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Microleakage of Posterior Composite Restorations Lined with Self-adhesive Resin Cements

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Clinical Relevance

Two self-adhesive resin cements resulted in minimal microleakage scores when used as liners in Class II composite restorations.

SUMMARY

Purpose: This study determined the microleakage of Class II composite restorations lined with self-adhesive resin-cements as bonding agents. Methods: Forty-five caries-free extracted molars were sterilized, mounted in acrylic bases and divided into five equal groups according to the adhesive used: RXU (RelyX-Unicem, self-adhesive resin-cement, 3M ESPE), BRZ (Breeze, self-adhesive resin-cement, Pentron Clinical Technologies), MON (Monocem, self-adhesive resin-cement, Shofu), PAN (Panavia-F-2.0, resin-cement with self-etch primer, Kuraray) and SBMP (Scotchbond Multi-Purpose, total-etch three-step adhesive, 3M ESPE). Class II MOD cavities were prepared with gingival floors located on dentin at one side and on enamel on the other. The bonding agent SBMP, used according to the manufacturer's directions, or a thin layer of resin cement, was applied on all cavity walls and cavosurface margins. Filtek Z250 (3M ESPE) was used to restore cavities in all groups. The specimens were subjected to 1,000 thermocycles between 5°C and 55°C. All tooth surfaces were sealed with nail-varnish to within 1 mm from the restoration margins. The specimens were immersed in 2% fuchsine red solution for 24 hours at 37°C. The teeth were then sectioned mesiodistally and dye penetration was assessed

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according to a five-point scale. Data were statistically analyzed with the Chi-square test (*p*<0.05). Results: Microleakage scores revealed that, on enamel margins, the SBMP group had significantly less microleakage than the RXU and BRZ groups, which, in turn, had significantly less microleakage than the MON and PAN groups; whereas on dentin margins, the RXU and BRZ groups had significantly less microleakage than the SBMP, MON and PAN groups. Conclusions: This *in-vitro* study showed that, when two self-adhesive resin-cements (RXU & BRZ) were used as liners in Class II composite restorations, they resulted in low microleakage scores as compared to the two other cements at both the enamel and dentin cavosurface margins.

INTRODUCTION

One major cause of failure of Class II resin composite restorations is recurrent caries.[1] Microgaps at the tooth-restoration interface permit the ingress of fluids and bacteria, a phenomenon referred to as microleakage, which contributes to the development of recurrent caries.[2-4] Composite materials undergo a volumetric polymerization shrinkage of about 2%.[5] Stresses generated by polymerization shrinkage can reach values ranging from 13 to 17 MPa.[6-7] Such high stresses can cause bond failure, with the material pulling away from the cavity margins during polymerization, with subsequent gap formation.[8] In the Class II situation, bond strength at the gingival margin is typically less than ideal and the gingival margin is particularly susceptible to marginal gap formation and microleakage.[9]

Several methods have been developed to counteract stress buildup along the tooth-restoration interfaces during the polymerization of Class II composite restorations. These methods utilize different light polymerization cycles and strategic incremental placement techniques in order to reduce the C-factor.[7-12] More recently, the use of glass fiber inserts was suggested for reducing overall polymerization contraction at the gingival margins of Class II composite restorations.[13]

Self-adhesive resin cements have been developed for use without the need for a separate bonding agent. By eliminating the etching, rinsing, priming and adhesive application steps, usage is simpler and less prone to potential errors associated with these steps. While these materials are manufactured to be primarily used for the cementation of crowns, fixed partial dentures and inlays/onlays, their potential for use as cavity liners has not as yet been explored.

Self-adhesive resin cements offer a simplified bonding procedure that is similar to self-etch bonding agents. However, self-adhesive cements are partially filled and would be expected to have improved mechanical properties over self-etch bonding agents. Furthermore, a self-adhesive tooth-cement-composite joint would be thicker than a tooth-adhesive-composite and, therefore, may potentially better resist polymerization contraction forces by viscous flow prior to complete setting. This may result in improved stress distribution as an intermediary layer between structures with greater elastic moduli, dentin and composite substrates.

The current study determined the microleakage of Class II resin composite restorations lined with self-etch or self-adhesive resin cements and compared them to conventionally-bonded resin composite restorations (total-etch three-step bonding). The null hypothesis being that there will be no significant difference in microleakage scores among the different experimental groups.

METHODS AND MATERIALS

Forty-five freshly extracted intact molars were employed. The teeth were sterilized with gamma irradiation (Gamma cell 220, Atomic Energy Ltd, Mississauga, Canada) and stored in water at 4°C. They were then cleaned with periodontal scalers and their apical foraminae were sealed with glass ionomer cement (GC Fuji I, GC Corporation, Tokyo, Japan). Two layers of nail varnish were applied onto the root surfaces to prevent dye penetration during microleakage testing. The roots of the teeth were then embedded in acrylic resin bases (Ivolen, Ivoclar Vivadent, Schaan, Liechtenstein) up to 2 mm apical to the cemento-enamel junction (CEJ). The teeth were then pumiced and divided into five equal groups (n=9). Standardized Class II MOD cavities were prepared with gingival margins located in dentin at one side (1.0 mm below the CEJ), and enamel at the other (1.0 mm above CEJ). All line angles were prepared rounded with tungsten carbide burs #245 (SS White, Great White Series, Lakewood, NJ, USA) in a water-cooled air turbine handpiece. The cavities were 4.0 mm wide bucco-lingually, with a pulpal floor depth of 2 mm and a 1.5 mm axial depth. The dimensions of the preparations were verified with a periodontal probe. A universal metal matrix band/retainer was placed around each prepared tooth and supported externally by low-fusing compound to maintain adaptation of the band to the cavity margins. Five different materials were used for bonding composite restorations: RXU (RelyX-Unicem, self-adhesive resin cement, 3M ESPE, St Paul, MN, USA), BRZ (Breeze, self-adhesive resin cement, Pentron Clinical Technologies, Wallingford, CT, USA), MON (Monocem, self-adhesive resin cement, Shofu Inc, Kyoto, Japan), PAN (Panavia-F 2.0, resin cement with self-etch primer, Kuraray Dental

Table 1: *Steps Followed for Materials Application*

Materials (Manufacturers)	Etchant	Primer	Adhesive	Luting Resin	Resin Filling
RelyX Unicem (3M ESPE, St Paul, MN, USA) Lot #330621	-------	------	------	Apply a thin layer of self-adhesive resin cement on all cavity surfaces with micro brush. Light cure (20 seconds).	Incremental application of resin composite restoration (Filtek Z250).
Breeze (Pentron Clinical, Wallingford, CT, USA) Lot #165893	-------	------	------	Apply a thin layer of the self-adhesive resin cement on all cavity surfaces with micro brush. Light cure (40 seconds).	Incremental application of resin composite restoration (Filtek Z250).
Monocem (Shofu Dental Co, San Marcos, CA, USA) Lot #080118	-------	------	------	Apply a thin layer of the self-adhesive resin cement on all cavity surfaces with micro brush. Light cure (20 seconds).	Incremental application of resin composite restoration (Filtek Z250).
PanaviaF 2.0 (Kuraray Medical Inc, Okayama, Japan) Lot #61155)	-------	Mix equal amounts of A & B ED primer II, apply the mix, and wait (30 seconds), gently air-dry.	---------	Mix equal amounts of A & B pastes (20 seconds), apply a thin layer of the mixture. Light cure (20 seconds).	Incremental application of resin composite restoration (Filtek Z250).
Scotchbond Multi-Purpose (3M ESPE, St Paul, MN, USA) Lot #200080516	37% phosphoric acid etching (15 seconds) water rinse (15 seconds) air-dry (5 seconds).	Apply primer and air dry (5 seconds).	Apply adhesive and light-cure (10 seconds).	---------	Incremental application of resin composite restoration (Filtek Z250).

Figure 1: *Representative prepared specimen with metal-matrix retainer that is secured with low-fusing compound. All cavity surfaces were lined with bonding adhesive or resin cement, then light-cured before restoration with composite.*

Co, Okayama, Japan) and, as a control group, SBMP (Scotchbond Multi-Purpose, total-etch adhesive, 3M ESPE).

The materials were applied according to the manufacturers' instructions (Table 1). For the cement groups, a thin layer of mixed cement was carefully applied to the entire cavity walls and floor and onto the cavosurface margins with a microbrush (Figure 1). Table 1 outlines the application procedures of the cements/bonding agent for each group. A Demi-LED light polymerization unit (Kerr Corporation, Middleton, WI, USA, mW/cm^2) was used for photopolymerization. Filtek Z250 universal composite restorative (3M ESPE) was used as the restorative material. An approximately 1 mm-thick horizontal layer of the composite was carefully adapted onto the gingival floor and light-polymerized for 40 seconds before a second diagonal increment was added and similarly light-polymerized. Third, fourth and fifth increments, filling up the remainder of the prepared cavity, were placed and similarly light-polymerized. The occlusal surfaces of the restorations were contoured with football-shaped multi-fluted carbide burs in a high-speed handpiece with water-cooling. Polishing was followed with aluminum oxide disks (Sof-Lex LX Pop-on, 3M ESPE). Excess proximal flash was removed with a sharp hand scaler. One investigator performed all the cavity preparations and restorations, while another examined the specimens to ensure that the cavities conformed to the dimensions and the restorations were free from defects. The restored teeth were stored in distilled water at 37°C for seven days. The specimens were then thermocycled between 5°C and 55°C (dwell time 30

Figure 2: *Proximal views of representative restored specimens.*

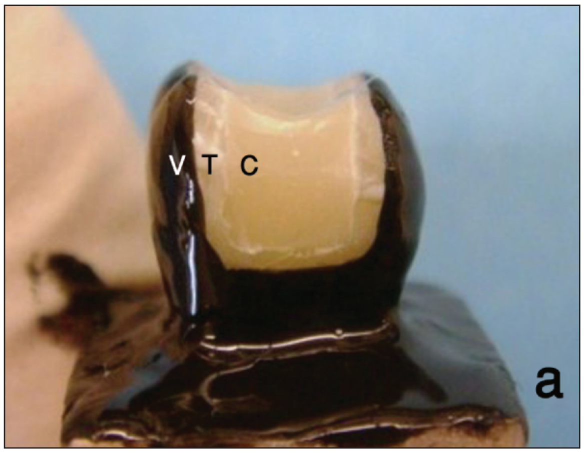

Figure 2a: *Two layers of black nail varnish were applied all over exposed surfaces to within 1 mm of the tooth-restoration interface. (C) = composite, (T) = tooth structure, (V) = varnish seal.*

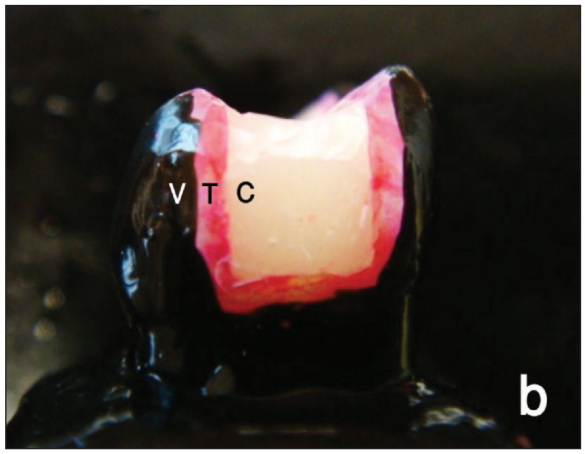

Figure 2b: *Specimen after immersion in the red dye for 24 hours. (C) = composite, (T) = tooth structure, (V) = varnish seal.*

seconds in each water bath with a transfer time of 15 seconds between baths) for 1,000 cycles.

Two layers of nail varnish were applied to the coronal tooth surfaces to within 1 mm from the tooth-restoration margins (Figures 2a and 2b). The specimens were then immersed in a 2% fuchsine red solution for 24 hours at 37°C, then rinsed with tap water for five minutes. Each tooth was then sectioned mesiodistally with a low-speed microslicing machine (Isomet, Buehler, Lake Buff, IL, USA) into two equal sections. All the sections were photographed with a high-resolution scanner (4800 x 9600 dpi, CanoScan 880F, Canon USA Inc, Melville, NY, USA) to produce digital images. The section with more dye penetration was selected to represent the specimen. The extent of die penetration was scored according to a five-point scale: 0 = no leakage, 1 = leakage extending to the outer half of the gingival floor, 2 = leakage extending to the inner half of the gingival floor, 3 = leakage extending past the gingival floor up to two-thirds of the axial wall, 4 = leakage extending through the axial wall up to the DEJ level. Two independent examiners evaluated the extent of dye penetration for each section. In case of disagreement, a third examiner was consulted to resolve the dispute. Chi square analysis (Procedure Frequency of SAS) was used to test the effect of the adhesive and tooth structure (enamel and dentin) on dye penetration scores ($p<0.05$). Statistical analysis was carried out using an SAS program (SAS 1988, Release 6.03 ed, SAS Institute, Cary, NC, USA).

The interfacial cement thicknesses at the axial wall and pulpal and gingival floors were measured with a traveling spot insight camera (Model 3.2.0, Diagnostic Instruments Inc, Sterling Heights, MI, USA) under an optical microscope at 60x magnification (SMZ800, Nikon Instruments Inc, Melville, NY, USA), and the range of the intermediate layer thickness was recorded.

RESULTS

For the SBMP group only, microleakage scores were significantly higher at the dentin gingival margin than at enamel ($p=0.037$). For each of the four cement groups, no significant difference was found between the microleakage scores at dentin and the enamel gingival margins ($p>0.05$). However, the Chi-square test revealed a significant difference in microleakage scores at the dentin gingival margins among the groups, except between RXU and BRZ ($p>0.05$) and between MON and PAN ($p>0.05$). Similar results were reported in the enamel gingival margins for the four cement groups. The RXU and BRZ groups showed the lowest microleakage scores at the dentin side, followed by the control (SBMP) group. While at the enamel side, SBMP showed the lowest microleakage, followed by the RXU and BRZ groups. The highest microleakage scores were recorded with the PAN and MON groups. Distribution of the microleakage scores among all groups is given in Table 2. Figures 3-7 show images of representative tooth sections from each group.

The intermediate cement layer thickness ranges were: RXU (26-61 µm), BRZ (23-68 µm), MON (28-74 µm) and PAN (13–100 µm). The thickness of the interfacial SBMP bonding agent could not be detected under light microscope.

DISCUSSION

Previous studies reported that composite restorations showed relatively greater microleakage at the gingival margins than at the occlusal margins.[14-15] The method used for the assessment of microleakage of Class II composite restorations in the current study has been

Table 2: *Prevalence of Microleakage Score in Different Groups and Tooth Structures*

Group		Enamel			Dentin			P2
	Score	#	%	P1	#	%	P1	
SBMP	0	6	66.67	a	1	11.11	d	0.037*
	1	1	11.11		0	0		
	2	0	0		0	0		
	3	1	11.11		2	22.22		
	4	1	11.11		6	66.67		
	Total	9	100		9	100		
RXU	0	2	22.22	b	4	44.44	b	0.289 NS
	1	7	77.78		4	44.44		
	2	0	0		1	11.11		
	3	0	0		0	0		
	4	0	0		0	0		
	Total	9	100		9	100		
BRZ	0	1	11.11	b	5	55.56	b	0.099 NS
	1	7	77.78		3	33.33		
	2	1	11.11		0	0		
	3	0	0		1	11.11		
	4	0	0		0	0		
	Total	9	100		9	100		
MON	0	0	0	c	0	0	c	1.000 NS
	1	0	0		0	0		
	2	0	0		0	0		
	3	0	0		0	0		
	4	9	100		9	100		
	Total	9	100		9	100		
PAN	0	2	22.22	c	0	0	c	0.261 NS
	1	0	0		1	11.11		
	2	0	0		0	0		
	3	0	0		1	11.11		
	4	7	77.78		7	77.78		
	Total	9	100		9	100		

P1= Probability level for the effect of tooth structure, groups with the same letter are not significantly different.
P2 = Probability level for the effect of tooth structure.
Means with the same letter within each column are not significantly different at $p \leq 0.05$.
NS = Insignificant ($p>0.05$).

previously reported.[13] Sterilization of the extracted teeth with gamma irradiation was used in the current study, as it has been shown to be effective and has no adverse effects on dentin structure or its permeability.[16] It was also reported that gamma irradiation neither affects the bond strength to dentin nor alters the dentin surface morphology.[17] Although seven days storage in distilled water at room temperature is relatively short compared to the life expectancy of composite restorations, it was deemed to be appropriate in the current study, considering that cements are more susceptible than restorative composites to dissolution during and immediately after their initial set.[18]

Since statistical analysis revealed variability in the mean microleakage scores among the different groups, the null hypothesis could not be substantiated. The outstanding performance of self-adhesive resin cements with indirect restorations (inlays, onlays and crowns) was the main motivating factor for conducting the current study.[19-20] Under the indirect restoration technique, self-adhesive resin cements are subjected to hydraulic stresses transmitted by the hard restoration under the biting forces exerted by the patient during cementation. This might be helpful for some cements that produce a better seal, as it may assist in limiting the adverse effects of polymerization contraction. However, varying results were obtained among the groups of self-adhesive cements used in the current study with direct restoration. RXU and BRZ resulted in significantly lower microleakage scores and, therefore, can be considered for use under direct composite restorations. In contrast, PAN and MON resulted in significantly high-

Figure 3: *Representative photograph of microleakage for the RXU group. The enamel side (E) shows no microleakage at the tooth-composite interface (only the enamel tooth structure is stained with the dye). The dentin side (D) shows no microleakage.*

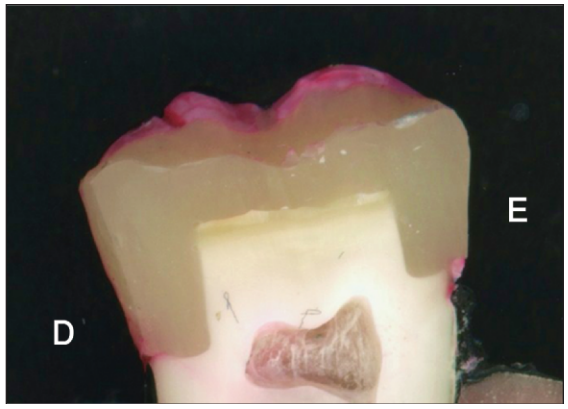

Figure 4: *Representative photograph of microleakage for the BRZ group. The enamel (E) and dentin (D) sides show microleakage extending to the outer half of the gingival floor (score 1).*

Figure 5: *Representative photograph of microleakage for the MON group. Photograph shows microleakage extended through the axial wall up to the pulpal floor (score 4) at both the enamel side (E) and the dentin side (D).*

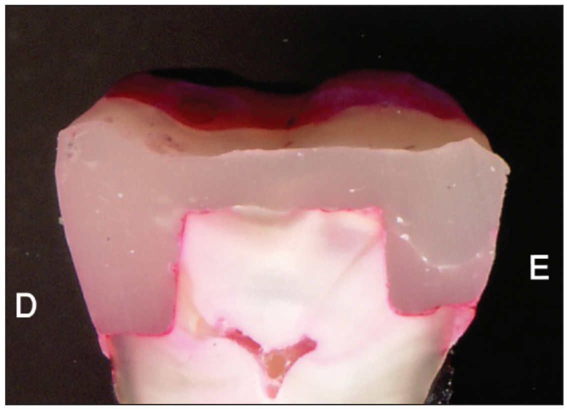

Figure 6: *Representative photograph for the PAN group. The photograph shows microleakage extended through the axial wall up to the pulpal floor (score 4) at both the enamel (E) and dentin side (D).*

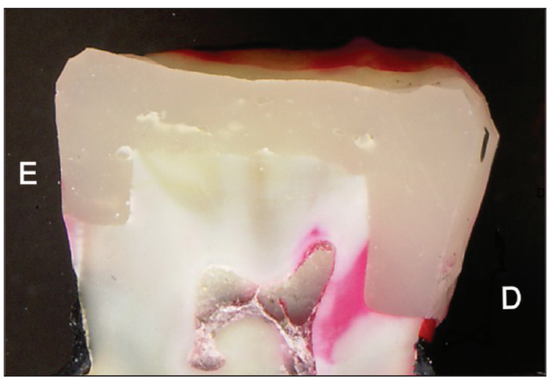

Figure 7: *Representative photograph for the SBMP group (control). The photograph shows no microleakage at the enamel side (E) and microleakage extending past the gingival floor up to two-thirds of the axial wall (score 3) at the dentin side (D).*

er microleakage scores at both the dentin and enamel margins and, therefore, should not be considered for such application. It is speculated that the different microleakage results of the self-adhesive resin cements can be explained partly by their different functional monomers and different chemical compositions. Differences in pH values may influence the ability of some of these cements to appropriately condition enamel and dentin in the direct restoration technique, thus resulting in less than ideal adhesion with subsequent microleakage. RXU was shown to have a low initial pH that rapidly rises upon mixing.[21] It seems, however, that this was sufficient to provide restorations with minimal microleakage.

Two studies reported low microleakage and good marginal seal when PAN was used with metal and ceramic crowns.[22-23] Other studies reported high bond strength with PAN when used with prepolymerized resin composite blocks.[20,24-25] The less-than-ideal performance of

PAN in the current study can be attributed to the direct (unpolymerized) nature of the restorations that were placed. Under the indirect restoration technique, the resin cement is sandwiched between the cavity surfaces and overlying prepolymerized restoration, both hard structures, thus, it is subjected to reduced polymerization contraction stresses. In contrast with direct restoration, the resin cement is subjected to contraction stresses of the overlaying resin composite increment.

Different thermal expansion coefficients of the restorative material and tooth structure may explain the high microleakage scores of PAN and MON. In the current study, all specimens were subjected to 1000 cycles between 5°C and 55°C, which is considered an appropriate artificial aging test according to ISO TR Standard 11405: 1994.[26] The coefficient of thermal expansion for Filtek Z250 was reported to be 41.5x 10^{-6}/°C,[27] while for enamel and dentin, the values were significantly lower at 11 x 10^{-6}/°C and 17 x 10^{-6}/°C, respectively.[28] It has been reported that the warm water bath (55°C) may accelerate the hydrolysis of the component of the interfacial material (bonding agent) with subsequent water absorption and leaching of the broken down collagen or poorly-polymerized resin oligomers.[29] The mismatch in the coefficient of thermal expansion may also create stresses at the bonding interface, allowing water percolation and, thus, increased microleakage. However, Crim and others found no difference in dye penetration during microleakage testing when specimens were thermocycled between 100 and 1500 cycles.[30] Therefore, one can only assume a limited coefficient of thermal expansion influence on the current study results.

The main purpose of applying a low-stiffness intermediate material layer is to absorb part of the stresses generated by composite polymerization shrinkage. For this reason, thicker adhesive layers of unfilled adhesives, filled adhesives and flowable composites, have been proposed for the dentin-composite interface. Van Meerbeek and others confirmed the positive effect of the elastic and low viscosity intermediate layer on the marginal adaptation and retention of composite restorations.[31] Braga and others also suggested that an elastic intermediate layer will increase cavity wall compliance and, therefore, decrease the destructive contraction stresses of direct composite restorations.[7] However, the results of the current study did not confirm the benefits of a thick intermediate layer at the tooth-composite interface. RXU and BRZ, which had an intermediate layer thickness range (23-68 µm), had low microleakage scores, while PAN and MON showed high microleakage results regardless of their thick intermediate layer (13–100 µm). It is possible that other factors, such as chemical composition or degree of polymerization contraction, played a larger role in microleakage than did the cement thickness or elasticity.

CONCLUSIONS

Within the limitations of this *in vitro* study, it can be concluded that:

1. Minimal leakage was observed with RelyX-Unicem and Breeze cements at both the dentin and enamel margins.
2. Panavia F 2.0 and Monocem resulted in significantly higher microleakage scores at both the dentin and enamel margins.

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