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Effect of New Generation Surface Sealants on the Marginal Permeability of Class V Resin Composite Restorations

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Clinical Relevance

Surface sealants, when applied to Class V resin composite restorations, can contribute to a significant reduction in microleakage, thus enhancing marginal integrity.

SUMMARY

This study evaluated, *in vitro*, the effectiveness of 5 surface sealants (Biscover, Optiguard, Seal-n-Shine, PermaSeal and DuraFinish); 1 pit and fissure sealant (Helioseal) and 1 dentin bonding agent (Adper Scotchbond MultiPurpose Adhesive) on the marginal sealing ability of Class V hybrid resin composite (Esthet•X) restorations. Ninety-six non-carious human molars were randomly assigned to 8 groups (n=12). Class V cavities were prepared on either the facial or lingual surfaces, with coronal margins in enamel and apical margins in cementum (dentin), and restored following manufacturers' instructions. Following finishing and polishing procedures, the covering agents were applied to each restoration and adjacent tooth surface, except for the control group restorations, which were not sealed. The teeth were thermocycled, immersed in a 1% methylene blue dye solution, sectioned and analyzed for dye penetration (leakage) using a 20x binocular microscope. Microleakage was evaluated at the coronal and apical margins using an 0-3 ordinal grading scale. Non-parametric data was analyzed at a $p \leq 0.05$ level of significance. The Kruskal-Wallis test showed a significant difference was exhibited among groups at the coronal margins, with Helioseal pit/fissure sealant and DuraFinish surface sealant exhibiting significantly less leakage than the control and Adper Scotchbond MultiPurpose adhesive. At the apical margins, DuraFinish surface sealant showed significantly less leakage than the Biscover, Seal-n-Shine and PermaSeal surface sealants or Helioseal pit/fissure sealant, Adper Scotchbond MultiPurpose adhesive and the control group. According to the Wicoxon signed-rank test, significantly greater leakage was revealed at the apical margins compared to the enamel margins of the material groups.

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DOI: 10.2341/05-77

INTRODUCTION

Class V carious and non-carious dental lesions (abrasion, erosion and abfraction) can be restored with glass ionomer cements, resin reinforced glass ionomer hybrid materials and, particularly, resin composite. Resin composite can be bonded micromechanically to tooth structure using various adhesive systems (total and self-etch), with predictably consistent results.[1] Quantitative adhesion testing of dental bonding agents to tooth structure has been performed using several methods, including bond strength (shear and tensile) and microleakage analysis. Studies have shown that, while inconsistent statistical correlation has been associated with bond strength and microleakage measurements, research has indicated a positive relationship, comparing the testing parameters.[2-5] Although progression (generational systems) with adhesive materials and techniques have demonstrated improved success and longevity, long-term marginal permeability (microleakage) of contaminants occurs with all restorations.[6] Microgap formation at the restoration/tooth interface, particularly at the apical region, occurs due to loss of marginal integrity caused by several factors, including material characteristics, polymerization source variables (shrinkage), cavity location and configuration (C-Factor), morphological and histological constituents of enamel and dentin, patient occlusion components, insertion technique and operator compliance with manufacturer instructions.[1,7-15]

A clinical technique (rebonding) recommended to positively influence these deficiencies and improve the marginal seal of resin composite and other esthetic restorative materials is the application of low-viscosity, unfilled resins to previously placed esthetic restorations. Following restoration, these low-viscosity resins, or covering agents, are applied to the material surface and surrounding tooth structure, infiltrating into interfacial gaps, promoting improved marginal sealing with a presumable reduction in microleakage. Also, these agents fill restoration surface micro-defects formed during material insertion (air entrapment), eliminate the O_2-inhibition layer and complete the mechanical finishing and polishing process with a resultant decrease in plaque formation and staining, along with a corresponding increase in wear resistance.[16]

Earlier attempts using pit and fissure sealants and/or dentin bonding agents as restorative covering agents were studied; however, their performance was directly related to the viscosity and wettability (fluidity) of the materials.[17-20] Currently, restorative covering agents, or "surface sealants," contain enhanced formulations, including unfilled resins (methacrylates) and other low molecular weight monomers, as well as extremely efficient photoinitiators and other modifiers. Accordingly, the effectiveness of these agents depends upon the flow rate and depth of penetration (fluidity) onto material subsurface microstructure prior to polymerization.[19, 21]

This study evaluated the effect of 5 new generation surface sealants, 1 pit and fissure sealant and 1 dentin bonding agent on the marginal permeability (microleakage) of Class V resin composites.

METHODS AND MATERIALS

Ninety-six extracted, non-carious human molars were cleaned of calculus, soft tissue and other debris using a periodontal scaling instrument. The teeth were stored in a 1% Chloramine-T solution (Fisher Chemical, Fairlawn, NJ, USA) consisting of 12% active chlorine diluted in distilled water. The teeth were then divided into equal groups of 12 and stored in distilled water immediately prior to treatment.

Cavity Design

In all groups, circular Class V cavity preparations were cut on the facial or lingual surfaces at the cementoenamel junction (CEJ), with the coronal margins located in enamel and the apical margins located in cementum (dentin). The preparations were cut with a #330 carbide bur in a high-speed handpiece cooled with an air-water spray. A bevel (0.5-mm wide) was placed on the enamel margin with a #257 diamond bur. Preparation dimensions (3.0 mm x 3.0 mm x 1.5 mm) were measured with a periodontal probe to maintain uniformity. One operator cut all preparations to ensure a calibrated size and depth. Each carbide bur was discarded after every group of teeth (12 preparations).

Restoration Groups

The teeth were randomly assigned to 8 treatment groups (n=12). All materials used followed manufacturer's instructions (Table 1).

Group 1 (control)

The preparation surfaces (enamel and dentin) were conditioned for 15 seconds with Ultra-Etch 35% phosphoric acid gel. Following application of the etchant, the preparations were thoroughly rinsed, ensuring that all etchant was removed with an air/water syringe and gently air-dried so as not to desiccate preparation surfaces. OptiBond Solo Plus was applied to the enamel and dentin surfaces with an applicator tip for 15 seconds, using a light brushing motion. The tooth surfaces were gently air-thinned for 3 seconds, then polymerized with a conventional halogen light source for 20 seconds. Esthet•X resin composite (shade A3.5) was placed in the preparations in 1 increment, with careful manipulation of the material and light polymerized for 40 seconds. All restorations were finished and polished. No surface sealant was placed on the restoration or adjacent tooth structure.

Table 1: *Materials Tested*

Material	Lot #	Manufacturer	Components (Manufacturer MSDS)
Biscover Liquid Polish	0400005393	BISCO, Inc Schaumburg, IL, USA	Ethoxylated Bisphenol A Diacrylate Urethane Acrylate Esther, Polyethyleneglycol Diacrylate
OptiGuard Surface Sealant	402363	Kerr MFG, Orange, CA, USA	Uncured Methacrylate Esther Monomers, photoinitiators
Seal-n-Shine Penetrating Finish/Polishing Resin	040602	Pulpdent Corporation Watertown, MA, USA	Acrylate resins
Helioseal Pit/Fissure Sealant	F65641	Ivoclar Vivadent NA Amhearst, NY, USA	Mono/Di Methacrylates, Titanium Dioxide, Dibenzoyl Peroxide
Adper Scotchbond MultiPurpose Adhesive	20040219	3M-ESPE Dental Products St Paul, MN, USA	Bisphenol-A Glycidylmethacrylate Hydroxyethylmethacrylate
DuraFinish Composite Glaze	05027	Parkell, Inc, Farmingdale, NY, USA	Methyl Methacrylate, Uncured Methacrylates, initiators
PermaSeal Composite Sealer/Bonding Agent	B05FC	Ultradent Product, Inc South Jordan, UT, USA	Tertiary Amine, Methacrylate Monomer
OptiBond Solo Plus Adhesive	405343	Kerr MFG, Orange, CA, USA	Alkyl Dimethacrylate Resins, Ethyl Alcohol, Ba Glass
Ultra-Etch Etchant Gel	NA	Ultradent Products, Inc South Jordan, UT, USA	35% phosphoric acid
Adper Scotchbond Etchant Gel	4BW	3M-ESPE Dental Products St Paul, MN, USA	35% phosphoric acid
Etch Royale Etching Gel	040428	Pulpdent Corp Watertown, MA, USA	37% phosphoric acid
Esthet•X Micro-Matrix Hybrid Resin Composite	0307313	Dentsply/Caulk Milford, DE, USA	Bisphenol-A Glycidylmethacrylate Ba Fluoro Aluminoborosilicate glass fillers

Group 2 (Biscover)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures were performed as in Group 1. The restorations/adjacent tooth surfaces were conditioned with Ultra-Etch 35% phosphoric acid gel followed by gentle rinsing and drying. One thin coat of Biscover was applied to the restoration/tooth surfaces, gently air-thinned and light polymerized for 15 seconds.

Group 3 (OptiGuard)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures, were performed similar to Groups 1 and 2. The restorations/adjacent tooth surfaces were conditioned with UltraEtch 35% phosphoric acid for 15 seconds, followed by gentle rinsing and drying. One coat of OptiGuard was applied to the restoration/tooth surfaces, gently air thinned and light polymered for 20 seconds.

Group 4 (Seal-n-Shine)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures, were performed as in Groups 1 through 3. The restorations/adjacent tooth surfaces were conditioned with Etch Royale 37% phosphoric acid gel for 15 seconds, followed by gentle rinsing and drying procedures. One coat of Seal-n-Shine was applied to the restoration/tooth surfaces and light polymerized for 20 seconds.

Group 5 (Helioseal)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures, were performed as in Groups 1 through 4. The restoration/adjacent tooth surfaces were etched with 37% phosphoric acid gel for 30 seconds, followed by careful rinsing/drying procedures. Helioseal pit and fissure sealant was then applied in a single coat to the surfaces and light polymerized for 20 seconds.

Group 6 (Adper Scotchbond MultiPurpose Adhesive)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures, were performed as in Groups 1 through 5. The restorations/adjacent tooth surfaces were conditioned with Adper Scotchbond 35% phosphoric acid gel for 15 seconds, followed by gentle rinsing and drying procedures. Adper Scotchbond MultiPurpose Adhesive was applied to the surfaces in a single coat and light polymerized for 10 seconds.

Group 7 (DuraFinish)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures, were performed as in Groups 1 through 6. The restorations/adjacent tooth surfaces were conditioned with UltraEtch 35% phosphoric acid gel for 15 seconds, followed by gentle rinsing and drying procedures. A thin layer of DuraFinish was applied to the surfaces and light polymerized for 30 seconds.

Group 8 (PermaSeal)

Preparation conditioning, placement and polymerization of the adhesive agent and composite, as well as finishing/polishing procedures, were performed as in Groups 1 through 7. The restorations/adjacent tooth surfaces were conditioned with Ultra-Etch 35% phosphoric acid gel for 5 seconds, followed by gentle rinsing and drying procedures. PermaSeal was rubbed onto the surfaces for 5 seconds, gently air thinned and light polymerized for 20 seconds.

Following restoration, all teeth were stored in distilled water for 24 hours prior to finishing/polishing and application of surface covering. The composites were finished/polished with Sof-Lex (3M-ESPE, St Paul, MN, USA) flexible aluminum oxide disks of decreasing abrasiveness (coarse to superfine). All covering agents were applied to the entire restoration and surrounding tooth surface (1.5 mm beyond the tooth/restoration interface).

All restorative materials were polymerized with a Schein (Sullivan-Schein, Melville, NY, USA) conventional halogen light. The light had previously been monitored with a radiometer and provided adequate intensity (≤800 mW/cm^2).

The teeth were stored in a humid environment at room temperature prior to thermocycling procedures.

Assessment of Microleakage

The teeth were thermocycled for 1000 cycles in separate water baths of 5°C and 55°C ± 2°C, with a dwell time of 60 seconds in each bath and a transfer time of 3 seconds. The root apices were sealed with utility wax, and 2 coats of nail varnish were applied to the entire tooth surface, leaving a 2.0-mm window around the restoration margin. The teeth were immersed in a 1% methylene blue dye solution for 24 hours at room temperature, removed, thoroughly rinsed and allowed to dry in order to set the dye. The teeth were invested in clear, autopolymerizing resin (Castin' Craft Clear Plastic Casting Resin, ETI, Fields Landing, CA, USA) and labeled. A Buehler Isomet (Buehler Ltd, Evanston, IL, USA) low-speed diamond saw, cooled with water, sectioned each tooth block transverse to the tooth through the center of the restoration from the facial to the lingual surface. Two sections were obtained from each specimen block (n=24), each side of the cut yielded dye penetration (leakage) readings. Each section was examined at 20x magnification using a Meiji (Meiji-Labax Co, Tokyo, Japan) binocular microscope (2 readings performed at the coronal and apical margins of each tooth block). Based on an ordinal ranking system, the degree of leakage was determined as follows: 0 = no dye penetration; 1 = dye pentration up to one-half the extension of the cavity wall; 2 = dye penetration greater than one-half the extension of the cavity wall, not including the axial surface; 3 = dye penetration greater than one-half the extension of the cavity wall, including the axial surface.

Statistical Analysis

To determine statistically significant differences in leakage at the coronal and apical margins separately among the treatment groups, non-parametric data was analyzed using the Kruskal-Wallis test. If a significant difference was observed at either margin location, a Mann-Whitney U multiple comparison test was performed. An intergroup comparison (coronal versus apical margin locations) was completed using the Wilcoxon signed-rank test. All statistical tests were performed at a $p \leq 0.05$ level of significance, using Statview 5.0 (SAS Institute, Cary, NC, USA).

RESULTS

Table 2 lists the distribution of microleakage scores at the coronal (enamel) and apical (dentin) margin locations. Mean leakage scores are shown in Figure 1.

The Kruskal-Wallis test revealed a significant (p=.0244) difference between material groups at the enamel margins. The DuraFinish surface sealant and Helioseal pit/fissure sealant exhibited significantly less leakage compared to the control and Adper Scotchbond MultiPurpose groups. At the dentin margins, a significant (p<.0001) difference was also observed among the groups. Significantly less leakage was exhibited by the DuraFinish surface sealant compared to the control group (p<.0001), Helioseal pit/fissure sealant (p=.0078), Biscover (p=.0001), Seal-n-Shine (p=.0093), PermaSeal (p=.0013) surface sealants and Adper Scotchbond MultiPurpose (p=.0293) adhesive. The Optiguard and Adper Scotchbond MultiPurpose groups showed significantly less leakage than the control group and the Biscover group.

The Wilcoxon signed rank test, which compared all 96 coronal versus apical surfaces pair-wise, confirmed there was significantly greater leakage (p<.0001) along the dentin than the enamel margins of all groups.

DISCUSSION

Microleakage has been defined as the "marginal permeability to bacterial, chemical and molecular invasion at the tooth/material interface" and is the result of breakdown of this boundary, causing microgap formation with resultant discoloration, recurrent caries, pulpal inflammation and possible restoration replacement.[22-26] Innovative insertion techniques (incremental placement) have been used to decrease the forces of material shrinkage following polymerization.[26-28] Adhesive systems have also been substantially improved, employing material specific formulations and simpler application techniques.[1,29-30] Although these technique and material improvements have been effective in changing the performance of esthetic restorative systems, efforts to prevent the formation of contraction gaps, thus completely eliminating microleakage, have been unsuccessful.

Much investigation has advocated the use of low-viscosity bonding resins as covering agents for newly placed and previously inserted resin composite restorations. These materials were initially used to fill minor surface micro-defects formed at the restoration/tooth interface.[31-32] Further research studied low-viscosity pit and fissure sealants and dentin bonding agents as covering agents for composites.[20] Studies showed these materials were ineffective in preventing marginal leakage, possibly due to forces of polymerization contraction. However, these studies concluded that the degree of penetration of a covering agent into the interfacial micro-gap directly corresponded to the material's viscosity (flowability) and capacity to adequately wet the restoration/tooth surfaces. Also, these materials must have a coefficient of thermal expansion and contraction similar to tooth structure, and they must be compatible with the respective restorative material. Further studies reported conflicting information regarding placement of covering agents prior to and following finishing/polishing procedures, respectively.[17,33] Additional research confirmed that low-viscosity "surface sealants" enhanced marginal sealing ability and decreased the percolation of oral fluids, while reducing surface micro-defects with a corresponding reduction in occlusal wear.[16,21,34-38] However, some investigators found that surface sealants and other covering adhesives did not "provide optimal superficial integrity."[39]

The space between the restorative material and tooth surface of a cavity preparation has been identified as being between 10 to 20 microns wide, permitting bacterial access and recurrent caries.[40] For adequate penetration of a surface sealant into an interfacial gap, a low-viscosity resin (200 cp or less) is required prior to polymerization.[20] For satisfactory surface wetting, the surface tension of the sealing material should be equal to or less than the critical surface tension of the

Table 2: *Distribution of Microleakage Scores (n=24)*

		Degree of Microleakage			
Group	**Coronal Margins**	**0**	**1**	**2**	**3**
1	Control	7	9	5	3
2	Biscover	16	3	1	4
3	Optiguard	14	5	3	2
4	Seal-n-Shine	11	6	4	3
5	Helioseal	19	1	3	1
6	SBMP	8	10	1	5
7	DuraFinish	20	2	0	2
8	PermaSeal	15	6	2	1
Group	**Apical Margins**	**0**	**1**	**2**	**3**
1	Control	0	0	024	24
2	Biscover	0	0	123	23
3	Optiguard	3	6	114	14
4	Seal-n-Shine	2	2	218	18
5	Helioseal	2	1	318	18
6	SBMP	2	4	216	16
7	DuraFinish	9	4	110	10
8	PermaSeal	1	1	022	22

0 Degree: no dye penetration; 1 Degree: dye penetration up to one-half the extension of the cavity wall; 2 Degree: dye penetration greater than one-half the extension of the cavity wall, not including the axial surface; 3 Degree: dye penetration greater than one-half the extension of the cavity wall, including the axial surface

SBMP: Adper Scotchbond MultiPurpose Adhesive

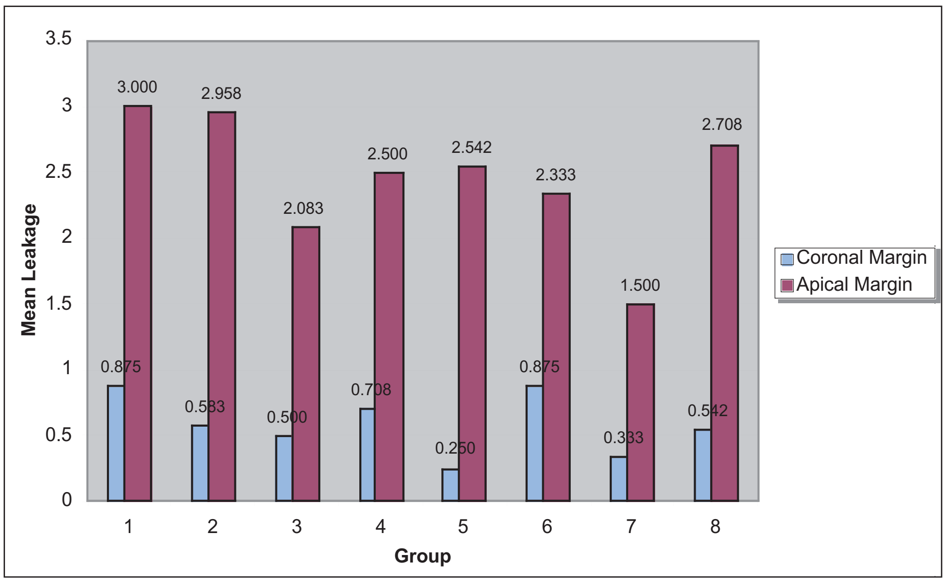

Figure 1. *Mean group leakage at the coronal and apical margins.*

restoration/tooth structure.[41] A highly polished, clean, dry surface free of saliva and/or smear layer debris permits favorable material wetting for a successful restoration seal.[20] The etched enamel/restoration surface demonstrates an ideal environment for placement of surface sealants, while at the dentin margin, a satisfactory result is challenging due to the complex nature of dentin; that is, the pressure gradient of the pulp and capillary action of fluid flowing outward through the dentinal tubules, filling the interfacial gaps.[6,12,42-43]

In this study, new generation, low-viscosity surface sealants specifically marketed for restoration glazing and/or marginal sealing, were tested. Their effectiveness in decreasing microleakage was compared to a pit and fissure sealant and a dentin bonding agent. Different materials were chosen in order to evaluate how their composition and physical characteristics influenced the fluidity and penetrability, thus preventing microleakage. Pit and fissure sealants and bonding agents can contain minute filler particles and opaquers that decrease fluidity of the material with a concurrent reduction in wettability of the prepared surfaces.[19]

The results of this study show that none of the materials tested were completely resistant to dye penetration (leakage), especially at the dentin margins. Significantly less leakage was exhibited at the enamel compared to the dentin margins. This result was expected and is in agreement with other research, whereby decreased permeability and increased sealing ability was observed at the enamel margins.[19,21,37-38] At the enamel margin, the Helioseal group revealed the lowest leakage values at the enamel margin and displayed significantly less leakage than the Adper Scotchbond MultiPurpose and control groups. DuraFinish revealed the lowest values (not significant) among the surface sealant groups.

At the dentin margin, all covering agents showed some degree of marginal protection (not necessarily always significant), with DuraFinish revealing significantly less leakage than the control group, Biscover, Seal-n-Shine and PermaSeal surface sealant groups, Helioseal pit/fissure sealant and Adper Scotchbond MultiPurpose adhesive.

The results were in limited agreement, with similar surface sealant studies reporting a better seal produced by Fortify (Biscover), a first generation surface sealant, compared to other low-viscosity adhesive agents.[38] A separate investigation reported significantly better results exhibited by 2 earlier generation surface sealants, Fortify and Protect-It, compared to a control group (no surface sealant).[21]

Photoiniator molecules in dental resin materials (adhesives, composites, etc) absorb visible light energy from an irradiation source (curing light) to initiate photopolymerization. Each photoiniation system has an absorption spectrum or wavelength range. Emission of light from curing units, corresponding (overlapping) with peak wavelength absorption of the photoiniator, is necessary for efficient material polymerization. Camphorquinone (CQ), the most common photoiniator, is used in the majority of resin products. Although CQ has wide spectral distribution (wavelength range) absorption from 400 to 500 nanometers (nm), with a peak sensitivity of 468 nm, disadvantages include its yellow color following polymerization. An alternative photoiniator, 1-phenyl-1, 2-propanedione (PPD), with an absorption spectrum from ultraviolet (UV) to visible wavelength range, can also be used for resin polymerization. PPD, which has a narrower effective wavelength range (350 to 420 nm), with peak absorption at 380 nm, imparts a perceptibly lighter shade of yellow, upon polymerization, thus reducing potential post-treatment curing problems.

Possible reasons for the reduced microleakage values associated with the DuraFinish product include: 1) DuraFinish incorporates PPD as the photoiniator to control shade changes following resin application. Potentially, a greater degree of polymerization can occur, as light energy from the UV to visible spectrum is absorbed, causing increased conversion of the PPD molecule, 2) the recommended curing period of DuraFinish, 30 seconds per manufacturer, was longer than the other surface sealant materials, 3) DuraFinish incorporates a nano-hybrid filler particle in its resin matrix formula.

The results of this study indicate that microleakage was not affected by tooth type, tooth surface (facial or lingual) preparation orientation or operator technique; however, cavity preparation/restoration (enamel or dentin surface) location does support the conclusion that enamel surface bonding provides a significantly better surface for the adhesion of esthetic, resin-based restorative materials. Enamel surface morphology, primarily inorganic content and water, is very conducive following removal of the smear layer to micro-mechanical adhesion of resin components. As previously stated, the dentin surface substructure and fluid movement, C-Factor (total dentin surface bonding area), together with orientation of the enamel rods and dentinal tubules to Class V preparation walls, play significant roles in total tooth surface bonding and long-term restoration success and longetivity.[6,12,44,45]

CONCLUSIONS

The results of this *in vitro* microleakage study may not predict the effectiveness of surface sealants, *in vivo*; however, the results showed that a significantly better seal was exhibited at the coronal (enamel) margin compared to the apical (dentin) margin of all groups. The results do suggest that, among the surface sealant materials, DuraFinish was most effective (significantly less leakage at the dentin margins than other covering agents) when applied to resin composite restorations.

Acknowledgements

The authors thank the following manufacturers for their generous material contributions used in this study: BISCO, Inc; 3M-ESPE Dental Products; Kerr MFG; Ultradent Products, Inc; Pulpdent Corp; Dentsply/Caulk and Ivoclar Vivadent.

(Received 23 May 2005)

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