Microleakage of Class II Posterior Composite Restorations with Gingival Margins Placed Entirely within Dentin

Lawrence W. Stockton, *DMD;* ***Susan T. Tsang,*** *DMD, BSc Dent, MSc Ortho*

Contact Author

Dr. Stockton

Email: *stocktn@ms.umanitoba.ca*

ABSTRACT

Purpose: Composite restorations are more frequently being placed with margins apical to the cementoenamel junction. However, margins within dentin are prone to microleakage. The purpose of this in vitro study was to evaluate various restorative procedures in terms of their ability to reduce microleakage in posterior composite restorations with gingival margins within dentin. We also examined the effect of staining time on microleakage.

Materials and Methods: Mesio-occlusal and disto-occlusal preparations were made in 50 extracted molars. Teeth were randomly assigned to receive 1 of 5 treatments followed by restoration with Z100 composite resin: acid etch (control); Clearfil SE Bond; Prompt-L-Pop; Vitrebond/Scotchbond Multipurpose Plus (closed-sandwich technique); or Geristore/Tenure (open-sandwich technique). After 48 hours of water storage followed by sectioning buccolingually, 1 restoration from each tooth was randomly assigned to either 2- or 4-hour immersion in 50% by weight silver nitrate solution. Restorations were removed and gingival floors analyzed to determine the percentage of surface area stained in each of 3 0.5-mm wide zones.

Results: Repeated measures ANOVA did not reveal statistically significant differences in staining for 2 and 4 hours. Compared with the control group, Clearfil SE bond produced statistically significant reductions in leakage in all 3 zones. Prompt-L-Pop did not reduce leakage significantly except in zone 3 (closest to the pulp). Vitrebond and Geristore both reduced microleakage in zones 2 and 3, but the reduction was greater with the use of Vitrebond.

Conclusion: Both Clearfil SE Bond and Vitrebond in a closed-sandwich technique were effective methods for reducing microleakage within dentin.

For citation purposes, the electronic version is the definitive version of this article: www.cda-adc.ca/jcda/vol-73/issue-3/255.html

An ideal restorative material would create a permanent and perfect seal between the restoration margin and the tooth structure.[1] Imperfect bonding leaves a microscopic gap that allows the infiltration of bacteria, fluids, molecules and ions between the restoration and the tooth structure, commonly referred to as microleakage.[2,3] Gap formation may result from shrinkage of the composite during polymerization or from mismatches between either the coefficients of thermal expansion of the tooth and the composite or between the elastic moduli of the tooth and the composite.[4,5] Although some degree

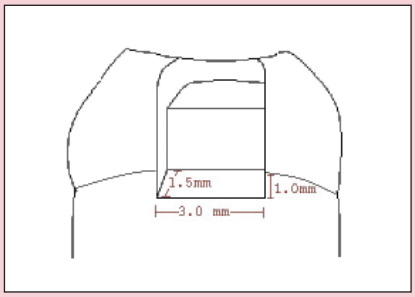

Figure 1: Dimensions of the cavity preparation.

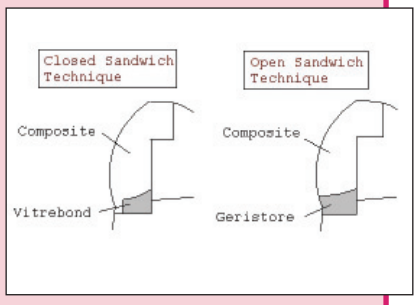

Figure 2: The use of Vitrebond in a closed-sandwich method and Geristore in an open-sandwich method.

of microleakage will occur with most dental materials, slight leakage can be tolerated by the pulp, and irritants are often removed by pulpal blood flow.[6] However, in some circumstances, microleakage becomes a source of postoperative sensitivity and recurrent caries and leads to the eventual failure of the restoration.[6]

Enamel margins generally produce consistent bonding and microleakage is less likely than with dentinal margins.[7–9] Clinically, however, margins are frequently placed apical to the cementoenamel junction, on dentin or cementum where moisture control and access for finishing are more problematic. Dentin bonding is more difficult because the heterogeneous nature of the tissue requires the bonding system to accommodate simultaneously the properties of the hydroxyapatite, collagen, smear layer and dentinal tubules and fluids.[10] Consequently, the ability to achieve an effective seal at the gingival margin becomes even more important in terms of the longevity of a resin restoration.

Bond failure may occur for several reasons, including moisture contamination and incomplete infiltration of resin into the demineralized layer. The latter may result from excessive etching or over-drying, which causes the collapse of the collagen fibrils.[11] Bonding systems with numerous steps, requiring the separate application of conditioner, primer and adhesive, increase the chance of error, which might compromise the bond. Although bonding is simplified in systems that combine the primer and adhesive, the process is still technique sensitive.

Resin-modified glass ionomer cement (RMGIC), used as a liner or base, can be valuable in controlling microleakage. Its placement using a sandwich technique can provide reliable chemical adhesion to dentin, a micromechanical bond to the overlying resin, pulp protection, anti-cariogenicity from fluoride release and a reduction in volume of resin used, thereby reducing the degree of shrinkage stress in the composite resin.[12,13] However, when RMGIC is applied up to the cavosurface margin of the gingival floor (open-sandwich technique), solubility in the oral environment predisposes the RMGIC portion of the restoration to deterioration.[14,15] In a survey of 954 dentists in Australia and Nordic regions, 75% to 80% of respondents had used the open-sandwich technique, but 14% to 17% of respondents reported that dissolution of the proximal cement occurred "often."[16,17] One solution to this problem is to prevent exposure of the glass ionomer to the oral environment by applying the RMGIC short of the cavosurface margin and placing a veneer of composite resin over the material (closed-sandwich technique). Alternatively, a material with lower solubility in the oral environment than the glass ionomer (such as a compomer) may be applied in an open-sandwich technique.

With the increasing frequency of use of posterior composite resins with margins located on dentin, methods are needed that minimize leakage and provide patients with a more successful restoration. The purpose of this in vitro study was to evaluate restorative procedures to determine which are best able to reduce microleakage in composite restorations when gingival margins are entirely within dentin. A second objective was to consider the effects of increased staining times on microleakage.

Methods and Materials

Fifty recently extracted human maxillary and mandibular permanent molars were collected, cleaned and stored in water for no more than 1 month. They were randomly assigned to 1 of the 5 test groups described below. A #56 straight fissure carbide bur in a high-speed handpiece with water coolant was used to make mesio-occlusal and disto-occlusal preparations whose occlusal extensions were separated by tooth structure. A new bur was used for every 10 preparations. The proximal box of each preparation had a width of 3 mm measured buccolingually and an axial depth of 1.5 mm measured at the gingival floor. The gingival floor was located 1 mm apical to the cementoenamel junction to ensure that placement was entirely in dentin. All cavity preparations and restorations were completed by 1 operator and all measurements were confirmed with a periodontal probe.

Following cavity preparation (**Fig. 1**), the bonding surfaces were treated as follows:

- **Acid etch (control group):** The cavity was etched with 35% phosphoric acid for 20 seconds, rinsed for 15 seconds and dried for 5 seconds with an air syringe.
- **Clearfil SE Bond** (Kuraray America, New York, NY) is a light-cured bonding system containing a self-etching primer and adhesive. Primer was applied to the cavity for 20 seconds and dried for 5 seconds with the air syringe held 5 cm from the tooth. This

step was repeated if the surface was judged not to be uniformly glossy. Adhesive was then applied, thinned with a gentle air stream and light-cured for 10 seconds.

- **Prompt L-Pop** (3M ESPE, London, Ont.) is an all-in-1 adhesive recommended for use with composites and compomers. It is supplied in premeasured form and is activated by mixing the 2 components. The components were mixed, applied to the cavity for 15 seconds and thinned with a gentle stream of air. If the surface was not uniformly glossy, the process was repeated. Light-curing was done for 10 seconds before placement of the composite resin.

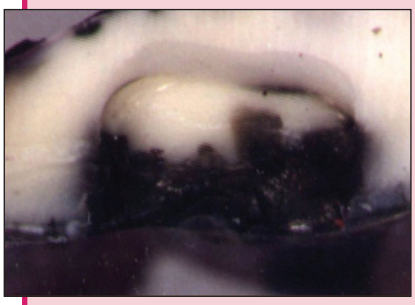

Figure 3: Occlusal photograph of the silver nitrate staining pattern present on the gingival floor of a proximal box following removal of composite bonded with Prompt-L-Pop.

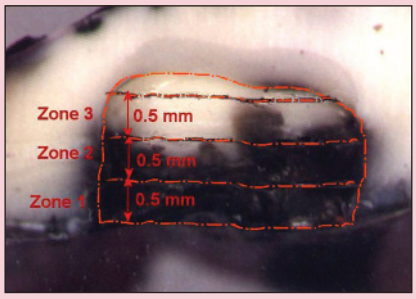

Figure 4: Division of the gingival floor depicted in **Fig. 1** into 0.5-mm wide zones. Computer software was used to calculate percentage of stained surface area in each zone.

- **Vitrebond/Scotchbond Multipurpose Plus (closed-sandwich technique):** Vitrebond (3M ESPE) is a resin-modified visible-light-cured glass ionomer base or liner; it was used here in a closed-sandwich technique. One scoop of powder was mixed with 1 drop of liquid on a paper pad using a small cement spatula and applied up to the gingival cavosurface margin of the gingival floor with the round end of a Dycal applicator (SP6061, Hu-Friedy, Chicago, Ill.) to a thickness of about 1 mm. After light-curing for 30 seconds, the small end of a hoe was used to remove 0.5 mm of glass ionomer along the gingival margin to expose the dentin. The cavity was etched with 35% phosphoric acid for 20 seconds, rinsed for 15 seconds and air-dried for 5 seconds. Scotchbond Multipurpose Plus primer (3M ESPE) was applied and gently dried for 5 seconds. If the surface was not uniformly shiny, the process was repeated. The adhesive was then applied, gently thinned with air and light-cured for 10 seconds.
- **Geristore/Tenure (open-sandwich technique):** Geristore (DenMat Corp, Santa Maria, Calif.) is a dual-cure poly-acid modified composite resin. Equal amounts of the 2 components were mixed on a paper pad using a plastic mixing stick. Using a Dycal applicator, the mixture was applied to the gingival floor up to the gingival cavosurface margin to a thickness of 1 mm, then light-cured for 30 seconds. Tenure (DenMat Corp) was prepared by mixing 4 drops of part A and 1 drop of part B, applied to all cavity walls for 10–15 seconds and thinned with a gentle blast of air.

Because of its greater solubility, Vitrebond will not remain intact if used in an open-sandwich technique; Geristore, on the other hand, has performed well in contact with oral fluids and is, therefore, a better choice for this technique (**Fig. 2**).

Following preparation of the bonding surfaces, a #2 Toffelmire matrix band was adapted around each tooth and Filtek Z100 composite resin (3M ESPE) was applied. Composite was placed in 2-mm increments, starting at the proximal box, with each increment cured for 40 seconds with a Vivadent Heliolux (Ivoclar Vivadent, St. Catharines, Ont.) light-curing unit (300 mW/cm^2) placed on the occlusal surface of the tooth and directed apically.

All materials were used according to manufacturers' directions with the exception of Geristore, which was placed on untreated tooth structure to allow comparison of the 2 sandwich techniques.

Excess composite was removed with fine esthetic finishing burs. The teeth were stored in water for 48 hours, then sectioned buccolingually with a #169L carbide bur in a high-speed handpiece. Nail varnish was applied to all unrestored enamel and dentinal surfaces to within 1 mm of the cavosurface margins, and rope wax was used to seal the apices. One restoration on each tooth was randomly assigned to be immersed in 50% by weight aqueous silver nitrate solution for 2 hours, while the other restoration was immersed for 4 hours.[18] During this part of the study, all samples and the silver nitrate solution were carefully protected from exposure to light. After removal from the staining solution, the samples were rinsed in running water for 15 minutes to remove silver nitrate solution from the external surfaces of the teeth and then immersed in Kodak Ready Pro Developer (Eastman Kodak, Rochester, NY) for 8 hours under a fluorescent lamp. Teeth were then rinsed in running tap water for 15 minutes and sectioned transversely with a #56 bur at a point 1.0 mm above the gingival floor. The restoration was then carefully removed with a hatchet to view the entire stained gingival floor. Leakage was assumed to originate from the gingival cavosurface margin and progress toward the pulp.

Table 1 Mean percentage stained surface area after immersion in silver nitrate solution for 2 hours and 4 hours (n = 10). No statistical differences between the 2 staining times were detected at $p \leq 0.05$

Group	Zone 1		Zone 2		Zone 3	
	2 h; % (SD)	4 h; % (SD)	2 h; % (SD)	4 h; % (SD)	2 h; % (SD)	4 h; % (SD)
No bonding agent	100.00 (0.00)	100.00 (0.00)	99.63 (1.16)	100.00 (0.00)	95.70 (13.60)	100.00 (0.00)
Clearfil SE	64.61 (36.57)	63.24 (35.70)	36.78 (39.04)	37.39 (37.76)	20.22 (32.54)	25.45 (40.48)
Prompt-L-Pop	97.63 (7.49)	100.00 (0.00)	91.08 (19.02)	87.85 (20.77)	53.83 (42.23)	44.60 (33.67)
Vitrebond	84.11 (19.65)	94.66 (7.65)	27.63 (24.50)	40.70 (31.68)	0.00 (0.00)	14.50 (33.21)
Geristore	76.76 (30.97)	86.62 (23.91)	61.55 (45.30)	77.68 (36.52)	44.55 (43.39)	61.65 (46.32)

Table 2 Combined mean percentage stained surface area after immersion in silver nitrate solution for 2 hours and 4 hours (n = 20). Within each column, means that are not significantly different are followed by the same letter

Group	Zone 1		Zone 2		Zone 3	
No bonding agent	100.00	a	99.82	a	97.85	a
Clearfil SE Bond	63.93	b	37.09	b	22.83	b,c
Prompt-L-Pop	98.82	a	89.46	a,c	49.21	b
Vitrebond	89.38	a	34.22	b	7.26	c
Geristore	81.69	a,b	69.61	c	53.10	b

The gingival floor was photographed (**Fig. 3**) using an intraoral camera with 35 mm film (100 ISO). The photographs were scanned and analyzed using imaging software (Scion Image, v 2.0, Scion Corporation, Frederick, Md.). The gingival floor was divided into 3 zones (**Fig. 4**), each 0.5 mm wide and the percentage of surface area stained by silver nitrate in each zone was calculated.

Repeated measures ANOVA and Tukey's test were used to determine significant differences between treatment groups. Results were considered significant at $p \leq 0.05$.

Results

The mean percentage of stained surface area in zones 1, 2 and 3 after immersion in silver nitrate for 2 hours and 4 hours is shown in **Table 1**. Analysis revealed no significant differences ($p \leq 0.05$) in the mean values between the 2-hour and 4-hour treatment for any of the restorative procedures. The 2-hour and 4-hour results for each procedure were combined for subsequent data analysis (**Table 2**).

In zone 1, only Clearfil SE Bond resulted in a significant reduction in staining surface compared with the control group (no bonding agent). Mean percentage staining ranged from a low of 63.93% for 1 self-etching adhesive system, Clearfil SE Bond, to a high of 98.83% for the other self-etching adhesive, Prompt-L-Pop. In zone 2, Clearfil SE Bond, Vitrebond in a closed-sandwich technique and Geristore in an open-sandwich technique all produced significant reductions in leakage compared with composite placed without bonding agent. Only Prompt-L-Pop did not result in a significant reduction in leakage. Staining in zone 2 ranged from about a third of the surface area for both Clearfil SE and Vitrebond to over 89% with Prompt-L-Pop. Microleakage in zone 3 was statistically reduced by all restorative treatments compared with the control treatment, and staining ranged from 7.26% for Vitrebond in a closed-sandwich technique to 53.10% for Geristore applied in an open-sandwich technique.

Discussion

Complete removal of the restoration permitted viewing of the entire gingival floor and allowed for comprehensive consideration of microleakage patterns. The use of this whole-wall technique has also been used by other investigators[9,19] and has been shown to provide a more accurate evaluation of microleakage than the slice method.[20] The use of computer software to express microleakage as a percentage of the surface area represents a unique modification of past methods and has been reported in 1 other microleakage study.[21] Traditional microleakage studies have relied on 1 or several mesiodistal sections through a restoration to score microleakage qualitatively. However, when margins are located on dentin, the continuity of the bond may vary due to the heterogeneous nature of dentin and the associated difficulties with developing adequate dentin bonding.[22,23] Irregular leakage patterns were noted

in several specimens in this study, and other studies have shown that measurements obtained through sectioning do not portray microleakage accurately.[8,9,20,22,24] Three-dimensional evaluations (restoration removal) reveal significantly greater leakage along dentinal margins of composite restorations than 2-dimensional evaluations (single longitudinal section).[8,9,20]

This study demonstrates the difficulty of achieving a successful dentinal seal with composite resins. We made every effort to place the restorations in a manner similar to protocols used in a clinical setting, although moisture control and cavity access were undoubtedly easier to achieve than they would be intraorally when proximal boxes are deep and extend past the cementoenamel junction. Nonetheless, despite more favourable conditions, moderate to considerable amounts of leakage occurred with all methods of restoration.

In all treatment groups, the amount of leakage decreased from zone 1 toward zone 3, but could not be completely eliminated, except in teeth restored with Vitrebond using a closed-sandwich technique and immersed in silver nitrate for 2 hours. Results from our Vitrebond treatment group are consistent with those obtained in a study by Wibowo and Stockton.[21] The ability of glass ionomer to reduce microleakage has been well documented,[15,21,25] but its use in proximal boxes has been limited by its physical characteristics. In an in vitro study, Holton and others[15] found deterioration on the surface exposed to a simulated oral environment when an RMGIC was extended out to the cavosurface margin, but no deterioration in samples with the glass ionomer liner protected by a veneer of composite resin (closed-sandwich technique).

Although the closed-sandwich technique is effective in reducing leakage, limited access to a cavity may make the correct placement of the glass ionomer cement difficult. As an alternative, we tested the suitability of Geristore in an open-sandwich technique, in which the material is placed up to the gingival cavosurface margin eliminating the step of adding a veneer of composite resin. Geristore is frequently used for endodontic and periodontic purposes due to its neutral pH, lower solubility and tissue biocompatibility.[26,27]

With 2- and 4-hour staining, Geristore produced a statistically significant reduction in leakage in zones 2 and 3 compared with the control group, indicating that a partial seal between dentin and Geristore was formed and, therefore, some bonding of the 2 surfaces may be possible. Although both Geristore and Vitrebond significantly reduced leakage in zones 2 and 3 compared with the control treatment, Vitrebond was more effective than Geristore. The proven ability of materials such as Vitrebond to achieve a durable chemical bond with dentin and enamel may explain the observed lower leakage of Vitrebond compared with Geristore. Although Geristore may have some potential to bond, it is a polymer and as polymers are known to be incapable of developing durable chemical bonding with dentin, the leakage observed with Geristore is not unexpected.

Other studies that applied a bonding system before Geristore also report variable results with the material. Owens and others[28] reported that Geristore resulted in average microleakage of 45% to 61% of the distance along the gingival floor, compared with 29% to 41% with Dyract (Dentsply International, York, Penn.) and 5% to 34% with Scotchbond Multipurpose and Z-100. The authors suggest that the greater microleakage with Geristore may have been a result of air trapped during the mixing of the 2-paste system. Davis and others[29] did not find any significant differences in microleakage among Geristore and other glass ionomers including Vitrebond, but did find statistically greater variation in bond strength of Geristore compared with other groups. Unpredictable bonding of compomers to dentin has been observed,[21] suggesting greater inconsistency in the ability of compomers to prevent leakage.

Clearfil SE Bond, a self-etching primer, was the only restorative method tested that resulted in significant reductions in leakage in all 3 zones. For both the 2-hour and 4-hour staining times, Clearfil SE Bond showed the least leakage in zone 1 and was the only method that significantly reduced leakage in this zone compared with the control group. In zones 2 and 3, however, leakage with Clearfil SE Bond was not statistically different from that with Vitrebond in a closed-sandwich technique. Besnault and Attal[30] also found significant reductions in microleakage with a self-etching material compared with a total-etch technique in dentin, but greater microleakage in enamel. Likewise, Pradelle-Plasse and others[31] report acceptable bonding with cervical dentin, but increased leakage in enamel. The bond strength of Clearfil SE Bond to enamel has been found to be similar to that using a total-etch technique, but shear bond strength to dentin has been found to be significantly higher with Clearfil SE Bond.[32,33] Considering these encouraging data and results of the current study, we believe that Clearfil SE Bond may be considered as an alternative to the closed-sandwich technique when dentin bonding is required.

Prompt-L-Pop is marketed as an all-in-1 adhesive to simplify the bonding process even further. According to the manufacturer, this is a self-etching primer adhesive system, allowing both mechanical and chemical bonding to dentin (ESPE, Prompt-L-Pop Scientific Manual). The advantages listed by the manufacturer include universal compatibility with compomer and composite restorative materials, greater hygiene, fewer steps with less introduction of error, fresh activation of the product with each application and reduced postoperative sensitivity due to incomplete infiltration of the demineralized zone. However, in our study Prompt-L-Pop did not have ac-

ceptable sealing capability. Leakage associated with Prompt-L-Pop was not statistically different from that in the control group in zones 1 and 2. The reduction in leakage was significant only in zone 3 and still covered 45% to 54% of the gingival floor. This is consistent with other studies that have reported mediocre results with Prompt-L-Pop.[33,34]

The purpose of subjecting 1 preparation on each tooth to a 2-hour staining time and the other to a 4-hour staining time was to observe the influence of staining time on the amount of microleakage. In the control group, the mean surface area stained after 2 hours in silver nitrate solution ranged from 100% in zone 1 to 95.70% in zone 3 due to unstained areas in 1 specimen. As the composite was placed without bonding agent, penetration was expected to be 100% in all specimens. In teeth that were acid etched and restored with composite resin but without bonding agent, Neme and others[35] found leakage along 50.5% of the depth of the gingival floor. Tulungolu and others[19] found that 60% of Class V restorations placed without bonding agent had microleakage to the axial wall and 40% had leakage halfway to the axial wall. It is unlikely that a fully resin-infiltrated hybrid layer would form between the composite resin and dentin without the application of a primer or bonding agent. Therefore, the incomplete coverage of the floor with stain is more likely due to insufficient time for stain or developer penetration.

A greater degree of leakage was observed in most groups after 4 hours of staining compared with 2 hours, but the differences were not statistically significant. It is possible that if specimens were left for longer than 4 hours, statistically significant differences would result. Although 4 hours of staining might provide a better representation of the depth of leakage than 2 hours, whether 4 hours is sufficient for penetration of the stain through the entire extent of the gap has yet to be determined.[36]

Irritants must be minimized in zone 3 to allow the pulp's self-defense mechanism to produce reparative or sclerotic dentin.[6]

If the material–tooth bond remains intact, the final stiffness of the material may compensate for remaining polymerization contraction stress and lead to a better seal.[37] Resin-modified glass ionomers have a lower Young's modulus than highly filled resin-based composites[38] and better flow characteristics during maturation[39] than resin-based composites, which means less shrinkage stress during polymerization and potentially less microleakage.

Conclusions

All restorations leaked, and all but 1 group leaked to a depth of at least 1 mm.

The use of a resin-modified glass ionomer in a closed-sandwich technique remains an effective method for reducing microleakage when proximal boxes have gingival cavosurface margins located in dentin.

When posterior restorations are expected to be large or have subgingival margins, alternatives to composite resin should be considered. If a composite resin is being used, materials and methods should be chosen carefully and attempts made to prevent contamination of the field that may further hinder successful bonding.

Immersion of restorations in silver nitrate for 4 hours did not result in significant increases in microleakage compared with immersion for 2 hours. Further study is necessary to determine whether immersion times greater than 4 hours will result in statistically significant findings and to establish appropriate staining times and method.

THE AUTHORS

Dr. Stockton *is an associate professor in the department of restorative dentistry, faculty of dentistry, University of Manitoba, Winnipeg, Manitoba.*

Dr. Tsang *is a graduate of the University of Manitoba's undergraduate and post-graduate (orthodontics) programs.*

Correspondence to: *Dr. Lawrence Stockton, Faculty of Dentistry, University of Manitoba, D126 –780 Bannatyne Ave., Winnipeg MB R3E 0W2.*

The authors have no declared financial interests in any company manufacturing the types of products mentioned in this article.

This article has been peer reviewed.

References

1. Taylor MJ, Lynch E. Microleakage. *J Dent* 1992; 20(1):3–10.

2. Kidd EA. Microleakage: a review. *J Dent* 1976; 4(5):199–206.

3. Bauer JG, Henson JL. Microleakage: a measure of the performance of direct filling materials. *Oper Dent* 1984; 9(1):2–9.

4. Pashley DH, Depew DD. Effects of the smear layer, Copalite and oxalate on microleakage. *Oper Dent* 1986; 11(3):95–102.

5. Tate WH, Friedl KH, Powers JM. Bond strength of composites to hybrid ionomers. *Oper Dent* 1996; 21(4):147–52.

6. Pashley DH. Clinical considerations of microleakage. *J Endod* 1990; 16(2):70–7.

7. Barkmeier WW, Cooley RL. Laboratory evaluation of adhesive systems. *Oper Dent* 1992; Suppl 5:50–61.

8. Gwinnett JA, Tay FR, Pang KM, Wei SH. Comparison of three methods of critical evaluation of microleakage along restorative interfaces. *J Prosthet Dent* 1995; 74(6):575–85.

9. Hilton TJ, Schwartz, RS, Ferracane JL. Microleakage of four Class II resin composite insertion techniques at intraoral temperature. *Quintessence Int* 1997; 28(2):135–44.

10. Anusavice KJ. Phillip's science of dental materials. 10th ed. Philadelphia: WB Saunders Company; 1996.

11. Bouillaguet S, Gysi P, Wataha JC, Ciucchi B, Cattani M, Godin C, and other. Bond strength of composite to dentin using conventional, one-step, and self-etching adhesive systems. *J Dent* 2001; 29(1):55–61.

12. Suzuki M, Jordan RE. Glass ionomer-composite sandwich technique. *J Am Dent Assoc* 1990; 120(1):55–7.

13. Loguercio AD, Alessandra R, Mazzocco KC, Dias AL, Busato AL, Singer Jda M, and other. Microleakage in class II composite resin restorations: total bonding and open sandwich technique. *J Adhes Dent* 2002; 4(2):137–44.

14. Welbury RR, Murray JJ. A clinical trial of the glass-ionomer cement-composite resin "sandwich" technique in Class II cavities in permanent premolar and molar teeth. *Quintessence Int* 1990; 21(6):507–12.

15. Holton JR, Nystrom GP, Douglas WH, Phelps RA 2nd. Microleakage and marginal placement of a glass-ionomer liner. *Quintessence Int* 1990; 21(2):117–22.

16. Forsten L. Clinical experience with glass ionomer for proximal fillings. *Acta Odontol Scand* 1993; 51(4):195–200.

17. Forsten L, Mount GJ, Knight G. Observations in Australia of the use of glass ionomer cement restorative material. *Aust Dent J* 1994; 39(6):339–43.

18. Wu W, Cobb EN, Dermann K, Rupp NW. Detecting margin leakage of dental composite restorations. *J Biomed Mater Res* 1983; 17(1):37–43.

19. Tulunoglu O, Uctash M, Alacam A, Omurlu H. Microleakage of light-cured resin and resin-modified glass-ionomer dentin bonding agents applied with co-cure vs pre-cure technique. *Oper Dent* 2000; 25(4):292–8.

20. Williams PT, Schramke D, Stockton L. Comparison of two methods of measuring dye penetration in restoration microleakage studies. *Oper Dent* 2002; 27(6):628–35.

21.Wibowo G, Stockton L. Microleakage of Class II composite restorations. *Am J Dent* 2001; 14(3):177–85.

22. Tay FR, Pang KM, Gwinnett AJ, Wei SH. A method for microleakage evaluation along the dentin/restorative interface. *Am J Dent* 1995; 8(2):105–8.

23. Wenner KK, Fairhurst CW, Morris CF, Hawkins IK, Ringle RD. Microleakage of root restorations. *J Am Dent Assoc* 1988; 117(7):825–8.

24. Mixson J, Eick JD, Chappell RP, Tira DE, Moore DL. Comparison of two-surface and multiple-surface scoring methodologies for in vitro microleakage studies. *Dent Mater* 1991; 7(3):191–6.

25. Abdalla AI, Davidson CL. Comparison of the marginal integrity of in vivo and in vitro Class II composite restorations. *J Dent* 1993; 21(3):158–62.

26. Greer BD, West LA, Liewehr FR, Pashley DH. Sealing ability of Dyract, Geristore, IRM, and super-EBA as root-end filling materials. *J Endod* 2001; 27(7):441–3.

27. Dragoo MR. Resin-ionomer and hybrid-ionomer cements: Part II: Human clinical and histologic wound healing responses in specific periodontal lesions. *Int J Periodontics Restorative Dent* 1997; 17(1):75–87.

28. Owens BM, Halter TK, Brown DM. Microleakage of tooth-colored restorations with a beveled gingival margin. *Quintessence Int* 1998; 29(6):356–61.

29. Davis EL, Yu X, Joynt RB, Wieczkowski G Jr, Giordano L. Shear strength and microleakage of light-cured glass ionomers. *Am J Dent* 1993; 6(3):127–9.

30. Besnault C, Attal JP. Influence of a simulated oral environment on microleakage of two adhesive systems in Class II composite restorations. *J Dent* 2002; 30(1):1–6.

31. Pradelle-Plasse N, Nechad S, Tavernier B, Colon P. Effect of dentin adhesives on the enamel-dentin/composite interfacial microleakage. *Am J Dent* 2001; 14(6):344–8.

32. Kubo S, Yokota H, Sata Y, Hayashi Y. Microleakage of self-etching primers after thermal and flexural load cycling. *Am J Dent* 2001; 14(3):163–9.

33. Brackett WW, Covey DA, St Germain HA Jr. One-year clinical performance of a self-etching adhesive in class V resin composites cured by two methods. *Oper Dent* 2002; 27(3):218–22.

34. Pontes DG, de Melo AT, Monnerat AF. Microleakage of new all-in-one adhesive systems on dentinal and enamel margins. *Quintessence Int* 2005; 33(2):136–9.

35. Neme AL, Evans DB, Maxson BB. Evaluation of dental adhesive systems with amalgam and resin composite restorations: comparison of microleakage and bond strength results. *Oper Dent* 2000; 25(6):512–9.

36. Chan MF, Jones JC. A comparison of four in vitro marginal leakage tests applied to root surface restorations. *J Dent* 1992; 20(5):287–93.

37. Kemp-Scholte CM, Davidson CL. Marginal integrity related to bond strength and strain capacity of composite resin restorative systems. *J Prosthet Dent* 1990; 64(6):658–64.

38. Gladys S, Van Meerbeek B, Braem M, Lambrechts P, Vanherle G. Comparative physico-mechanical characterization of new hybrid restorative materials with conventional glass-ionomer and resin composite restorative materials. *J Dent Res* 1997; 76(4):883–94.

39. Hallett KB, Garica-Godoy F. Microleakage of resin-modified glass ionomer cement restorations: an in vitro study. *Dent Mater* 1993; 9(5):306–11.