In vitro evaluation of microleakage of indirect composite inlays cemented with four luting agents

David A. Gerdolle, DDS,[a] Eric Mortier, DDS,[b] Carole Loos-Ayav, MD,[c] Bruno Jacquot, DDS,[d] and Marc M. Panighi, DDS, PhD[e]
Henri Poincaré University and University Hospital, Nancy, France [Q1]

Statement of problem. Microleakage around dental restorations is implicated in the occurrence of secondary carious lesions, adverse pulpal response, and reduced restoration longevity.

Purpose. The aim of this in vitro study was to evaluate the microleakage of indirect resin composite inlays cemented with 4 luting agents.

Material and methods. Standardized Class V inlay preparations overlapping the cemento-enamel junction were prepared on the buccal and lingual surfaces of 40 extracted human mandibular third molars. Eighty postpolymerized, heat-treated resin composite inlays (Targis, 72 specimens, 8 controls) were processed in stone replicas and cemented into the preparations using 4 luting agents (n = 18 + 2 controls for each cement group): a resin composite used with a bonding agent (Variolink II/Excite), a resin composite used with a self-etching primer, but without bonding agent (Panavia F/ED Primer), a modified resin composite used with a bonding agent (Resinomer/One Step), and a resin-modified glass-ionomer cement (Fuji Plus). Thirty-six inlays (n = 9 + 1 control) were subjected to thermal cycling (2000 cycles, 5°C/55°C), whereas the other 36 were not. All the teeth were then immersed in 1% methylene blue dye solution for 48 hours. Microleakage score, margin location (enamel/cementum), thermal cycling history, and preparation location (buccal/lingual) were analyzed using a multivariate model (α=.05). Multivariate analysis was performed using a polychotomous logistic regression.

Results. The preparation location had no significant effect on dye penetration. The margin location (enamel or cementum) and the thermal cycling had a significant effect on microleakage (odds ratios [ORs] = 17.6 and 8.04, respectively). In comparing the 3 resin-based luting agents (Variolink II, Panavia F, and Resinomer) to Fuji Plus, Panavia F exhibited the lowest significant overall microleakage (OR = 0.09), followed by Variolink II (significant OR equal to 0.43), whereas Resinomer demonstrated the greatest significant overall microleakage (OR = 1.35).

Conclusions. Within the experimental conditions of this in vitro study, thermal cycling significantly increased the microleakage (OR = 8.04). The overall microleakage at the enamel margins was significantly lower than the overall microleakage at the cementum margins for the 4 luting agents tested (OR = 17.6). (J Prosthet Dent 2005;93:000.)

CLINICAL IMPLICATIONS

Higher dye penetration at the cementum margins and the significant increase in marginal leakage as a result of thermal aging suggest that the luting agents tested must be carefully considered for subgingival preparations.

The use of resin-based composite materials has increased in the last 20 years, and these materials are now reported to be the most frequently used in the practice of esthetic dentistry.[1] Although they are known to offer a significant number of benefits and advantages to both the practitioner and the patient alike, polymerization shrinkage continues to be an inherent disadvantage of resin-based composite materials.[2] Polymerization shrinkage is commonly believed to be the primary cause of marginal gap formation, microleakage, and subsequent pulpal pathology.[2] The use of indirect restorations is viewed as a possible method of minimizing this disadvantage. Extraoral polymerization aids in the relief of residual internal stresses and in the enhancement of both the physical and the mechanical properties.[3] More importantly, this process may restrict the volume of intraorally polymerized material,[4] ensuring that the negative effects of polymerization shrinkage

[a]Research Fellow, Prosthodontics Department, School of Dentistry, Henri Poincaré University.
[b]Research Fellow, Operative Dentistry and Endodontics Department, School of Dentistry, Henri Poincaré University.
[c]Assistant, Clinical Epidemiology and Evaluation Department, CEC-INSERM, University Hospital.
[d]Senior Lecturer, Biomaterials Department, School of Dentistry, Henri Poincaré University.
[e]Professor, Operative Dentistry and Endodontics Department, School of Dentistry, Henri Poincaré University.

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Table I. Materials used in study

Materials	Codes	Manufacturer	Batch no.	Primary components
Variolink II	RC 1	Ivoclar Vivadent, Schaan, Liechtenstein	Base: C09470Catalyst: C09915	Bis-GMA (13.9%), UDMA (7%), TEGDMA (7%), catalyst and stabilizers (0.9%), silanized filler (72 wt%)
Panavia F	RC 2	Kuraray, Tokyo, Japan	Paste A: 00085APaste B: 00039A	Bis-GMA, phosphate monomer MDP, silanized filler (78 wt%)
Resinomer	MRC	Bisco, Schaumburg, Ill	Base: 5570Catalyst: 5571	Bis-GMA (25%), TEGDMA (20%), HEMA (10%), filler (70 wt%)
Fuji Plus	RMGIC	GC, Tokyo, Japan	Powder: 070881Liquid: 240781	Powder: fluoro-alumino-silicate Liquid: copolymer of acrylic and maleic acid, HEMA, water, initiator, Powder/liquid ratio: 2/1
Targis		Ivoclar Vivadent	B06128	Bis-GMA, UDMA, decanediol dimethacrylate, filler: (77 wt%)

All information provided by manufacturers.
Bis-GMA, bisphenol A diglycidyl methacrylate; *UDMA*, urethane dimethacrylate; *TEGDMA*, triethyleneglycol dimethacrylate; *MDP*, 10-methacryloxy dihydrogen [Q15]. phosphate; *HEMA*, 2-hydroxyethyl methacrylate.

are confined to the width of the luting gap.[5,6] The size of the polymerization contraction, which can occur at the dentin-luting agent interface of indirect restorations, has been identified as 1 to 7 μm wide in restorations having a 200-μm luting agent film thickness.[7,8] However, the interface between the restorative material and the tooth structure is known to be of clinical significance[2] and may result in marginal discoloration, secondary caries, or pulpal pathology.[9] Therefore, the ability of the luting agent to seal to the tooth tissues is of significance in many restorative procedures.[10,11] Despite the improvements in the formulation of modern dentin adhesive systems, the bond strength and marginal adaptation of resin composite to dentin remain less predictable than adhesion to enamel.[12] Clinically, most preparations, especially those located in posterior teeth, may not be confined to the enamel but may have margins located in the cementum, as well as in the dentin.[13,14] The adhesive interface between a tooth and the restorative material at the gingival margin is acknowledged as a problematic zone in terms of microleakage.[14] The use of indirect restorations has been shown to be an effective way to improve the seal on both dentin and cementum margins by restricting the shrinkage volume of intraorally polymerized material.[4,7,14] Resin composite or ceramic can be used as indirect restoration materials and are considered to have predictable results, but the fabrication of indirect resin composite inlays is technically easier and less expensive compared to ceramic inlays.[6] [Q2] Resin composite inlays have demonstrated acceptable clinical results over several years.[15-17]

In vitro evaluation remains an essential method in the initial screening of dental materials and acts as an indicator as to the theoretical amount of leakage that may or may not occur in vivo.[18] Although no available product satisfies all the requirements of an ideal luting agent, the advent of adhesive techniques has allowed practitioners to expand services to procedures that cannot be provided with traditional water-based luting agents.[13] Currently, there are 3 main types of luting agents commercially available for composite or ceramic inlays: resin composite (RC), modified resin composite, the so-called compomer (MRC), and resin-modified glass-ionomer cement (RMGIC). Each type is chemically and [Q3] physically different.[19] However, it is recognized that none of them is suitable for every clinical situation.[20] Chemical variations of tooth substrate,[3,10] dimensional changes,[21-23] adhesive properties of the materials,[13,24] and differences in the coefficient of thermal expansion of luting materials with tooth restorations[25] are recognized to be the primary factors that will affect the sealing ability and, consequently, the clinical durability. It is known that many different and varied techniques have been used to test the in vitro cavity-sealing ability of restorations. These have included the use of dyes, chemical tracers, radioactive isotopes, air pressure, bacteria, neutron activation analysis, scanning electron microscopy, artificial caries techniques, and electrical conductivity.[26] The use of organic dyes is one of the most common methods of detecting leakage in vitro because dyes are inexpensive, easily detectable, and can be safely used because they are nontoxic.[27] Thus, the purpose of this study was to evaluate, via dye penetration, the marginal leakage of indirect resin composite inlays cemented with 4 different luting agents, with and without thermal cycling.

MATERIAL AND METHODS

The same operator performed all procedures according to the ISO requirement.[28] Forty freshly extracted human third molars, stored for less than 3 months,

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Table II. Conditioning agents used in study

Materials	Manufacturer	Batch no.	Primary components
Excite	Ivoclar Vivadent, Schaan, Liechtenstein	C15056	Bis-GMA, HEMA, phosphoric acid acrylate, glycerine dimethacrylate, ethanol (etching gel: phosphoric acid)
ED Primer	Kuraray, Tokyo, Japan	Liquid A: 00047A Liquid B: 00041A	HEMA, 5-MNSA, MDP, water, catalyst
One Step	Bisco, Schaumburg, Ill	3616	Biphenyl dimethacrylate, HEMA, acetone (etching gel: phosphoric acid)
Fuji Plus	GC, Tokyo, Japan	220781	Citric acid (10%), ferric chloride (2%), water

All information provided by manufacturers.*Bis-GMA*, Bisphenol A diglycidyl methacrylate; *UDMA*, urethane dimetacrylate; *TEGDMA*, triethyleneglycol dimethacrylate; *MDP*, 10-methacryloxy dihydrogen phosphate; *HEMA*, 2-hydroxyethyl methacrylate; *5-MNSA*, N-methacryloyl-5-aminosalicylic acid.

were selected as specimens for the study. All gingival remnants were removed, and the crowns were thoroughly cleaned with prophylactic rotary instruments (Screw-in cups; W & H Dentalwerk, Bürmoos, Austria). Before storage, the teeth were examined under a binocular microscope (×10, model S2H; Olympus, Tokyo, Japan) to ensure that the specimens were exempt from any decay, cracks, or previous restorations. The teeth were stored in 0.1% T chloramine (Prolabo, Paris, France) at 4°C for a week, then in distilled water at 4°C for 3 months (maximum) and, finally, in distilled water at 23°C ± 2°C during the last 12 hours before use. Standardized, nonbevelled Class V (U-shaped) cavities were prepared and finished on the buccal and lingual surfaces with 90-μm and 20-μm diamond rotary cutting instruments (Nos. 802 314 009 and 801 314 023; Komet, Lemgo, Germany) under constant air-water spray. The margins were located on both sides of the cemento-enamel junction (CEJ), in enamel on the occlusal aspect of the preparation, and in cementum at the gingival margin. The dimensions of the preparations (mesio-distal width: 4.6 ± 0.1 mm; occluso-gingival height: 2.6 ± 0.1 mm; pulpal depth: 2 ± 0.1 mm) were verified after each preparation with an electronic caliper (Digimatic, model 500-181U; Mitutoyo, Kanagawa, Japan) accurate to 10 μm. After preparation, and after each step of the experiment, the teeth were stored in distilled water at 23°C. A single impression was made with a 2-phase vinyl polysiloxane material [Q4] (Gumak; Pierre Roland, Merignac, France) and poured into Type IV stone (Fuji Rock; GC, Tokyo, Japan). After a setting time of 1 hour, 80 postpolymerized heat-[T1] treated resin composite inlays (Table I), were produced on the stone replicas, according to the manufacturer's instructions. The inlays were trimmed until an appropriate seating was obtained. An in situ trial evaluation of fit, with a light-bodied vinyl polysiloxane material (S4; [Q5] Bisco, Schaumburg, Ill), was also performed to ensure that the inlays could be positioned precisely in the preparations. Finally, airborne-particle abrasion with Al_2O_3 (Cobra 50 μm; Renfert, Hilzingen, Germany) was performed on the intaglio surfaces of the inlays.

Following the conditioning and priming of the teeth in accordance with the manufacturers' instructions, the inlay restorations (n = 18 for each luting agent) were cemented into place with 1 of the luting agents. The 4 luting agents and their primary constituents are summarized in Tables I and II. The molar specimens [T2] were assigned to receive a pair of luting agents according to the 6 possible pairing combinations (RC1/RC2, RC1/MRC, RC1/RMGIC, RC2/MRC, RC2/RMGIC, and MRC/RMGIC). The specimens were randomly assigned to groups by drawing lots. A visible light-polymerizing unit with an irradiating diameter of 9 mm (Elipar Highlight; 3M ESPE, St Paul, Minn)was [Q6] used to polymerize the luting agents. Light-activation energy was controlled to assure a minimum value of 600 mW/cm^2. A distance of between 1 and 2 mm was maintained between the light tip and the specimens. Following polymerization, the specimens were immediately placed into distilled water at a temperature of 23°C ± 2°C for 24 hours. Polishing was achieved using flexible disks (Sof-Lex XT Pop-On; 3M ESPE). Half of the restored teeth (9 inlays for each luting cement) were exposed to 2000 cycles of thermal stress. The specimens were alternatively immersed in water baths of 5°C and 55°C for a dwell time of 40 seconds and a transfer time of 3 seconds. The root apexes were then sealed with a resin composite (Z100; 3M ESPE), which was used without a bonding agent. The teeth were entirely coated with nail varnish (L'Oreal, Paris, France), except for the restorations and 1 mm around the restoration margins. For each group of specimens (thermal cycled and non–thermal cycled), 2 additional tooth specimens for each cement type were used as controls. A prepared specimen with 1 inlay cemented and entirely coated with nail varnish (L'Oreal) served as a negative control, and the other prepared specimen, with a nonluted inlay in place and without varnish coating, served as a positive control. All of the specimens were then soaked in a 1% methylene blue dye (Prolabo, Paris, France) for 48 hours. The specimens were rinsed in distilled water. Then, to evaluate the dye penetration, the specimens were sectioned with a 500-μm-thick slow-speed

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Table III. Leakage scores

Variables			Total	Score 0	Score 1	Score 2	Score 3
Luting cement (type)	Total		864	438	295	36	95
	VariolinkII (RC1)		216 (4 × 54)	116	65	8	27
		EM		51	3	0	0
		TEM		41	13	0	0
		CM		12	42	0	0
		TCM		12	7	8	27
	Panavia F (RC2)		216 (4 × 54)	161	40	13	2
		EM		50	4	0	0
		TEM		50	4	0	0
		CM		43	11	0	0
		TCM		18	21	13	2
	Resinomer (MRC)		216 (4 × 54)	101	65	6	44
		EM		47	7	0	0
		TEM		41	12	1	0
		CM		13	40	1	0
		TCM		0	6	4	44
	Fuji Plus (RMGIC)		216 (4 × 54)	60	125	9	22
		EM		29	25	0	0
		TEM		8	38	4	4
		CM		22	32	0	0
		TCM		1	30	5	18
Margin location	Total		n = 864	438	295	36	95
	Enamel		n = 432	317	106	5	4
	Cementum		n = 432	121	189	31	91
Thermal cycling	Total		n = 864	438	295	36	95
	Yes		n = 432	171	131	35	95
	No		n = 432	267	164	1	0
Preparation location	Total		n = 864	438	295	36	95
	Buccal		n = 432	218	149	23	42
	Lingual		n = 432	220	146	13	53

EM, Non–thermal cycled enamel margins; *TEM,* thermal cycled enamel margins; *CM,* non–thermal cycled cementum margins; *TCM,* thermal cycled cementum margins.

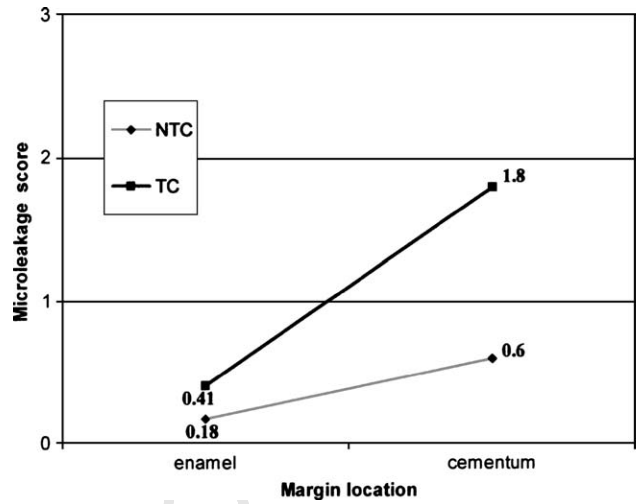

Fig. 1. Graph of thermal cycling effect on microleakage score versus margin locations (n = 864). *NTC,* No thermal cycling; *TC,* thermal cycling.

Table IV. Factors associated with the score variation (n = 864)

Variable	OR [$CI_{95\%}$]*
Margin location	
Enamel	1
Cementum	17.6 [12.33-25.13]
Thermal cycling	
No	1
Yes	8.04 [5.80-11.17]
Luting cements	
RMGIC	1
RC2	0.09 [0.05-0.14]
RC1	0.43 [0.30-0.64]
MRC	1.35 [0.50-1.10]

*$CI_{95\%}$, 95% confidence interval.

[Q16].

diamond-coated blade (Isomet Plus; Buehler, Lake Bluff, Ill) under water coolant. A first section was centered along the mesio-distal axis to separate the buccal and the lingual surfaces. Three 1-mm-thick bucco-lingual sections were then made for each half-specimen; 1 in the center of the restoration, 1 in the mesial margin, and 1 in the distal margin of the restoration. The sections were examined on each side under a binocular microscope (×10, model S2H; Olympus, Tokyo, Japan). Dye penetration was measured on the 6 enamel margins and 6 cementum margins for a total of 12 measurements per inlay. As there were 18 inlays per material, there were 216 measurements made for each luting agent. The degree of dye penetration was identified according to the following numerical criteria: 0 = no penetration; 1 = penetration to the enamel or cementum aspect of the preparation wall; 2 = penetration to the dentin aspect of the preparation wall, but not including the pulpal floor; 3 = penetration that included the pulpal floor of the preparation.[28]

Statistical analyses were performed using the statistical software (SAS/STAT, Version 8.2; SAS Institute, Cary, NC). Microleakage score, margin location (enamel/cementum), thermal cycling, and preparation location (buccal/lingual) were analyzed using a multivariate model (α=.05). This model provides regression coefficients of independent variables (margin location, thermal cycling, preparation location, and luting agents). Odds ratios (ORs) expressed the effect, when changing an independent variable based on the probability

FLA 5.0 DTD ■ YMPR707_proof ■ 26 April 2005 ■ 5:02 pm

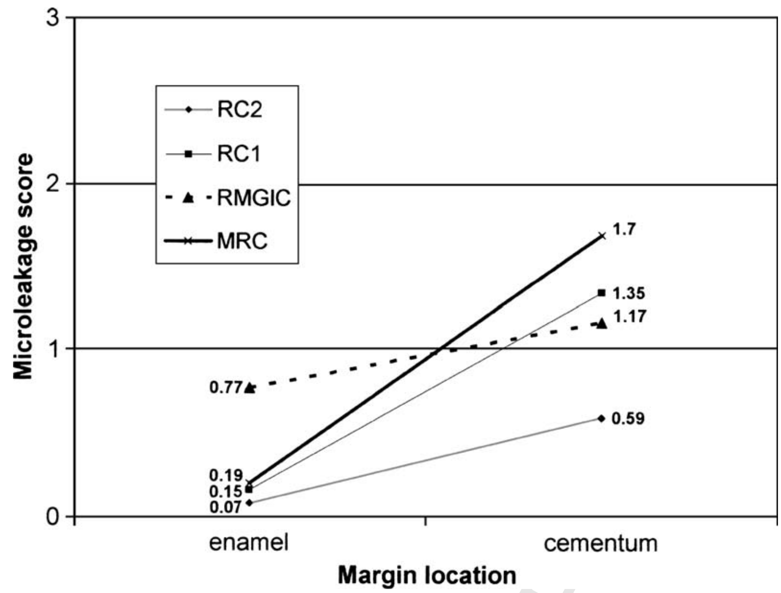

Fig. 2. Graph of luting agent effect on microleakage score versus margin locations (n = 864).

of having a score value higher by 1 unit, while holding other variables in the equation model constant (ORs are given with their 95% confident limits). Multivariate analysis was performed using an ordinal polychotomous logistic regression.

RESULTS

The negative controls appeared to show no evidence of dye penetration, whereas the positive controls demonstrated complete penetration of the cavity walls for both the thermal cycled and the non–thermal cycled specimens. The dye penetration data (Table III) and the polychotomous stepwise logistic regression results (Table IV) are presented in accordance with each of the variables of this study: the various luting agents, the margin location, and thermal cycling. The buccal or the lingual preparation location on the teeth had no significant influence on the dye penetration. Conversely, the polychotomous stepwise logistic regression results indicated that margin location (significant OR = 17.6) and thermal cycling (significant OR = 8.04) were the 2 strongest and most consistent predictors of increased microleakage. The statistical model confirmed the finding that microleakage may have been dependent on the type of luting agent. In comparing the 3 resin-based luting agents (RC1, RC2, MRC) to RMGIC, RC2 exhibited the lowest significant overall microleakage (OR = 0.09), followed by RC1 (significant OR equal to 0.43), whereas MRC demonstrated the greatest significant overall microleakage (OR = 1.35). The regression analysis revealed significant interactions pertaining to the score variation between the margin location and the thermal cycling, as well as between the margin location and the luting cements. Figure 1 illustrates the effect of thermal cycling on microleakage according to the margin location. This study confirmed that the occurrence of microleakage is higher at the cementum margin than at the enamel margin. This study also showed that microleakage occurs whether or not the specimens are subjected to thermal cycling. Regarding thermal cycling, it was noted that the amount of dye penetration between enamel and cementum margins was considerably increased when a specimen was exposed to this procedure. Figure 2 presents the effect of the 4 luting agents on the microleakage score at the margin locations. In each incidence, the score values were higher at the cementum margin than at the enamel margin. This study showed that the increase of microleakage at the cementum margins was significantly greater for RC1 and MRC than for RC2 and RMGIC.

DISCUSSION

All materials used in this study exhibited some degree of microleakage, and these findings agree with other studies.[3-6] According to Browning and Safirstein,[4] microleakage between tooth substrate and restorative materials can be expected for all restorative polymers. One probable explanation for this is that the adhesive bond becomes weakened, or even broken, by the unavoidable dimensional changes that occur when materials polymerize.[2] However, polymerization contraction is only one of the parameters that has a role in the mechanisms and durability of adhesion. There are a number of other factors, including the extent of the marginal gap, varying coefficients of thermal expansion for restoration and luting materials,[12,21] degradation of the particular bonding or restorative materials,[11,17] or the dissolution of liners or smear layers.[13] The initial marginal gap formation between tooth structure and a luting agent is frequently the result of the polymerization contraction of the luting agent, even if there is only a very thin layer.[8] Therefore, a lack of marginal sealing will occur if the adhesion of luting agents to the tooth structures does not compensate for the shrinkage stress exerted by the luting agent in the first stage of polymerization.[8] This may explain why, even before thermal cycling, marginal leakage was observed in many of the study specimens. Both RC and MRC have a free-radical polymerization process; therefore, the shrinkage stress may be sufficient to produce a marginal gap and subsequent leakage. The setting procedure of RMGIC is somewhat different, as it is essentially achieved by an acid-base reaction.[20] A [Q8] polymerization reaction also occurs with the HEMA and urethane dimethacrylate-based monomers contained in the matrix, and this may serve also to produce subsequent shrinkage.[2,20] In addition, the fact that RMGIC has demonstrated weaker bond strengths to enamel and dentin may, to a great extent, explain the high leakage scores.[20] Another explanation may lie in the in vitro experimental conditions themselves. Despite the decreased susceptibility to early dehydration exhibited by RMGIC, and the attempt between the experimental steps to maintain dentin hydration by constant water storage at 23°C ± 1°C, there may have been insufficient water in the extracted teeth to prevent some dehydration problems.[19,22] Thus, microleakage may have resulted from dye absorption into the layer of porous material and/or the result of the bond joint breakdown as a result of the changes in the physical [Q9] properties of the cement.[4,23]

According to leakage scores (Table III), the thermal cycling significantly increased the microleakage of the 4 luting materials. The relationship between thermal changes and the consistency of the temperature exposure is an important variable in evaluating the biomaterial microleakage potential.[2,3,21,25] In the literature,[21] dwell times varied from 10 to 120 seconds, although the extent of dye penetration has been shown to be independent of the dwell times between 4 and 30 seconds. Because dental tissues are poor thermal conductors, the dwell time was set at 40 seconds to compensate for the thermal inertia of the materials and to allow thermal [Q10]. diffusion across the specimens. With respect to the number of thermal cycles, the degree of dye penetration at the tooth restoration interface has been shown not to differ significantly when the specimens are subjected to a number of cycles between 100 and 1500.[21] Thus, it could be expected that significant differences might reasonably occur with 2000 cycles, as was the case in this study. The RC2 specimens were least affected by the thermal cycling, followed by RMGIC. However, it was demonstrated that both RC1 and MRC were less susceptible to microleakage prior to thermal cycling than RMGIC. Owing to the difference in thermal expansion between the tooth and luting agent, the thermal cycling of an inlay restoration between high and low temperatures may cause a rupture of the bond between the tooth and the luting agent.[2] This could be the cause of the increased rate of leakage for the RC1 and MRC specimens. Some physicochemical properties of RMGIC may explain its behavior under thermal stress, such as hygroscopic expansion of the luting material,[4] reduced setting stress owing to water absorption,[22] improved bonding ability, or polymerization during storage in water, by the increased value of flexural modulus.[4] Thus, [Q11] these properties may compensate for the relative weakness of the bond strength on dental hard tissues. Moreover, the water sorption mechanism may decrease the sealing ability of the resin-based materials by affecting their mechanical properties. In fact, the water solubility of some matrix components could create deterioration in the material structure and, subsequently, tracer penetration.[4] Therefore, the RC and the MRC adhesion properties seem to be a major parameter in terms of sealing ability.

The findings of this study would seem to concur with previously reported findings that adhesion to enamel demonstrates less leakage than adhesion to cementum or dentin.[13,14] In fact, the evidence now seems to clearly indicate that cementum is not able to offer a sufficient crystalline structure to provide a high micromechanical bond with the luting materials.[10,14] As a consequence, the leakage scores for the 4 luting materials were always lower at the enamel margins (EM and TEM) than at the [Q12] cementum margins. Under these conditions, the ability of a material to bond chemically to the tooth structures could assist in improving the sealing ability. The sealing ability of RMGIC at the cementum margin is higher than that of both RC1 and the MRC and could be the outcome of a twofold adhesion mechanism. The conditioning treatment removes the smear layer, cleans the surface, and exposes the collagen fibrils up to 0.5 μm depth, leaving a large part of the hydroxyapatite mineral content linked to the collagen fibrils.[20] The chemical bonding, which is the consequence of the acid-base process of the glass-ionomer setting reaction, can occur with calcium of the hydroxyapatite that remains attached to the collagen fibrils.[10] The HEMA and urethane dimethacrylate monomers may interdiffuse in collagen fibrils, establishing a micromechanical bond in the partly demineralized dentin.[20] The resin composite-based luting materials are not able to chemically bond to tooth structure, according to a similar acid-base process. Their sealing ability seems primarily based on the micromechanical overlap in the conditioning tooth crystalline structures.[10] Nevertheless, RC2 contains MDP, a phosphate ester-bonding agent, which [Q13] can chemically bond to tooth structure and, as a result,

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improve the sealing ability.[3] The best sealing ability can be observed, in fact, at the cementum margin for this material. The diphenyl sulfone derivative in MRC may have this ability as well. However, it was MRC that demonstrated the highest leakage at this margin.

To establish whether a correlation might exist between the in vitro results of this and a previously conducted study,[18] the present study was performed in accordance with the ISO/TS 11405:2003 standard guidelines.[28] It is accepted that the present study may have underestimated the actual leakage by comparing a sectioning method with other methods that screen the entire volume of the preparations.[26] Moreover, the ISO 11405 specification[27] may create unfavorable polymerization conditions for the RMGIC, especially during uncontrolled dehydration conditions. Thus, the overall microleakage may be overestimated for this material. For these reasons, the results of the present study may not accurately predict the clinical behavior of the tested materials, and long-term clinical trials are needed to assess the performance of the 4 luting agents tested.

CONCLUSIONS

None of the 4 luting agents prevented dye penetration. For all of the luting agents tested, dye percolation was significantly larger at the preparation cementum margins. Thermal cycling significantly increased microleakage at all margins, except at the enamel margin for RC2 (Panavia F). These 2 observations suggest that the use of the tested luting agents must be carefully considered for subgingival preparations. The luting agent RC2 (Panavia F/ED Primer), using a self-etch bonding procedure, offered the best sealing ability for every test condition. The systems RC1 (Variolink II/Excite) and MRC (Resinomer/One Step), using a bonding agent, demonstrated less microleakage at the enamel margin but high microleakage at the cementum margin after thermal cycling. The RMGIC system (Fuji Plus) showed a large dye microleakage at all margin locations.

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Reprint requests to:
Dr David Alain Gerdolle
12, rue Saint Georges
54000 Nancy
FRANCE
Fax: +33 383 393 901
E-mail: gerdolled@aol.com

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TOC Summary:

Based on the results of this study, higher dye penetration at the cementum margins and the effect of thermal aging on marginal leakage indicate that use of the tested luting agents for subgingival preparations deserves careful consideration.

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