Experimental Comparison of Cavity Sealing Ability of Five Dental Adhesive Systems after Thermocycling

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Purpose: To evaluate the cavity sealing obtained after thermocycling with five adhesive systems in which one all-in-one adhesive was compared to three one-bottle adhesives, and to observe the effect of a low-charged resin layer added to a one-bottle adhesive.

Materials and Methods: Twenty-five recently extracted teeth were randomly allocated to five experimental adhesive systems (n = 5 each): Optibond Solo (OS), Scotchbond 1 (SB1), PQ 1, Prompt-L-Pop (PLP), SB1+Revolution (R). On each tooth, two rectangular cavities at the cementoenamel junction were filled with a microhybrid composite (Z100) and the tested adhesives. Teeth were thermocycled and stained with $AgNO_3$ + vitamin C. Leakage was evaluated on a 6-point (0-5) severity scale and the highest score was selected for each restoration. Results were treated by ordinal logistic regression and considered to be significant at $p < 0.05$.

Results: No significant difference was found between leakage values for enamel and dentin interfaces. Leakage scores never exceeded 2 for OS, SB1 and SB1+R, while they reached a maximum of 5 in 20% of PLP cases. OS was significantly better than the other adhesive systems, which were statistically equivalent. The addition of a flowable composite layer on SB1 did not yield a significant difference, but tended to give better results mainly at the dentin interface.

Conclusion: The all-in-one adhesive PLP, because of quite variable results, seems less reliable than the one-bottle adhesives, of which OS provides significantly the best results. Addition of a flowable composite on SB1 appears to yield slightly better results.

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Leakage is the main cause of postoperative sensitivity and pulpal inflammation, and compromises the lifetime of obturations.[2,3,15] It is now widely accepted that current adhesive resins have good biocompatibility with the pulp when applied on dentin. Direct pulp capping with methacrylate-based adhesives has been evaluated, with variable results. Failures are partly attributed to leakage.[23] Thus, pulp biocompatibility of fillings is chiefly related to their watertightness, which prevents bacteria and their toxins from accessing dentin and pulp tissues.[10,23] The filling's seal is accomplished by the hybrid layer, in which resin impregnates demineralized collagen fibers of etched dentin.[13,20,27] This layer resists the composite polymerization contrac-

Table 1 Distributions of the maximum leakage score at the enamel interface (n = 10), dentinal interface (n = 10), and by restoration (n = 10)

Adhesive system	Interface	Leakage score					
		0	1	2	3	4	5
OS	Enamel	4	5	1			
	Dentin	5	4	1			
	Restoration	3	5	2			
PQ1	Enamel		5	5			
	Dentin		7	1	1	1	
	Restoration		5	3	1	1	
PLP	Enamel	2	4	2	1		1
	Dentin	3	4	1			2
	Restoration	1	4	2	1		2
SB_1	Enamel		7	3			
	Dentin	2	4	4			
	Restoration		4	6			
SB_1 + R	Enamel	1	6	3			
	Dentin	2	8				
	Restoration		7	3			

Leakage scores: 0 = none, 1 = slight, 2 = moderate, 3 = high, 4 = subtotal, 5 = total.

tion stress but also undergoes internal strain that might break it.[28] To minimize this strain, a lightly-filled resin lining has been proposed, which, with a lower elastic modulus may compensate for the volumetric shrinkage of the restoration.[4,9]

The quality of the hybrid layer can be affected by operative errors, particularly in the total-etch phase, in which the degree of dentin etching and drying is critical.[27,28] The main objective of the fifth generation of adhesives is a simplification of the technique.[21] However, some of them (eg, the one-bottle products) still require a separate etching of dental tissues. On the other hand, all-in-one adhesives do not require a separate etching step.

The purpose of this experimental study was to compare the microleakage allowed after thermocycling by one all-in-one adhesive (Prompt-L-Pop) and three one-bottle adhesives used with a total-etch technique (Scotchbond 1, Optibond Solo, and PQ1). In addition, the effect of a flowable composite layer (Revolution) added to one of the one-bottle (SB 1) adhesives was also tested.

MATERIALS AND METHODS

Twenty-five recently extracted caries-free human molars were preserved in refrigerated physiological saline solution. On each tooth, two rectangular cavities (h x w x l = 2 x 2 x 3 mm) were prepared at the cementoenamel junction. The margins of the cavities were prepared as butt joints, half in the enamel and half in the cementum. Teeth were randomly and equally (n = 5 per group) distributed across the five adhesive systems tested (Table 1).

One all-in-one adhesive (Prompt-L-Pop [PLP], 3M ESPE, Seefeld, Germany) was tested, as were three one-bottle adhesives used with a total-etch technique (Scotchbond 1 [SB1], 3M; Optibond Solo [OS], Kerr, Karlsruhe, Germany; and PQ1, Ultradent, South Jordan, UT, USA). In addition, a flowable composite layer (Revolution, Kerr) was added to one of the one-bottle (SB1+R) adhesives and tested. Each adhesive was used according to the respective manufacturer's instructions.

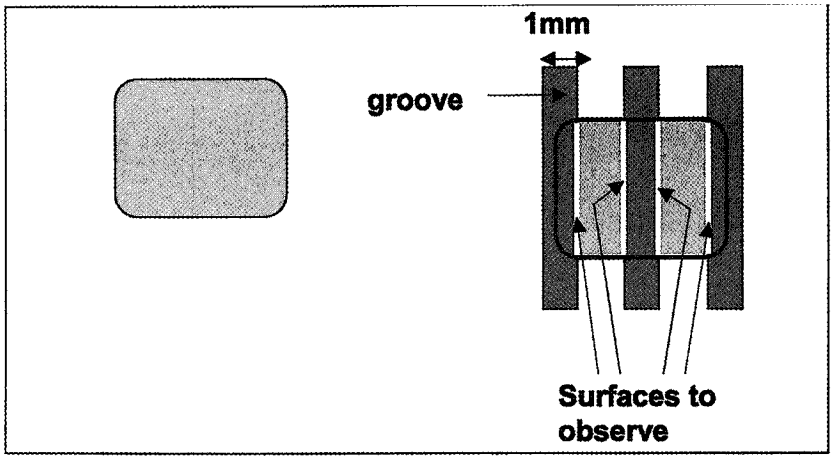

Fig 1 Preparation of grooves on each restoration.

All restorations were made with the same composite (Z100, 3M), which was placed in two oblique layers and polymerized with a halogen lamp (XL 3000, 3M) for 40 s. They were finished with diamond burs and polished with disks (Soflex, 3M). The Revolution flowable composite was placed after SB1 was polymerized, in a thin layer like a lining which covered the pulpal and lateral walls of the cavity but left free approximately 0.5 mm from the cavosurface angles. The Revolution layer was polymerized 20 s.

Filled teeth were immersed in saline solution and almost immediately thermocycled (5°C to 55°C) for 800 cycles in 22 h. Apices were obturated with self-polymerizing resin (Paladur, Heraeus-Kulzer, Wehrheim, Germany) before teeth were immersed for 6 h in a 50% silver nitrate solution. They were thoroughly rinsed and dipped in a 35% vitamin C solution for silver disclosure. On each restoration, three grooves 3 mm deep were prepared with a 0.9-mm-diameter cylindrical drill, which provided a groove width of about 1 mm. Two grooves were on the sides of the restoration, while the third was centrally positioned (Fig 1). These preparations yielded four evaluable surfaces for each obturation, ie, a total of 200 surfaces. Each surface showed an enamel side and cementodentin side, in other words, a total of 400 tooth/filling interfaces.

Silver nitrate leakage was evaluated on a 6-point scale (Fig 2):

Score 0 : no leakage.

Score 1: slight leakage up to the enamel-dentin junction or a depth of 0.5 mm on the radicular wall.

Score 2: moderate leakage up to a maximum of half of the lateral wall (leakage depth ≤ 1 mm).

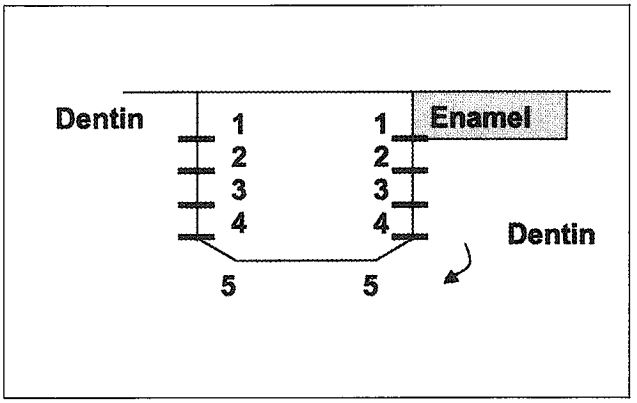

Fig 2 Leakage evaluation scale.

Score 3: high leakage, over half of the lateral wall (1 mm < leakage depth < 2 mm).

Score 4: subtotal leakage on the entire lateral wall (leakage depth = 2 mm).

Score 5: total leakage partly or entirely on the pulpal wall of the cavity (leakage depth > 2 mm).

Each section was examined by two methods: (a) magnifying glass under a direct light source, and (b) magnified on a screen by means of an intraoral camera.

Statistical Analysis

Leakage scores were analyzed by ordinal logistic regression, in which the covariates were the enamel or dentin interface and the experimental group of adhesive systems. All results were considered to

Table 2 Comparison of the five adhesive systems by ordinal regression[a]

Adhesive systems			p value
OS	vs	PQ_1	0.024 *
OS	vs	PLP	0.017 *
OS	vs	SB_1	0.027 *
OS	vs	SB_1 + R	0.17
PQ_1	vs	PLP	0.89
PQ_1	vs	SB_1	0.95
PQ_1	vs	SB_1 + R	0.31
PLP	vs	SB_1	0.83
PLP	vs	SB_1 + R	0.25
SB_1	vs	SB_1 + R	0.34

[a] overall significance of the model: $p < 0.001$

be significant at $p = 0.05$. Calculations were done with the SAS (version 8.02 for Windows) statistical package.

RESULTS

For each restoration, three scores were selected: the highest at the enamel interface, the dentin interface, and for the entire cavity. These scores are displayed in Table 1. No statistical difference was found between the enamel and dentin interfaces ($p = 0.19$).

Scores were never higher than 2 (leakage depth ≤ 1 mm) for OS, SB1 and SB1+R. Higher scores (3 to 5) were found only for PQ1 and PLP. For PQ1, scores of 3 and 4 were found at the dentin interface of two different restorations in two different teeth. For PLP, one score 3 and one score 5 were found at enamel interfaces and two scores 5 at dentin interfaces. These scores were observed on different cavities and teeth.

The comparison of adhesive systems by means of ordinal logistic regression analysis is displayed in Table 2. It is seen that OS was significantly different from PQ1, PLP, and SB1. None of the other adhesive systems differed significantly from each other. When comparing OS with SB1+R, scores were slightly though not significantly better for OS ($p = 0.17$).

DISCUSSION

Thermocycling is the only in vitro means of simulating thermal stress in teeth. It is considered as a quick model of the in vivo leakage process.[1,2,14] In fact, both in vitro and in vivo, leakage depends on the adhesive strength and thermal expansion coefficient of restorations. Ideally, composite and dental tissue coefficients should be identical.[8,12] If they differ substantially, a long-term degradation in the restoration's seal may result because of the stress generated at each temperature change.[7] It has been shown that a higher number of cycles does not significantly enhance leakage. Thermal stress arises early and an exceedingly large number of cycles is unnecessary.[11] For Arcoria et al,[1] 500 cycles already induced good aging of the restoration.

In the present study, four surfaces were observed on each restoration: one on each side and two in the middle. Gwinett et al[17] compared leakages evaluated either on a single section through the middle of the preparation or by two sophisticated three-dimensional observation techniques: direct observation after tooth demineralization and sequential grinding with computer image acquisition and three-dimensional reconstruction. They found significantly greater leakage at the gingival margin with the three-dimensional techniques than with the single-section technique.

In different studies, the number of sections varied from 3 to 10.[6,18,22,25] Yoshiyama et al[29] made four sections and justified this by the fact that, in Class V cavities, the orientation of the tubuli was not the same everywhere on the total prepared surface. This can influence the quality of adhesion. Our choice was inspired by the studies of Hatibovic-Koffman et al[18] and Toledano et al,[25] who observed three sections and obtained different leakage measurements on mesial and distal sides.

From the eight scores obtained for each restoration, the highest were selected at the enamel interface, the dentin interface, and for the whole cavity. This seems the best approach to evaluating the efficacy of adhesives. Indeed, an adhesive which allows occasional leakage as far as the pulp wall of the cavity must be considered worse than an adhesive that allows generalized minimum leakage but never up to this wall. This is particularly true in the total-etch technique, in which hybridization of the dentin by the adhesive system ensures pulp protection. If leakage occurs, it will be less deleterious if

it stops far from the pulp tissue, and if it is present at the enamel rather than the dentin interface.

Leakage being minimal on enamel, it is usually recognized as the reference value. In this study, leakage at the enamel interface was not different from that at the dentin interface for any of the adhesive systems. This may be due to the fact that cavity margins were not bevelled.

Among the worst leakage scores by restoration, five were ≥ 3 and were found with PQ1 (3 and 4) and PLP (3 and two 5 s). PLP was the only adhesive that allowed leakage up to the pulpal wall. This happened on one of the observed surfaces at enamel interfaces and on four surfaces at the dentin interface (in cavities on two different teeth). These poor sealing efficacy results of PLP on dentin could be related to the results of Inoue et al.[19] These authors observed pretesting failures of samples prepared with PLP for a microtensile bond strength test and concluded there was an inconsistency in bonding to dentin of some self-etching adhesives. Frankenberger et al[16] also obtained lower bond strengths for PLP when it was applied in one layer as recommended by the manufacturer. In this case, they observed an inconsistent hybrid layer, although the latter was clearly present when several layers had been applied. In the present study, only one layer of PLP was applied. For PQ1, leakage scores of 3 and 4 at the dentin interface were each found only on one surface on two different teeth.

The three other adhesive systems never yielded scores greater than 2 and OS showed the best results with 30% of the scores being 0.

Though the difference between SB1 and SB1+R was not significant ($p = 0.34$), the addition of a layer of flowable composite (R) under the restoration appeared to improve the performance of SB1, particularly at the dentin interface where scores never exceeded 1. This effect needs to be confirmed in future studies. Flowable composites contain the same particles of charge as hybrid composites but in lower proportions. Their mechanical properties are not sufficient to be used alone in restorations unless they are exposed to little mechanical force.[3] In addition, their setting contraction is more important and would induce more stress to the adhesive.[6] Thus, their favorable effect on the seal's impermeability can appear paradoxical. This might be explained by the fact that increased fluidity enhances the moistening property of the resin, which can then better coat the surface irregularities.[4,5,9,24,26] Furthermore, flowable composites have a lower elastic modulus, which allows the absorption of the stress associated with the polymerization contraction of the overlying composite and with the volumetric variations related to temperature changes.[3]

CONCLUSION

The present study compared the efficacy against leakage of a self-etching all-in-one adhesive (PLP) and three one-bottle (OS, PQ1, SB1) adhesives. PLP showed more irregular results, since it allowed occasional leakage up to the pulpal wall of the cavity, which is unacceptable particularly in the total-etch technique. One-bottle adhesives, except PQ1 in two cases, yielded generalized minimal leakage that remained far from the pulpal wall. Among the one-bottle adhesives, OS was significantly better than the other systems, which were statistically equivalent. The addition of a flowable composite in a thin layer over SB1 tended to improve results, but this finding needs to be researched further.

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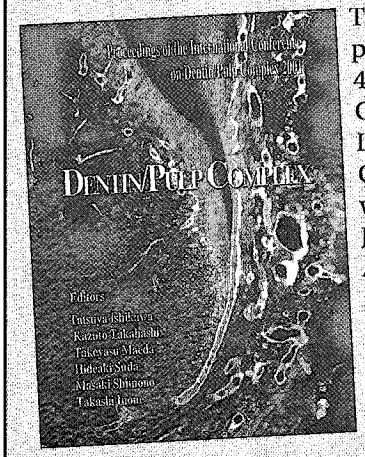

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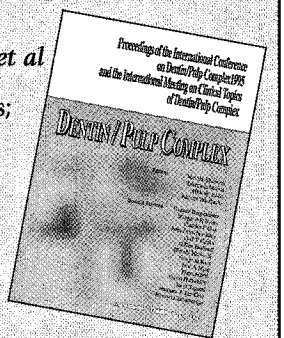

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