the light, thus reducing shrinkage stress and the interfacial gap.[19]

It has been demonstrated that it is possible to reduce the effects of resin shrinkage by starting polymerization reactions gradually and progressively.[20–22] This technique was also adopted in the present study to include all the relevant efforts to reduce the residual stress. Although this variable was not measured, the favorable results in group 1 provide indirect evidence of the utility of this technique.

According to other studies, shear bond strengths between 17 and 21 MPa are required to resist contraction forces of composite resin and to prevent gap formation at the dentin-restoration interface.[23,24] The adhesive used in the present investigation was reported to produce bond strengths of around 19 MPa.[25] In group 1 (SB + Z250), only 2 of 20 specimens had gaps. These gaps were smaller than in the other groups in which lining materials were applied under the restoration (Figure 4A). The presence of polyalkenoic acid is thought to assist the bond strengths of SB to dentin.[26] The accumulation of the polyalkenoate-based, electron-dense material at the superficial zone of the hybrid layer has been correlated with stress reduction.[26]

Reports have shown that lining materials can detach from the dentin during polymerization contraction of the composite and create gaps as a result of an adhesion of the liners (Figure 4B) to the

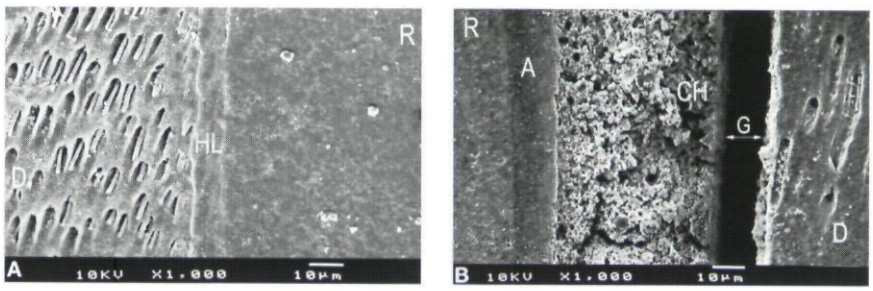

Figure 4. A, *Scanning electron microscope (SEM) image of group 1 specimens (D-A-R) with excellent marginal adaptation.* B, *SEM image of a specimen from group 2 (CH-A-R). Note that there is no gap formation between the composite resin (R) and calcium hydroxide (CH) with the interposition of the adhesive layer (A). The interfacial gap (G) is clearly formed between calcium hydroxide (CH) and dentin (D). (Original magnification ×1,000)*

restorative resin.[3,8,14,18] In group 2 (LF + SB + Z250), the gap formation was verified at the dentin–calcium hydroxide interface (see Figure 4B) in all of the analyzed specimens (see Figure 2). These findings are in agreement with those of other authors who have observed gaps in the same percentage of specimens, although of smaller magnitudes.[14] The small discrepancy may be because of the cavity C-factor. Most authors have used a C-factor of 1, favoring the adaptation of the restorative material to the preparation.[16,17]

It is possible that the sectioning procedures and ultrasonication contributed to an increase in the magnitude of gaps between the dentin and calcium hydroxide, as suggested by Papadakou and colleagues.[27] There were gaps in all of the dentin–calcium hydroxide interfaces (see Figure 2) but an absence of gaps in all of the calcium hydroxide–adhesive system–composite interfaces (see Figure 3). Thus, gaps did not result from specimen preparations but from the lack of adhesion of calcium hydroxide to the dentin (see Figures 4B and 5C) or the resin-modified glass ionomer (Figure 5B).

Resin-modified glass ionomer has often been recommended as the most appropriate substitute for dentin.[1,5] The placement of resin-modified glass ionomer over calcium hydroxide cement in deep cavities has been suggested as a treatment that corrects the weak strengths of calcium hydroxide and uses the good properties of both.[2] However, the efficacy of this procedure was not very good in group 3 (LF + VT + SB + Z250). There was gap formation in all of the interfaces between dentin and calcium hydroxide and between calcium hydroxide and resin-modified glass ionomer (see Figures 2 and 5). These results confirm that Life did not adhere to the dentin or to Vitrebond.[6,14,28] They also indicate that the average of gap width in the LF-VT interface was greater than in the dentin-LF interface. These highly significant values indicate the lack of adhesion between the two lining materials and the higher bond strength of Vitrebond to the composite resin,[29] and its polymerization shrinkage.[30,31]

The incorporation of a resinous phase to a light-cured glass ionomer has improved its physical and mechanical properties,[32,33] as well as the bond strength of liners to dentin.[34] The Vitrebond liquid contains both 2-hydroxyethyl methacrylate (HEMA) and polyacrylic acid. The acid component reacts with dentin, producing a mild etching effect and allowing penetration of the HEMA component into the dentinal tubules.[35,36] Thus, the adhesion process is primarily chemical rather than mechanical.[36] Moreover, an ionic exchange occurs between the Vitrebond and the dentin surface.[34] However, in group 4 (VT + SB + Z250), all the specimens presented gaps at the dentin-VT interface (see Figures 2 and 6B). This result suggests that the bond strength of Vitrebond to dentin is weaker than its adhesion to Z250. During composite resin polymerization shrinkage, the weakest bond failed.

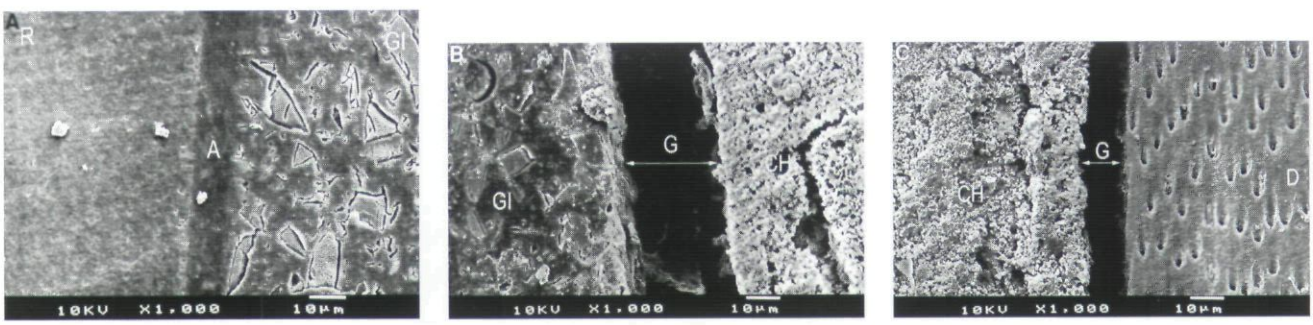

Figure 5. Scanning electron microscope (SEM) image of a specimen from group 3. A, *Adaptation of the resin-modified glass ionomer (GI) to the composite resin (R).* B, *Gap formed between the resin-modified glass ionomer and the calcium hydroxide.* C, *Gap formation between the calcium hydroxide liner and dentin. (Original magnification ×1,000)*

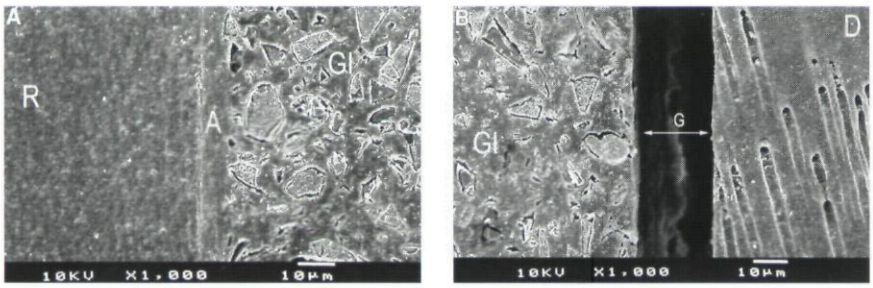

Figure 6. Scanning electron microscope image of a specimen from group 4 (GL-A-R). A, Adaptation of the resin-modified glass ionomer (GI) to the composite resin (R). B, Marginal gap formed at the junction between the resin-modified glass ionomer and dentin. A = adhesive layer. (Original magnification ×1,000)

Previous investigations have shown that liners containing HEMA manifested higher shear strength at liner-composite than at dentin-liner interfaces.[33] Probably, the application of a bonding adhesive (ie, Single Bond) prior the composite resin enhanced the bond strength between the glass ionomer and the composite resin (Figure 6A).

Other research has also demonstrated differences in bond strengths of Vitrebond to dentin versus those to composite resin.[29] Thus, as the resin-modified glass ionomer tended to adhere more to adhesive resin than to dentin during the composite polymerization shrinkage, the Vitrebond detached from the cavity floor.[31] However, gap formation was also observed in 7 of 20 specimens between the resin-modified glass ionomer and composite resin (see Figure 3). These gaps probably occurred because of the physicochemical adhesiveness of the glass ionomer to tooth structure[32–36]; in these specimens Vitrebond offered some resistance to polymerization contraction of the composite resin.

In groups 2 (LF + SB + Z250) to 4 (VT + SB + Z250), the only difference was the substitution of Life for Vitrebond. All the specimens in both groups presented gaps at the dentin interface, demonstrating the inability of either lining material to prevent the formation of gaps at the cavity floor. This observation was unexpected, considering that calcium hydroxide cement does not adhere to dentin,[2,6,9,14] whereas bond strengths for Vitrebond to dentin are about 12 ± 3 MPa.[32] Apparently, this degree of adhesion was not sufficient to resist the polymerization shrinkage stress of composite resin and avoid detachment.

Kemp-Scholte and Davidson showed that the application of an intermediate layer of light-cured glass ionomer under composite resin resulted in complete marginal adaptation.[13] However, cohesive failure and crack formation were observed in the lining material, which certainly could have contributed to stress relief.[13] Thus, the base material might reduce the polymerization shrinkage stresses by debonding from the cavity floor and creating an undesirable gap.[18]

Despite the chemical bond of resin-modified glass ionomer to dentin, a previous hybridization might increase bond strengths, thereby preventing gap formation.[37–39] Prior studies have shown formation of a hybrid layer and a continuous link between the bonding resins and the resin-modified glass ionomer, yielding a continuous interface when dentin was pretreated with a bonding agent.[38,39] It has also been verified that the application of an adhesive system produces a significant improvement in bond strength of resin-modified glass ionomer to dentin, to levels comparable with the bond strength of composite resin.[38,39] The results obtained in group 5 (SB + VT + Z250) confirm the increase in bond strength of resin-modified glass ionomer to dentin (Figure 7A). Five of 20 specimens presented gaps at the dentin-VT interface (see Figure 3), whereas only 2 of 20 specimens did *not* present gaps at the VT-Z250 interface (see Figures 2 and 7B).

Upon comparing groups 4 (VT + SB + Z250) and 5 (SB + VT + Z250) (see Figures 2 and 3), it can be noticed that there was a reversal in the gap formation, depending on where the adhesive was applied. In other words, gaps were minimized at the interface containing the adhesive. The previous application of adhesive increased the bond strength to dentin and may be a good

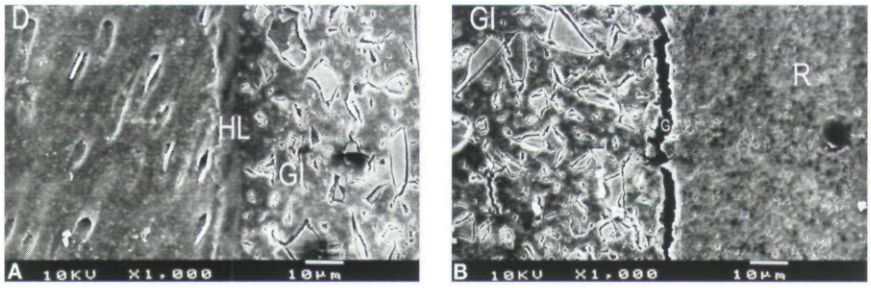

Figure 7. Scanning electron microscope image of a specimen from group 5 (D-A-GI). A, Observe the absence of gaps between the hybridized dentin (D) and resin-modified glass ionomer (GI). B, Debond between the resin-modified glass ionomer and the composite in the absence of an adhesive layer (A). (Original magnification ×1,000)

solution for those materials that produce weak bonding to dentin.[39]

To completely eliminate gap formation, a bonding agent should theoretically be applied prior to the application of a liner and prior to the application of composite resin. However, this hypothesis was not confirmed in group 6 (SB + VT + SB + Z250). Of this group's 20 specimens, 7 presented gaps at the dentin-VT interface, 6 produced gaps between the VT-Z250 interface, and 3 specimens had gaps at both interfaces. Although the number of gaps was smaller in relation to the other groups, they achieved higher width values, similar to those presented at the interfaces without adhesive in group 3 (Figure 8). Chadwick and Woolford found no significant differences in shear bond strengths between Vitrebond and composite resin with or without an intermediate bonding agent.[40] These results are in disagreement with the observations of the current study. The dentin-VT and VT-Z250 interfaces of group 6 presented a similar number of gaps. This suggests that the hybridization of dentin prior to the application of the resin-modified glass ionomer increases its adhesion, producing similar results to the bonding of resin composite.[38]

Another factor that should be taken into consideration is the possibility of shrinkage of the specimen during processing, coating, and SEM observations.[41] The specimens were dried using hexamethyldisilazane, which helps to prevent collagen collapse and to better preserve the collagen network.[11] It has been shown that even specimens that are fixed can shrink, regardless of the drying technique.[41] However, it is imperative to fix biologic specimens before the SEM analysis to reduce the potential of artifacts.[11] Specimen replicas obtained from polyvinylsiloxane impressions were also indicated for gap analysis.[42,43] Although the impression material was able to penetrate within the tubules, at magnifications larger than ×400, the replica technique provided insufficient information.[44] Since many specimens of the current study did not show gaps, the experimental procedures used were valid. It was also desirable to stress the interfaces to determine how effectively the various materials would adhere to each other.

The results obtained in this study demonstrate that the lining materials do not have enough bond strength to dentin to resist the polymerization shrinkage of composite resin and avoid gap formation. The hybridization of dentin by resin minimized gap formation. However, the use of adhesives on deep dentin

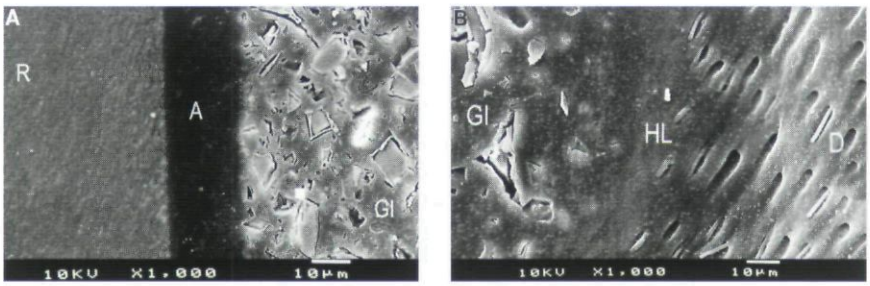

Figure 8. Scanning electron microscope image of a specimen from group 6. A and B, Absence of gaps when different materials were coupled with an adhesive. (Original magnification ×1,000)

increases the risk of adverse biocompatibility.[45–47] Several studies have demonstrated cytotoxic effects of adhesive system components as an important cause of pulpal irritation and the importance of remaining dentin thickness to protect the pulp-dentin complex.[45–47] Even though postoperative sensitivity has been related to the absence of lining materials,[2,45,47] protective layers do not necessarily prevent sensitivity.[48]

Thus, knowledge of biocompatibility, the technical sensitivity of the adhesive systems, and the adhesive properties of currently available materials can help clinicians select the most appropriate materials for each clinical situation.[2,6]

CONCLUSIONS

The following can be concluded from the results of this study:

- Resin hybridization of dentin significantly reduced gap formation in high C-factor cavity preparation.
- Microgaps at the axial wall were less frequent when the interfaces were treated with adhesive.
- Similar microgaps were found at the dentin interface when resin-modified glass ionomer or calcium hydroxide was used as pulp protection.

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Reprint requests: Sillas Duarte Jr, DDS, MS, PhD, São Paulo State University at Araraquara—UNESP, Department of Restorative Dentistry, Division of Operative Dentistry, R:Humaitá, 1680, Araraquara, São Paulo, Brazil, CEP: 14801-903, CP: 331; e-mail: sillas01@yahoo.com.br