

Clinical Evaluation of a Low-shrinkage Composite in Posterior Restorations: One-Year Results

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Clinical Relevance

Filtek Silorane showed acceptable clinical performance after one year. However, the low-shrinkage resin combined with the self-etch adhesive did not provide any advantage over the methacrylate-based composite combined with the total-etch adhesive.

SUMMARY

Objectives: The aim of this study was to compare the one-year clinical performance of three restorative systems, which included a novel low-shrinkage composite and two bonding strategies.

Materials and Methods: Twenty-five patients received three Class I (occlusal) or Class II restorations performed with one of three re-

storative systems: Filtek Silorane Restorative System (FS); Adper Scotchbond 1 XT, a two-step etch-and-rinse adhesive, with Filtek Z250 (XT); and Adper Scotchbond SE, a two-step self-etch adhesive, with Filtek Z250 (SE). All materials were applied following the manufacturer's instructions. Two independent observers evaluated the restorations at baseline, after six months, and after one year, according to the United States Public Health System modified criteria. The Kruskal-Wallis test and the Mann-Whitney *U*-test were computed to compare the behavior of the restorative systems; Friedman and Wilcoxon tests were used to analyze the intrasystem data ($\alpha=0.05$).

Results: All restorations were evaluated at one year. FS and XT performed statistically similarly at one year, but marginal staining for SE was statistically worse. Intrasystem comparisons between baseline and one year also showed deterioration of marginal staining for SE, while a deterioration of the marginal adaptation was recorded for both SE and FS. XT was the only system for which there was no

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statistical change of the parameters measured in this study.

Conclusions: Both restorative systems using self-etch adhesives showed a tendency to degradation of marginal adaptation after one year of clinical use, compared to baseline values. Although the clinical performance of FS was deemed acceptable after one year, this study did not find any advantage of the silorane-based composite over the methacrylate-based composite. The low-shrinkage associated with FS may not be a determinant factor for clinical success.

INTRODUCTION

The improvements in dental adhesives and resin composites, along with a minimally invasive approach to caries treatment, have made these restorative materials very popular for direct posterior restorations. Nevertheless, the longevity of these restorations is still affected by the consequences of their polymerization shrinkage. The volumetric reduction due to polymerization generates stress within the material, at the adhesive interface, and in the tooth structure.¹ The physical mismatch between the shrinkage-prone restorative material and the stiffer tooth structure may result in microleakage, marginal staining, gap formation, postoperative sensitivity, and enamel microcracks or cusp deflection.^{2,3}

Filtek Silorane, introduced in 2007, is the first commercially available resin composite not based on bisphenol A diglycidyl methacrylate or urethane dimethacrylate, the dimethacrylate monomers most commonly used.⁴ This novel silorane-based resin takes its name from the combination of its chemical blocks, siloxanes and oxiranes. The silorane molecule has a siloxane core with four attached oxirane rings that open upon polymerization to bond to other monomers.^{5,6} This mechanism implies a slight reduction of the initial distance between monomers, which results in a volumetric shrinkage of less than 1%, which might generate less stress on the adhesive interface.^{5,7,8} This characteristic has been validated by other *in vitro* studies,^{9,10} in which the silorane-based resin resulted in a significantly lower cusp deflection when applied to MOD preparations, in comparison to methacrylate-based resins. Moreover, the silorane-based resin has been shown to have adequate physical and mechanical properties, which make it suitable for clinical application.^{6,11}

The specific chemistry and curing mechanism of the silorane-based resin composite required the

development of a dedicated adhesive by the respective manufacturer. In the case of Filtek Silorane, a two-step self-etch adhesive was developed. This adhesive is composed of a self-etch primer and a hydrophobic bonding resin.^{12,13} Self-etch adhesives have become increasingly popular as they are more user-friendly, less technique-sensitive, and may reduce postoperative sensitivity^{14,15} compared to etch-and-rinse adhesives. However, the adhesion to enamel achieved by etch-and-rinse adhesives is still considered the “gold standard”^{14,16,17} as a result of the deep etching pattern created by the low pH of phosphoric acid. Therefore, the performance of self-etch adhesives on enamel may depend on their aggressiveness. “Strong” self-etch adhesives result in a more stable and satisfactory enamel bond than do “mild” self-etch adhesives, especially on ground, aprismatic enamel.^{18–20} In fact, selective etching of enamel margins with phosphoric acid has been recommended^{21–23} in clinical situations prior to applying “mild” self-etch adhesives.

Clinical trials are the ultimate test with which to measure the clinical effectiveness and durability of adhesives and resin composites.²⁴ This is of paramount relevance, as there is no clinical evidence to back the deleterious effect of polymerization stress on restoration longevity.²⁵ Accordingly, the aim of this study was to compare the one-year clinical performance of three restorative systems in posterior restorations: the low-shrinkage silorane-based resin composite with its proprietary self-etch adhesive and a widely studied methacrylate-based resin composite, Filtek Z250, used with either a two-step etch-and-rinse adhesive or with a two-step self-etch adhesive. The null hypothesis was that there would be no differences in clinical performance for the three restorative systems after one year.

MATERIALS AND METHODS

Before participating in the study, subjects signed a written informed consent. Both the consent and this research protocol had previously been reviewed and approved by the Ethics Committee of the Rey Juan Carlos University.

All patients, with ages ranging from 18 to 60 years (average 29.8 years), required at least three Class I (occlusal) and/or Class II restorations (Table 1). The dental health status of patients was normal in all other respects. Specific exclusion criteria were as follows:

- Fewer than 20 teeth;
- History of existing tooth sensitivity;

Table 1: Number of Restorations by Location (Tooth) and Number of Surfaces for Each Restorative System

Restorative System	Number of Restorations	Tooth		Class			
		Premolars	Molars	I	II		Total
					OM or OD	MOD	
Filtek Silorane Restorative System (FS)	25	12	13	12	10	3	13
Adper Scotchbond 1 XT + Filtek Z250 (XT)	25	8	17	14	10	1	11
Adper Scotchbond SE + Filtek Z250 (SE)	25	13	12	12	12	1	13
Total (%)	75 (100)	33 (44)	42 (56)	38 (50.6)	32 (42.6)	5 (6.6)	37 (49.3)

- Periodontal disease;
- Extremely poor oral hygiene;
- Bruxism;
- Known allergy to resin-based materials or other materials used in this study;
- Pregnancy or breast-feeding; or
- Chronic use of anti-inflammatory, analgesic, and psychotropic drugs.

Further, excluding criteria for the teeth to be restored were as follows:

- Nonvital teeth;
- Abutment teeth for fixed or removable prostheses; and
- Teeth without a normal occlusal relationship with natural dentition or without at least one adjacent tooth contact.

Bitewing radiographs of the teeth to be restored were taken preoperatively, unless the patient had radiographs taken within the previous year. There was an even distribution of the restorations that replaced existing restorations with clinical or radiographic signs of recurrent caries or esthetic failures and restorations that were performed to treat primary caries lesions.

All operative procedures were performed by the same operator (B.B.). Restorations were placed under local anesthesia with rubber dam isolation. The cavity design was restricted to eliminate carious tissues from primary caries lesions or to remove the restorative material and carious tissues when existing restorations were replaced. Cavities were prepared using diamond burs (Komet-Brasseler, Lemgo, Germany) with no intentional bevels on enamel cavo-surface margins. In deep cavities, dentin was covered

with a resin-modified glass ionomer cement (Vitre-bond, 3M ESPE, St Paul, MN, USA). An appropriate matrix system (Palodent, Dentsply, Konstanz, Germany) and wooden wedges were applied to the cervical margins of proximal preparations.

The restorative systems evaluated in this study were the Filtek Silorane Restorative System, Adper Scotchbond 1 XT + Filtek Z250, and Adper Scotchbond SE + Filtek Z250 (Table 2).

Initially, the three restorative systems were randomly assigned to each of the three teeth for which restorative treatment was needed, regardless of the characteristics of the tooth and restoration class. However, interference in the randomization procedure within patients was eventually performed in order to equally distribute materials into some important variables, such as tooth type and position, restoration class, and restoration size, in such a way that the influence of those factors was minimized.²⁶ All adhesive systems were applied according to the manufacturer's instructions (Table 2). Resin composites were placed in 2-mm increments. Each increment was light-cured for 20 seconds using a LED Demetron I polymerization unit (Kerr, Orange, CA, USA) with a minimum light output of 550 mW/cm².

After polymerization, coarse finishing was accomplished with carbide burs under water cooling and, if needed, with a #12 blade and aluminum-oxide disks (Sof-Lex, 3M ESPE). Final finishing of the occlusal surface was accomplished with polishing points (Enhance and PoGo, Dentsply).

Clinical Evaluation

All restorations were evaluated after one week (baseline), six months, and one year for the following

Table 2: *Materials Used in the Study (3M ESPE, St Paul, MN, USA)*

Adhesives (Batch No.)	Composition	Instructions for Use	Type
Silorane System Adhesive (also known as LS System Adhesive or P90 System Adhesive) (Primer: 8AP; Adhesive: 8AK)	Primer: phosphorylated methacrylates, Bis-GMA, HEMA, water, ethanol, silane-treated silica filler, Vitrebond™ copolymer, initiators, stabilizers	Primer: application for 15 sec with black microbrush, followed by gentle air dispersion and 10 sec of light-curing	Two-step self-etch
	Adhesive: hydrophobic DMA, phosphorylated methacrylates, TEGDMA, silane-treated silica filler, initiators, stabilizers	Adhesive: application with green microbrush, followed by gentle air dispersion and 10 sec of light-curing	
Adper Scotchbond 1 XT (also known as Adper Single Bond Plus or Adper Single Bond 2) (318655)	HEMA, Bis-GMA, GDMA, water, ethanol, silane-treated silica nanofiller, photoinitiator	Acid etch: phosphoric acid (Scotchbond™ Etchant, 3M ESPE): 35% (15 sec). Rinse (10 sec). Blot excess water using a cotton pellet or minisponge. Do not air-dry Adhesive: apply two to three consecutive coats of adhesive for 15 sec with gentle agitation using a fully saturated applicator. Gently air thin for 5 min to evaporate solvent. Light-cure for 10 sec	Etch-and-rinse
Adper Scotchbond SE (also known as Adper SE Plus) (Liquid A: 7AF; Liquid B: 8AL)	Liquid A (colored wetting solution): water, HEMA, surfactant, rose bengal dye	Liquid A: apply to the cavity so that a continuous red-colored layer is obtained on the surface	Two-step self-etch
	Liquid B (adhesive): UDMA, TEGDMA, TMPTMA, HEMA phosphate and MHP, bonded zirconia nanofiller, initiator system based on camphorquinone	Liquid B: scrub into the entire wetted surface of the bonding area for 20 sec. Red color will disappear quickly, indicating that the etching components have been activated. Air-dry thoroughly for 10 sec. Apply second coat to the entire bonding surface. Light air application. Light-cure for 10 sec	
Resin Composites	Organic Matrix	Inorganic Filler	
Filtek Silorane (8BH)	3,4-Epoxy cyclohexylethylcyclopoly-methylsiloxane, bis-3,4-epoxycyclohexylethylphenylmethylsilane, yttrium fluoride (15%), camphorquinone, iodonium salt, stabilizers, pigments	Silanized quartz particles: 50% volume, 70% weight Size: 0.1–2 µm	
Filtek Z250 (7LY)	Silane-treated ceramic, bisphenol A polyethylene glycol diether dimethacrylate, UDMA, Bis-GMA, TEGDMA, water (<2%)	Quartz and zirconia particles: 60% volume, 78% weight Size: 0.01–3.5µm (0.6 µm, on average)	
Abbreviations: Bis-GMA, bisphenol A diglycidyl methacrylate; GDMA, glycerol 1,3-dimethacrylate; HEMA, 2-hydroxyethyl methacrylate; MHP, methacrylic phosphate; TEGDMA, triethylene glycol dimethacrylate; TMPTMA, trimethylolpropane trimethacrylate (hydrophobic TMA); UDMA, urethane dimethacrylate.			

parameters: color match, retention, marginal adaptation, anatomic form, surface roughness, marginal staining, sensitivity, and secondary caries (Table 3). Pre- and postoperative sensitivity was determined

with a dental syringe placed 2 cm from the tooth surface. Two clinicians (L.C. and E.C.) evaluated the restorations blindly at each recall using the modified United States Public Health Service (USPHS)

Table 3: *Modified USPHS Criteria Used*

Criteria	Code	Definition
Color match	Alfa Beta Charlie	Restoration matches adjacent tooth structure in color and translucency.
		Mismatch is within an acceptable range of tooth color and translucency.
		Mismatch is outside the acceptable range.
Retention	Alfa Beta Charlie	Full retention.
		Partial retention.
		Restoration is lost.
Marginal adaptation	Alfa Beta Charlie	Restoration closely adapted to the tooth. No crevice visible. No explorer catch at the margins, or there was a catch in one direction.
		Explorer catches. No visible evidence of a crevice into which the explorer could penetrate. No dentin or base visible.
		Explorer penetrates into a crevice that is of a depth that exposes dentin or base.
Anatomical form	Alfa Beta Charlie	Restorations continuous with existing anatomic form.
		Restorations discontinuous with existing anatomic form but missing material not sufficient to expose dentin base.
		Sufficient material lost to expose dentin or base.
Surface roughness	Alfa Beta Charlie Delta	Surface of restoration is smooth.
		Surface of restoration is slightly rough or pitted, but can be refinished.
		Surface deeply pitted, irregular grooves, and cannot be refinished.
		Surface is fractured or flaking.
Marginal staining	Alfa Beta Charlie	No staining along cavo-surface margin.
		<50% of cavo-surface affected by stain (removable, usually localized).
		>50% of cavo-surface affected by stain.
Sensitivity ^a	Alfa Beta Charlie Delta	None.
		Mild but bearable.
		Uncomfortable, but no replacement is necessary.
		Painful. Replacement of restoration is necessary.

Table 3: Modified USPHS Criteria Used (cont.)

Criteria	Code	Definition
Secondary caries	Alfa Beta	Absent.
		Present.
^a Postoperative sensitivity at baseline was registered one week after the restoration insertion.		

criteria as adapted by Wilson and others²⁷ (Table 3). When disagreements arose during evaluations, the examiners had to reach a consensus. To help with the evaluation of marginal discoloration, intraoral color photographs were collected at baseline and at the recall appointments. Clinical photographs consisted of digital images at 1.3× magnification taken with a Nikon D80 camera with a 105-mm Micro-Nikkor lens (Nikon USA, Melville, NY, USA).

The statistical analyses were carried out with the SPSS 16.0 for Windows software (SPSS Inc, Chicago, IL, USA) using the nonparametric Kruskal-Wallis test and Mann-Whitney *U*-test to compare the behavior of the three restorative systems at baseline, six months, and one year. Friedman and Wilcoxon nonparametric tests were used to compare the data obtained for each restorative system at each evaluation period. The level of confidence was set at $\alpha = 0.05$.

RESULTS

A total of 75 restorations were placed in 25 patients. The distribution of the restorations was similar between Class I (38) and Class II (37) cavities (Table 1). All patients attended the six-month and one-year recalls (100% recall rate). The results are summarized in Table 4.

Comparison of the Performance of the Three Restorative Systems at One Year

Adper Scotchbond SE + Filtek Z250 resulted in significantly worse marginal staining than did the other two restorative systems at one year ($p=0.028$). This deterioration had already been detected at the six-month recall appointment ($p=0.013$) (Figure 1).

All restorative systems resulted in a percentage of Alfa ratings above 90% at one year for the categories of retention and anatomical form. However, Alfa ratings for surface roughness, and in particular, marginal adaptation, decreased for all of the restorative systems, although this reduction did not result

in statistical differences among them. Secondary caries was only detected in one tooth restored with Filtek Silorane, which had previously shown a fracture of the material at the six-month evaluation. Both findings had no statistical repercussions.

Baseline vs One-year Evaluation for Each Restorative System

Filtek Silorane Restorative System—Marginal adaptation was significantly worse at one year compared to baseline ($p=0.005$), as seven of 25 restorations were rated Bravo and one was rated Charlie. Additionally, surface roughness was statistically similar at baseline and after one year, but it was different at six months ($p=0.02$), as 28% of the restorations were rated Bravo at this recall. Filtek Silorane was the only system that rated Bravo in secondary caries and retention, Charlie in adaptation and anatomical form, and Delta in surface roughness. However, all of these ratings came from a single restoration and did not lead to any statistical significance. Only one restoration showed a true color modification over time, and two did not match adjacent tooth structure because of the yellowish and very opaque aspect of the Filtek Silorane resin composite.

Adper Scotchbond 1 XT + Filtek Z250—Marginal staining, surface roughness, and in particular marginal adaptation parameters resulted in worse rankings at one year (four restorations were rated Bravo), although there were no statistical differences ($p>0.05$). No Charlie ratings were assigned to this restorative system for any of the criteria. Postoperative sensitivity (slight discomfort associated with cold beverages) was found in one patient during the first week after the restoration was placed.

Adper Scotchbond SE + Filtek Z250—Marginal adaptation and marginal staining were significantly worse at one year compared to baseline. Adaptation deficiencies increased ($p=0.002$) in the last six months, as seven restorations rated Bravo and one was rated Charlie at one year. Marginal staining

Table 4: Number of Evaluated Restorations in Each Criterion for Each Experimental Group

Criteria Materials→	Code	Baseline			6 months			1 year		
		FS	XT	SE	FS	XT	SE	FS	XT	SE
Color match	A	23	25	23	22	24	23	22	24	22
	B	2	—	2	3	1	1	3	1	1
	C	—	—	—	—	—	1	—	—	2
Retention	A	25	25	25	24	25	25	24	25	25
	B	—	—	—	1	—	—	1	—	—
	C	—	—	—	—	—	—	—	—	—
Marginal adaptation	A	24	25	25	20	23	24	17	21	18
	B	1	—	—	4	2	1	7	4	7
	C	—	—	—	1	—	—	1	—	—
Anatomic form	A	25	25	25	24	25	25	24	25	25
	B	—	—	—	—	—	—	—	—	—
	C	—	—	—	1	—	—	1	—	—
Surface roughness	A	23	24	25	17	21	22	22	22	21
	B	2	1	—	7	4	3	2	3	4
	C	—	—	—	—	—	—	—	—	—
	D	—	—	—	1	—	—	1	—	—
Marginal staining	A	25	25	23	24	24	18	23	22	16
	B	—	—	2	—	1	6	1	3	8
	C	—	—	—	1	—	1	1	—	1
	D	—	—	—	—	—	—	—	—	—
Sensitivity	A	25	24	24	25	25	25	25	25	25
	B	—	1	1	—	—	—	—	—	—
	C	—	—	—	—	—	—	—	—	—
	D	—	—	—	—	—	—	—	—	—

Table 4: Number of Evaluated Restorations in Each Criterion for Each Experimental Group (cont.)										
Criteria	Code	Baseline			6 months			1 year		
		FS	XT	SE	FS	XT	SE	FS	XT	SE
Secondary caries	A	25	25	25	25	25	25	24	25	25
	B	—	—	—	—	—	—	1	—	—
Abbreviations: FS, Filtek Silorane Restorative Sysm; SE, Adper Scotchbond SE, a two-step self-etch adhesive, with Filtek Z250; XT, Adper Scotchbond 1 XT, a two-step etch-and-rinse adhesive, with Filtek Z250.										

appeared during the first six months ($p=0.014$) and remained stable at the one-year recall, when eight restorations rated Bravo and one was rated Charlie. This restorative system was the only one that resulted in one Charlie rating for color match. Additionally, one patient experienced postoperative sensitivity after restoration placement, which disappeared gradually after a few days.

DISCUSSION

In this study, Filtek Silorane and the etch-and-rinse adhesive Adper Scotchbond 1 XT + Filtek Z250 resulted in statistically similar clinical parameters at one year. The other system formed by the self-etch adhesive Adper Scotchbond SE and Filtek Z250 resulted in increased marginal staining at one year. Thus, the first null hypothesis must be partially rejected.

Early marginal staining is usually a clinical sign that a restoration is prone to failure or that the adhesive interface undergoes degradation with time.²⁸ Marginal discoloration may be caused by several factors, including the presence of excess filling materials, a deficient restoration around the margin, and the formation of gaps.²⁹ However, the nature of the adhesive system is a determinant factor. The marginal staining associated with Adper Scotchbond SE + Filtek Z250 restorations must have been caused by the adhesive itself, since the other system using the same resin composite showed no alteration in this parameter. Adper Scotchbond SE is a strong self-etch system ($pH=1$).³⁰ Although marginal discoloration has been associated with a poor etching ability of self-etch adhesives at the enamel margins,^{21,23,28} significant marginal staining and color changes have been reported for self-etch adhesives with a pH similar to that of Adper Scotchbond SE.²⁸ Adper Scotchbond SE is a two-

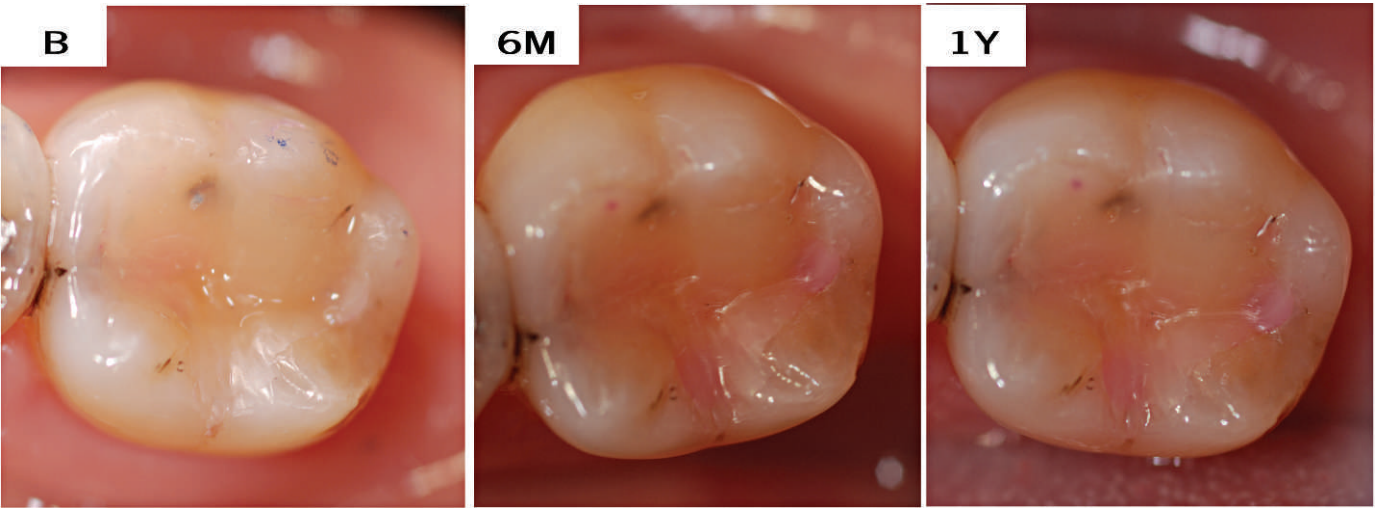


Figure 1. First molar. Occlusal restoration with Adper Scotchbond SE and Filtek Z250. Staining around this Class I restoration was observed at six-month and one-year evaluations, being rated Charlie (>50% of cavo-surface is affected). Furthermore, the one-year photograph shows that staining has progressed in depth across the adhesive interface. This stain also caused color changes in the resin composite close to the bonded walls. B, baseline; 6M, six-month recall; 1Y, one-year recall.

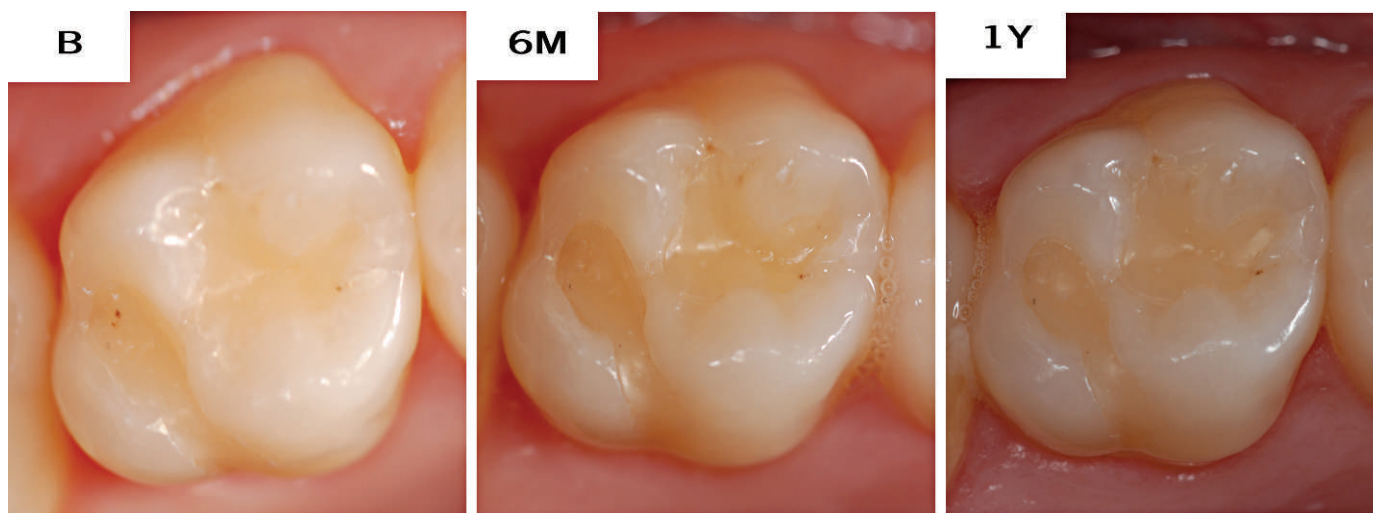


Figure 2. First molar. Occlusal restoration with Adper Scotchbond 1 XT and Filtek Z250. This restoration preserved its original aspect after six months and one year. No signs of adhesive deterioration were found. B, baseline; 6M, six-month recall; 1Y, one-year recall.

step self-etch adhesive in which water is separate from the adhesive solution to increase stability of the material.³¹ In fact, conventional methacrylate monomers undergo rapid hydrolysis under acidic aqueous conditions.³¹ Liquid A is a 2-hydroxyethyl methacrylate (HEMA)–water solution without etching capacity, and Liquid B is the solution containing the acidic monomers. The combination of acidic hydrophilic and hydrophobic monomers in the same solution (in this case, Liquid B) may cause a low degree of carbon double bond (C=C) conversion and increased permeability of adhesive interfaces. Other factors may be responsible for the marginal staining observed in the current study with SE. The change of color from pink to yellow that results from the adequate mix of Liquid A and Liquid B confirms that the acidic monomers have been activated (ionized). However, the activation of Liquid B into an etching agent, based on the superficial moisture provided by the 80% water in Liquid A, may result in an incomplete conversion of the acidic monomers. Their inclusion in a HEMA-rich and still-colored adhesive interface would enhance their susceptibility to hydrolytic degradation and, consequently, marginal staining.^{30,32} This mechanism was corroborated by the presence of the characteristic pink color of Liquid A in most of the stained margins around Adper Scotchbond SE + Filtek Z250 restorations (Figure 1).

A recent study³² has revealed high color instability after water immersion of a self-etch adhesive (One-Up Bond F, Tokuyama Dental Corporation, Tokyo, Japan), with a very similar color-change mechanism to that of Adper Scotchbond SE. Water sorption and

discoloration of the adhesive interface may affect the color appearance of the restoration.³² This phenomenon is highly consistent with what evaluators found in the present study, as all the restorations with Adper Scotchbond SE + Filtek Z250 that rated Bravo or Charlie for color match presented a variable saturation of pink. Some of these restorations already had slight pink marginal staining at the baseline evaluation (Figure 1).

Regarding the comparisons between the baseline and one year for each restorative system, only Adper Scotchbond 1 XT + Filtek Z250 was statistically invariable for all of the parameters tested (Figure 2). Therefore, the second null hypothesis must also be partially rejected. The only system including an etch-and-rinse adhesive obtained the best clinical outcome, which is consistent with the results of previous clinical research.^{21,28} Moreover, in a literature review³³ focused on marginal integrity, significantly better *in vitro* and *in vivo* enamel marginal adaptation were found with etch-and-rinse adhesives compared to self-etch systems.

Restorations performed with Adper Scotchbond SE + Filtek Z250 exhibited a statistically lower number of Alfa ratings for marginal adaptation and marginal staining parameters at one year. Filtek Silorane also resulted in significantly worse marginal adaptation after one year. Marginal adaptation is influenced by many factors, such as the polymerization shrinkage of the composite resin or the adhesive system used.³⁴ Both factors could influence the clinical results of this study, since restorative systems were made of different resin composites and adhesives.

Polymerization shrinkage of resin composites may be a potentially harmful factor for the clinical survival of direct restorations as a result of the transfer of stresses to the adhesive interface.³⁵ Ideally, marginal adaptation, which depends on polymerization shrinkage and resulting stress, should be assessed at baseline because both shrinkage and resulting stress take place during the placement of the restoration. Other clinical factors, such as wear and the integrity of the adhesive interface, may have induced changes in marginal adaptation over the one year of clinical use.

As Filtek Silorane Restorative System has been conceived by its manufacturer for posterior restorations only, Class I and II lesions were selected for this study. The resulting cavity designs produce high C-factor values, which contribute to higher shrinkage stress. The application technique of the resin composite may also influence the bonding effectiveness.³⁶ In this study, the incremental technique was used in all restorations, as it has been demonstrated to benefit the bond strength of both methacrylate-based^{37,38} and silorane composites.³⁶

The higher polymerization shrinkage of Filtek Z250 combined with high C-factor may create a more unfavorable environment than is associated with Filtek Silorane, as the silorane composite has been reported to undergo up to 1% volumetric shrinkage,⁵ according to the manufacturer's information. However, recent research has found Filtek Silorane's volumetric shrinkage to be slightly higher (1.4%)^{6,10} and close to the 1.7% total volumetric shrinkage determined for Filtek Z250.⁶ Moreover, the elastic

modulus of Filtek Silorane is also higher than that of Filtek Z250, which might be attributed to a more significant influence of the organic matrix on composite stiffness.⁶ Although the relationship between elastic modulus and polymerization stress is still not well defined, the *in vitro* study by Boaro and others⁶ measured a greater polymerization stress for Filtek Silorane than for Filtek Z250, which contradicts the belief that lower polymerization shrinkage is related to lower polymerization stress values, as was originally expected.³⁹ These studies confirm that reduced shrinkage *per se* does neither guarantee attenuation of stress in restored teeth,¹⁰ nor does it improve the interfacial integrity of the restoration,⁶ which is in line with the findings of previous clinical studies.^{25,40} The authors of another clinical report⁴¹ related to Filtek Silorane analyzed exclusively the marginal adaptation and reported better marginal adaptation for the methacrylate-based resin composite (Ceram.X, Dentsply) compared to that of Filtek Silorane.

Many of the marginal defects detected in the present study appeared to result from the fracture of thin areas of resin composite flash that extended to non-instrumented enamel surfaces adjacent to the cavity margins. Better contouring at polishing should eliminate these areas of marginal flash. Mild self-etch systems have a less stable bonding capacity to enamel, probably because of a shallower etching pattern.^{42,43} The use of adhesives with a more efficient etching capacity may have reduced the occurrence of such defects, especially in high-stress-

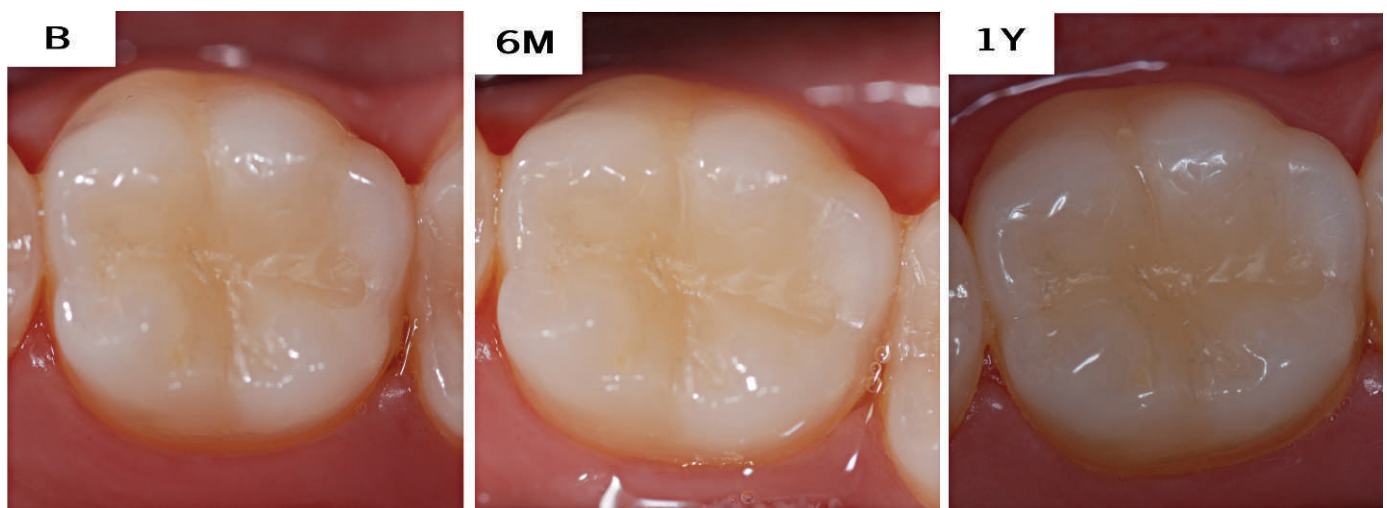


Figure 3. First molar. Occlusal-palatine restoration with the Filtek Silorane Restorative System. Although Filtek Silorane composite displayed a yellowish and opaque appearance in some restorations, the restorations shown were rated Alfa for color match. No staining was detected. B, baseline; 6M, six-month recall; 1Y, one-year recall.

bearing areas, because of the improvement of enamel etching.⁴⁴

The adhesive system that accompanies Filtek Silorane requires separate light-curing of the primer and the bonding, thereby establishing the bonding mechanism to dentin in the first application step, resembling one-step self-etch adhesives. This bonding mechanism uses a form of nano-interaction, typical of ultra-mild self-etch adhesives, which is related to the relatively high pH (2.7) of the respective primer. Mine and others¹³ observed a tight superficial interaction and very slight inter- and intracrystallite demineralization with subsequent resin infiltration, when bonded to enamel. This nano-interaction bonding mechanism is clinically relevant for a methacryloyloxydecyl dihydrogen phosphate (MDP)-based two-step self-etch adhesive⁴⁵ and may also occur with the polyalkenoic acid copolymer⁴⁶ (or Vitrebond™ copolymer) incorporated in the two-step self-etch Silorane System Adhesive used in the present study. Recent *in vitro* research^{46,47} found evidence of the Vitrebond carboxylic acid reacting with calcium ions. It has been demonstrated^{13,47} that the Silorane System Adhesive provides a tight, stable, and water-resistant adhesion to dentin. However, information about its performance when it is bonded to enamel is still scarce.

As mentioned above, the Filtek Silorane Restorative System has been specially designed for posterior restorations, for which the esthetic requisites are not so relevant. Accordingly, the manufacturer only provides four shades. At the six-month and one-year assessments three restorations were rated as Bravo. It is noteworthy that the two Bravo ratings with Filtek Silorane at baseline were caused by the poor esthetic characteristics of the silorane-based resin composite (Figure 3). In fact, evaluators deemed these restorations too yellow and very opaque; thus, their translucency differed from that of tooth structure (Figure 3). Both restorations were also rated Bravo in the subsequent follow-up assessments; therefore, only one restoration showed a real color modification over time. These observations derived from the *in vivo* analysis are consistent with recent *in vitro* research demonstrating low translucency and high color stability of silorane-based resin composite compared to those of methacrylate-based resin composites.^{48,49}

CONCLUSIONS

The clinical performance of the Filtek Silorane Restorative System was found acceptable after one year. Additionally, stable adhesion to enamel with self-etch adhesives is still a challenge, as both

restorative systems including these products showed a deterioration of their marginal adaptation after one year.

Despite the limitations of this study, the clinical outcomes led to the perception that the Filtek Silorane Restorative System did not provide any remarkable advantage for the evaluated criteria when compared to the other systems, and they reinforced the findings that etch-and-rinse adhesives are still the benchmark when it comes to clinical performance. Further recalls are planned to follow up with regard to the clinical performance of these restorations, as wider differences between the restorative materials might surface at later stages.

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