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Bonding Performance of Simplified Adhesive Systems in Noncarious Cervical Lesions at 2-year Follow-up: A Double-blind Randomized Clinical Trial

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Clinical Relevance

The composition and adhesion strategy of current simplified adhesives may be used for noncarious cervical lesions with minimal dentin sclerosis.

SUMMARY

Objectives: This study aimed to evaluate the bonding performance of a universal adhesive used according to self-etching or etch-and-rinse protocols in noncarious cervical lesions (NCCLs) and to compare the two protocols with their respective gold standard techniques.

Methods and Materials: This randomized, double-blind clinical study enrolled 34 participants who met the inclusion criteria, 29 of whom returned after two years. They received 152 restorations bonded with one of the three adhesives (Scotchbond Universal Adhesive, Adper Single Bond 2, or Clearfil SE Bond) and one of the two bonding techniques tested. The NCCLs were restored with nanocomposite resin (Filtek Supreme). Final contours were done with a fine diamond rotary instrument and polished with rubber points. The restorations were evaluated using the FDI World

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Dental Federation criteria at baseline (seven days after the restoration procedure), 6, 12, and 24 months. Descriptive statistics, Kruskal-Wallis, Friedman analysis of variance, and least significant difference tests were performed.

Results: No statistically significant differences were found in esthetics or the functional and biological evaluated criteria among the adhesive systems and techniques.

Conclusions: The Scotchbond Universal system behaved similarly to the conventional etch-and-rinse or self-etching systems in all the adhesion strategies in the evaluated periods.

INTRODUCTION

The development of new adhesive systems has been prompted by the need to simplify single-bottle adhesives and provide faster, more user-friendly, and less technique-sensitive products.[1] Recently, multimode simplified adhesive systems with fewer steps, known as universal adhesives, have been launched as viable options for enamel and dentin bonding,[2,3] These adhesives can be used with the self-etching or etch-and-rinse strategy[3,4] and act as silane agents for ceramics and metals.[5]

Differences in composition and structure between enamel and dentin make the bonding strategy decision challenging. The etch-and-rinse strategy with phosphoric acid remains the gold standard for enamel. Studies on self-etching adhesives[6,7] indicate that the adhesives are usually not able to form a proper and uniform layer, resulting in lower bond strengths compared with etch-and-rinse systems.[8] Dentin, however, has a higher organic content than enamel, and etching with phosphoric acid can increase collagen degradation by activating metalloproteinases and cathepsins. The use of self-etching adhesives could decrease this degradation phenomenon.[9-11]

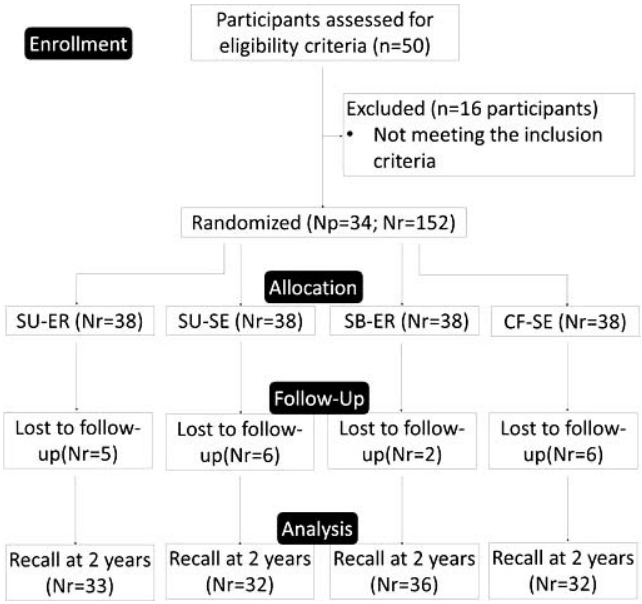

Figure 1. *Flowchart of the Model Under Study. Np, number of participants; Nr, number of restorations; SU, Scotchbond Universal Adhesive; ER, etch-and-rinse; SE, self-etching; SB, Adper Single Bond 2; CF, Clearfil SE Bond.*

Recent studies with universal multimode adhesives have shown that the bonding strategy used—self-etching or etch-and-rinse—does not influence short-term bonding performance.[3,12,13] However, at a three-year follow-up, some marginal degradation was found for the self-etching strategy when used in noncarious cervical lesions (NCCLs).[14]

NCCLs are characterized by cervical dental tissue loss without the presence of caries. Their etiology is multifactorial and is often associated with dentin

Table 1: *Dentin Sclerosis[a] and Preoperative Sensitivity Scales*

Category	Criteria
Dentin Sclerosis Scale	
1	No sclerosis present; dentin is light yellowish or whitish with little discoloration; dentin is opaque with little translucency or transparency
2	More sclerosis than category 1 but less than halfway between categories 1 and 4
3	Less sclerosis than category 4 but more than halfway between categories 1 and 4
4	Significant sclerosis present; dentin is dark yellow or even discolored (brownish); glassy appearance with significant translucency or transparency evident
Preoperative Sensitivity Scale	
1	Absence of dentin sensitivity
2	Presence of dentin sensitivity

[a] *Adapted from Swift et al.*[18]

Table 2: *Compositions and Application Mode of the Adhesive Systems*

Adhesive System	Composition	Application Mode[a]	
Scotchbond Universal Adhesive (3M ESPE, St Paul, MN, USA)	Methacryloyloxydecyl dihydrogen phosphate, phosphate monomer, dimethacrylate resins, hydroxyethyl methacrylate-modified polyalkenoic acid copolymer, filler, ethanol, water, initiators, silane.	Etch-and-rinse	Apply etchant for 15 s.
			Apply the adhesive for 20 s,
			Gently air for 5 s,
			Light cure for 10 s.
		Self-etch	Do not etch.
			Apply the adhesive for 20 s,
			Gently air for 5 s,
			Light cure for 10 s.
Adper Single Bond 2 (3M ESPE, St Paul, MN, USA)	Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiators, methacrylate functional copolymer of polyacrylic, polyitaconic acids, silica particles.	Etch-and-rinse	Apply etchant for 15 s.
			Apply 2 to 3 consecutive coats of the adhesive for 15 s,
			Gently air for 5 s,
			Light cure for 10 s.
Clearfil SE Bond (Kuraray, Kurashiki, Okayama, Japan)	*Primer*: 10-MDP, HEMA, hydrophilic dimethacrylate, di-camphorquinone, N,N-diethanol-p-toluidine, water. *Bond*: 10-MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, di-camphorquinone, N,N-diethanol-p-toluidine, silanated colloidal silica	Self-etch	Do not etch.
			Apply primer and leave for 20 s,
			Do not rinse,
			Dry with mild air flow,
			Apply the adhesive and distribute with mild air flow,
			Light cure for 10 s.

Abbreviations: 10-MDP, 10-methacryloyloxydecyl dihydrogen phosphate; HEMA, 2-hydroxyethyl methacrylate; Bis-GMA, bisphenol A-glycidyl methacrylate.
[a] *According to the manufacturer's instructions.*

sensitivity and poor esthetics.[15] Bonding to NCCLs is challenging because of the general absence of macromechanical retention and the presence of both enamel and dentin margins requiring different adhesive strategies. Therefore, this clinical study aimed to evaluate the bonding performance of a universal adhesive used according to the self-etching and the etch-and-rinse protocols in NCCLs and to compare the two protocols to their respective gold standard techniques. The null hypothesis tested was that no difference would be found between the two protocols after a two-year follow-up.

METHODS AND MATERIALS

This randomized, double-blind clinical study followed the CONSORT statement.[16] The experimental design was a controlled, double-blind, randomized clinical trial and was conducted after approval from the local Institutional Review Board. This trial was registered in the Brazilian Clinical Trials Registry (ReBEC - www.ensaiosclinicos.gov.br) under the identification number RBR-4rw55d.

Sample-Size Calculation

The tooth was used as the statistical unit. Sealed Envelope online software (www.sealedenvelope.com) was used to calculate the sample size. At least 30 teeth per group were required to provide an 80% assurance that the limits of a two-sided 90% confidence interval would exclude a difference among the groups of more than 15%. To account for dropout during the experimental period, an enrollment of 38 teeth per group was determined.

Participants

Fifty participants from the Department of Restorative Dentistry triage center were examined by four precalibrated operative dentistry professionals to determine whether they met the inclusion criteria (Figure 1). Teeth with NCCLs were selected by using a mouth mirror, an explorer, and a periodontal probe. Prior to participation in the study, all participants signed a written informed consent and received oral hygiene instructions.

The study inclusion criteria were that the patient had to be in good general health, be at least 18 years old, have an acceptable oral hygiene level, and present with at least 20 teeth in occlusion. Participants were required to exhibit NCCLs with a depth of at least 1 mm and have both enamel and dentin margins with the cavosurface margin of at least 50% enamel. Also, the selected teeth had to be vital and not mobile.[12,13,17] Individuals with poor oral hygiene, severe bruxism, and severe or chronic periodontitis were excluded.

Table 3: *FDI Criteria Used for Clinical Evaluation* [20]

	Esthetic Property	Functional Properties		Biological Properties	
	1. Marginal Staining	**2. Fracture and Retention**	**3. Marginal Adaptation**	**4. Postoperative Sensitivity**	**5. Secondary Caries**
1. Clinically very good	1.1 No marginal staining	2.1 Restoration retained, no fractures/ cracks	3.1 Harmonious outline, no gaps, no discoloration	4.1 No hypersensitivity	5.1 No secondary or primary caries
2. Clinically good (after correction very good)	1.2 Minor marginal staining, easily removable by polishing	2.2 Small hairline crack	3.2.1 Marginal gap (50 μm) 3.2.2 Small marginal fracture removable by polishing	4.2 Low hypersensitivity for a limited period of time	5.2 Very small and localized demineralization. No operative treatment required
3. Clinically sufficient/ satisfactory (minor shortcoming with no adverse effects but not adjustable without damage to the tooth)	1.3 Moderate marginal staining, not esthetically unacceptable	2.3 Two or more or larger hairline cracks and/or chipping (not affecting the marginal integrity)	3.3.1 Gap >150 μm not removable 3.3.2 Several small enamel or dentin fractures	4.3.1 Premature/ slightly more intense. 4.3.2 Delayed/ weak sensitivity; no subjective complaints, no treatment needed	5.3 Larger areas of demineralization, but only preventive measures necessary (dentin not exposed)
4. Clinically unsatisfactory (repair for prophylactic reasons)	1.4 Pronounced marginal staining; major intervention necessary for improvement	2.4 Chipping fractures that damage marginal quality; bulk fractures with or without partial loss (less than half of the restoration)	3.4.1 Gap >250 μm or dentin/base exposed 3.4.2 Chip fracture damaging margins 3.4.3 Notable enamel or dentin wall fracture	4.4.1 Premature/ very intense 4.4.2 Extremely delayed/weak with subjective complaints 4.4.3 Negative sensitivity; intervention necessary but not replacement	5.4 Caries with cavitation (localized and accessible and can be repaired)
5. Clinically poor (replacement necessary)	1.5 Deep marginal staining not accessible for intervention	2.5 Partial or complete loss of restoration	3.5 Filling is loose but *in situ*	4.5 Very intense, acute pulpitis or nonvital Endodontic treatment is necessary, and restoration has to be replaced	5.5 Deep secondary caries or exposed dentin that is not accessible for repair of restoration

Restorative Procedures

Before placement of the restorations, the characteristics of the NCCLs were evaluated. The cavity dimensions in millimeters (height, width, and depth) and the geometry of the cavity (labeled at <90°, 90% to 135°, >135°) were evaluated from a photographic profile. Each profile was measured by computer software (Image J v1.52, Wayne Rasband, National Institutes of Health, Bethesda, MD, USA). The amount of sclerotic dentin was measured according to the criteria described by Swift and others[18] (Table 1). Preoperative sensitivity was also evaluated by applying air for 10 seconds from a dental syringe placed 2 cm from the tooth surface (Table 1).

Participants who met the inclusion criteria received restorations bonded with one of the three adhesives and one of the two bonding techniques tested. Randomization was achieved by using a random list generated by a website (www.random.org) and allocated using sealed envelopes. The operators were not blinded to group assignment when performing the restorations; however, participants and examiners were blinded to the adhesive and technique used.

Treatment was performed according to a predetermined procedure, which included prophylaxis of the cavities using a rubber cup with pumice and water; shade selection with VITA Classical shade guide, and local anesthesia (Mepivalem AD 2%, DLA Pharmaceutical Ltda, Dentsply, Catanduva, SP, Brazil). No additional retention or bevels were made in the cavities. All procedures were carried out using the relative isolation method with cotton rolls, saliva aspirator, and gingival retraction cord (Ultrapak #000, Ultradent Products, Inc, South Jordan, UT, USA) in the gingival sulcus.

The teeth were etched with 37% phosphoric acid (Condac 37, FGM, Joinville, SC, Brazil) applied for

Table 4: *Baseline Characteristics of the Subjects and the Noncarious Cervical Lesions Included in the Study Groups*

Characteristics of Research Participants	**No. (%) of Subjects/Lesions**			
Sex				
Male	13 (38)			
Female	21 (62)			
Age (y)				
< 20	0 (0)			
21-40	5 (15)			
41-60	27 (79)			
> 60	2 (6)			
Characteristics of Class V lesions	**SU/ER**	**SU/SE**	**SB/ER**	**CF/SE**
Degree of dentin sclerosis				
1	28 (18.4)	24 (15.8)	24 (15.8)	24 (15.8)
2	9 (5.8)	12 (7.8)	13 (8.6)	13 (8.6)
3	1 (0.7)	2 (1.3)	0 (0)	1 (0.7)
4	0 (0)	0 (0)	1 (0.7)	0 (0)
Tooth distribution				
Anterior				
Incisors	4 (2.6)	5 (3.3)	4 (2.6)	4 (2.6)
Canines	3 (2.0)	4 (2.6)	7 (4.6)	3 (2.0)
Posterior				
Premolar	22 (14.5)	22 (14.5)	21 (13.8)	24 (15.8)
Molar	9 (5.9)	7 (4.6)	6 (3.9)	7 (4.6)
Position				
Maxillary	22 (14.5)	21 (13.8)	22 (14.5)	23 (15.1)
Mandibular	16 (10.5)	17 (11.2)	16 (10.5)	15 (9.9)
Depth				
Flat (1.0-1.5 mm)	11 (7.2)	10 (6.6)	9 (5.9)	9 (5.9)
Medium (1.5-2.0 mm)	17 (11.2)	21 (13.8)	16 (10.5)	16 (10.5)
Deep (>2.0 mm)	10 (6.6)	7 (4.6)	13 (8.6)	13 (8.6)
Cervico-incisal height (mm)				
<1.5	6 (3.9)	6 (3.9)	6 (3.9)	5 (3.3)
1.5-2.5	19 (12.5)	22 (14.5)	18 (11.8)	22 (14.5)
2.6- 4.0	9 (5.9)	7 (4.6)	8 (5.3)	5 (3.3)
>4.0	4 (2.6)	3 (2.0)	6 (3.9)	6 (3.9)
Preoperative sensitivity				
Yes	18 (11.8)	24 (15.8)	19 (12.5)	20 (13.2)
No	20 (13.2)	14 (9.2)	19 (12.5)	18 (11.8)
Width (mm)				
< 4.0	21 (13.8)	19 (12.5)	21 (13.8)	22 (14.5)
4.0- 5.9	11 (7.2)	16 (10.5)	14 (9.2)	11 (7.2)
6.0- 7.9	3 (2.0)	2 (1.3)	3 (2.0)	4 (2.6)
> 8.0	3 (2.0)	1 (0.7)	0 (0.0)	1 (0.7)
Shape of angle				
< 90	6 (3.9)	5 (3.3)	7 (4.6)	3 (2.0)
90-135	26 (17.1)	29 (19.1)	27 (17.8)	32 (21.1)
> 135	6 (3.9)	4 (2.6)	4 (2.6)	3 (2.0)

Abbreviations: SU, Scotchbond Universal Adhesive; ER, etch-and-rinse; SE, self-etch; SB, Adper Single Bond 2; CF, Clearfil SE Bond.

Table 5: *Number and Percentage of Success for Each Studied Variable (Kruskal-Wallis)*

Variable	Success (Scores 1, 2, and 3) No. of restorations (%)	Failure (scores 4 and 5) No. of restorations (%)	*p*-value
Degree of dentin sclerosis			
1	67 (50.4)	15 (11.3)	0.5135
2	40 (30.1)	6 (4.5)	
3	3 (2.3)	1 (0.8)	
4	1 (0.8)	0 (0.0)	
Depth			
Flat (1.0-1.5mm)	26 (19.5)	5 (3.8)	0.1603
Medium (1.5-2.0mm)	56 (42.1)	7 (5.3)	
Deep (>2.0mm)	29 (21.8)	10 (7.5)	
Cervico-incisal height (mm)			
<1.5	11 (8.3)	4 (3.0)	0.5034
1.5- 2.5	62 (46.6)	9 (6.8)	
2.6- 4.0	22 (16.5)	6 (4.5)	
>4.0	16 (12.0)	3 (2.3)	
Width (mm)			
< 4.0	59 (44.4)	10 (7.5)	0.6083
4.0- 5.9	40 (30.1)	10 (7.5)	
6.0- 7.9	7 (5.3)	2 (1.5)	
> 8.0	5 (3.8)	0 (0.0)	
Shape of angle			
< 90	13 (9.8)	4 (3.0)	0.1362
90- 135	87 (65.4)	13 (9.8)	
> 135	11 (8.3)	5 (3.8)	

30 s to the enamel and 15 seconds to the dentin (depending on the technique used), followed by air-water spray for 30 seconds to remove the acid. Excess water was removed with absorbent paper, leaving a moist dentin surface. Subsequently, the cavities received the adhesive system applied using the two different techniques, etch-and-rinse or self-etch, according to the manufacturer's instructions. The compositions and application mode are described in Table 2.

The cavities were restored with a direct restorative nanocomposite resin (Filtek Supreme, 3M ESPE, St Paul, MN, USA). Increments up to 2 mm in thickness were placed and light polymerized (750 mW/cm^2; Emitter A, Guilin Woodpecker Medical Instrument Co, Guilin, China) for 20 seconds each. Final contour was achieved with a fine diamond rotary instrument (KG Sorensen, SP, Brazil) immediately after the restorative procedure. The restorations were polished with rubber points (Astropol F, Ivoclar Vivadent AG, SP, Brazil) seven days after placement.

Calibration Procedures for Clinical Assessment

For training purposes, two experienced and calibrated examiners observed 10 photographs that were representative of each score for each criterion. They evaluated 10 individuals each on two consecutive days. These individuals had cervical restorations but were not part of this study. An intraexaminer and interexaminer agreement of at least 85% was necessary before beginning the evaluation.

Clinical Assessment

The restorations were evaluated using the FDI World Dental Federation criteria[19,20] as shown in Table 3. The most relevant items for testing the adhesive performance were selected. The primary measurable variable was restoration retention and fractures, followed by the secondary measurable variables: marginal staining, marginal adaptation, postoperative sensitivity, and recurrence of caries. Those measurable variables were ranked as (1) clinically very good, (2) clinically good, (3) clinically

Table 6: *Comparison of the Tested Adhesive Systems According to the FDI Criteria Compared by Kruskal-Wallis Test at $p<0.05$ for Each Recall Time* [a]

Time	Baseline (After 7 Days)					6 months				
FDI Criteria	**SU/ER**	**SU/SE**	**SB/ER**	**CF- SE**	***p*** [a]	**SU -ER**	**SU- SE**	**SB- ER**	**CF- SE**	***p***
Functional properties										
Fracture and retention										
VG	38	37	38	38	0.392	36	35	37	35	0.725
GO	-	1	-	-		2	3	1	2	
SS	-	-	-	-		-	-	-	-	
UN	-	-	-	-		-	-	-	-	
PO	-	-	-	-		-	-	-	1	
Marginal adaptation										
VG	38	37	37	37	0.799	36	33	37	33	0.301
GO	-	1	1	1		2	5	1	3	
SS	-	-	-	-			-	-	1	
UN	-	-	-	-			-	-	-	
PO	-	-	-	-			-	-	-	
Esthetics properties										
Marginal staining										
VG	38	38	38	38	-	36	36	35	32	0.512
GO	-	-	-	-		2	1	3	4	
SS	-	-	-	-		-	1	-	1	
UN	-	-	-	-		-	-	-	-	
PO	-	-	-	-		-	-	-	-	
Biological properties										
Postoperative sensitivity										
VG	35	34	34	36	0.806	34	33	35	33	0.910
GO	3	3	3	2		4	4	2	4	
SS	-	-	-	-		-	1	-	-	
UN	-	1	1	-		-	-	1	-	
PO	-	-	-	-		-	-	-	-	
Recurrence of caries										
VG	38	38	38	38	-	38	38	38	37	-
GO	-	-	-	-		-	-	-	-	
SS	-	-	-	-		-	-	-	-	
UN	-	-	-	-		-	-	-	-	
PO	-	-	-	-		-	-	-	-	

Abbreviations: SU, Scotchbond Universal Adhesive; ER, etch-and-rinse; SE, self-etch; SB, Adper Single Bond 2; CF, Clearfil SE Bond; VG, clinically very good; GO, clinically good; SS, clinically sufficient/satisfactory; UN, clinically unsatisfactory; PO, clinically poor.

[a] *Comparison among the groups at the same follow-up (Kruskall-Walis test);*

sufficient/satisfactory, (4) clinically unsatisfactory, and (5) clinically poor.

The two calibrated examiners conducted the evaluations according to the periods: baseline (one week after the restorative procedures) and 6, 12, and 24 months after the restorative procedures. If there were disagreements between the two examiners in the individual analysis, they discussed the situation to reach a consensus. Both participants and examiners were unaware of the material used to perform the restorations, accordingly resulting in a double-blind study.

Statistical Analysis

Statistical analysis was performed for each criterion in R statistical language R Studio (version 3.4.4, R Studio Team, Boston, MA, USA). Only data from the participants who attended the recall were included in the statistical evaluation in a procedure called per-protocol analysis. Descriptive statistics were used to demonstrate the frequency distribution of

Table 6: *Comparison of the Tested Adhesive Systems According to the FDI Criteria Compared by Kruskal-Wallis Test at $p<0.05$ for Each Recall Time [a] (ext.)*

Time	**12 months**					**24 Months**				
FDI Criteria	**SU- ER**	**SU- SE**	**SB- ER**	**CF- SE**	***p***	**SU- ER**	**SU- SE**	**SB- ER**	**CF- SE**	***p***
Functional properties										
Fracture and retention										
VG	34	31	34	30	0.315	31	25	29	24	0.192
GO	1	3	2	3		-	3	1	2	
SS	-	1	1	1		-	-	2	1	
UN	-	-	-	-		-	-	-	-	
PO	1	2	-	1		1	2	4	3	
Marginal adaptation										
VG	30	32	32	27	0.512	25	14	22	16	0.074
GO	5	3	4	6		6	14	10	10	
SS	-	-	1	1		-	-	-	1	
UN	-	-	-	-		-	-	-	-	
PO	-	-	-	-		-	-	-	-	
Esthetics properties										
Marginal staining										
VG	30	27	31	24	0.546	26	17	24	17	0.251
GO	3	6	5	8		3	8	7	7	
SS	-	1	1	1		-	1	-	1	
UN	2	-	-	1		2	1	1	1	
PO	-	-	-	-		-	-	-	-	
Biological properties										
Postoperative sensitivity										
VG	30	30	31	33	0.351	30	24	26	24	0.287
GO	4	4	4	-		1	3	5	2	
SS	1	-	1	1		-	-	-	1	
UN	-	1	1	-		-	1	1	-	
PO	-	-	-	-		-	-	-	-	
Recurrence of caries										
VG	35	35	37	34	-	31	28	32	27	-
GO	-	-	-	-		-	-	-	-	
SS	-	-	-	-		-	-	-	-	
UN	-	-	-	-		-	-	-	-	
PO	-	-	-	-		-	-	-	-	

the lesions according to the characteristics of the lesions. The Kruskal-Wallis test was performed to analyze all evaluated criteria among the groups at each evaluation time. The difference in the performance of each group at baseline and after each recall visit (6, 12, and 24 months) was assessed by the Friedman repeated analysis of variance, followed by the least significant difference test for multiple comparisons when applicable. Cohen kappa statistics were used to test interexaminer agreement. In all statistical tests, the level of significance was set to 5%.

RESULTS

In this study, 152 restorations were placed in 34 participants, with a median of four restorations per participant (minimum one and maximum 10 restorations) and reevaluated after six months, one year, and two years. In the recall after two years, 29 participants were evaluated with 133 restorations. Details regarding the research participants and characteristics of the restored cavities are presented in Table 4.

None of the characteristics of the cavity influenced retention of the restoration (Table 5). Also, no

Table 7: *Percentage of Acceptable Restorations (Scores VG, GO, and SS) for Each Recall Time According to the Experimental Group Compared by Friedman Test and Least Significant Difference Test at* $p<0.05$

Adhesive	Single Bond Universal – Etch and rinse (SU-ER)					Single Bond Universal – Self-Etch (SU-SE)				
Time	BL	6 mo	12 mo	24 mo	*p*	BL	6 m	12 mo	24 mo	*p*
Functional properties										
Fracture and retention	100	100	97	94	0.194	100 a	100 a	95 b	87.5 b	0.024
Marginal adaptation	100	100	100	100	N/A	100	100	100	100	N/A
Esthetics properties										
Marginal Staining	100	100	94	94	0.111	100	100	100	97	0.392
Biological properties										
Postoperative sensitivity	100	100	100	100	N/A	97	100	97	96	0.511
Recurrence of caries	100	100	100	100	N/A	100	100	100	100	N/A

Abbreviations: VG, clinically very good; GO, clinically good; SS, clinically sufficient/satisfactory; SU, Scotchbond Universal Adhesive; ER, etch-and-rinse; SE, self-etch; SB, Adper Single Bond 2; CF, Clearfil SE Bond; BL, baseline; N/A, not applicable.

[a] *Groups connected by the same letter indicate not statistically significant differences among the follow-ups for the same group* ($p>0.05$).

statistically significant differences in esthetics or functional and biological evaluated criteria were found among adhesive systems and techniques (Table 6).

The comparisons of each group at baseline and after each recall visit (6, 12, and 24 months) for each criterion are presented in Table 7.

DISCUSSION

The formation of NCCLs has been associated with occlusal factors[21] and biocorrosive processes that alter dentin morphology and structure,[22] directly influencing the adhesion and therefore the survival rates of these restorations. The success of restorations involving cavities without additional mechanical retention, such as NCCLs, is directly related to the adhesion strategy used.

Factors inherent to dentin, such as the presence of humidity, which varies according to the depth, presence of caries-affected tissue, degree of demineralization, and lack of retention provided by high tissue loss, have been associated with failure at the adhesive interface. Also, external factors, such as pH challenges, saliva, and thermal-mechanical stress, contribute to reduced longevity of the restorations.[23-25] Therefore, longitudinal clinical studies are preferable in evaluating the adhesive longevity of restorations as the materials are exposed to all the oral conditions and can be tested in similar conditions.

The adhesive strategy frequently used for dentin differs from that for enamel due to the inherent characteristics of the tissues. Often, the adhesives used in dentin are self-etching and provide less aggressive acid conditioning; this minimizes the collapse of collagen fibrils after drying, which leads to decreased bond strength.[26] Enamel, however, requires etching with phosphoric acid to increase retention.[6] and currently, the so-called selective etching technique has been adopted for restoration of cavities involving both enamel and dentin. The adhesive systems chosen for this study, both etch-and-rinse and self-etching, represents the most popular systems and have been designated as gold standards in the literature. The universal system, however, was used in both adhesive strategies to evaluate its bonding performance longitudinally. The results of this study showed findings with regards to the evaluated criteria of retention, esthetics, and functional and biological factors. The null hypothesis was not rejected for a two-year follow-up of the two protocols.

The retention rates comparing the adhesion strategies and the adhesive systems used (Table 6) were not significantly different, showing that the universal system tested is a viable option for restoring NCCLs over the two-year term. However, most of the teeth restored in this study presented minimal or no dentin sclerosis. In addition, no significant differences (Table 5) were found between the success rate and the study variables (degree of dentin sclerosis, depth, height, width, angle of lesion), findings that were consistent with those of previous studies.[13,14,27]

The action mode of universal adhesives is entirely different from that of the conventional self-etching and etch-and-rinse systems and can be applied over wet or dry dentin. The hybrid layer may not represent the primary mechanism of action in long-term dentin adhesion.[28] The success of universal adhesives regarding bonding is attributed to the

Table 7: *Percentage of Acceptable Restorations (Scores VG, GO, and SS) for Each Recall Time According to the Experimental Group Compared by Friedman Test and Least Significant Difference Test at* $p<0.05$ *(ext.)*

Adhesive	Single-Bond2 – Etch and Rinse (SB-ER)					Clearfil SE – Self-Etch (CF-SE)				
Time	BL	6 mo	12 mo	24 mo	*p*	BL	6 mo	12 mo	24 mo	*p*
Functional properties										
Fracture and retention	100 a	100 a	100 a	89 b	0.007	100 a	97 ab	92 b	84 b	0.015
Marginal adaptation	100	100	100	100	N/A	100	100	100	100	N/A
Esthetics properties										
Marginal Staining	100	100	100	97	0.392	100	100	97	96	0.392
Biological properties										
Postoperative sensitivity	97	97	97	97	N/A	100	100	100	100	N/A
Recurrence of caries	100	100	100	100	N/A	100	100	100	100	N/A

presence of 10-methacryloyloxydecyl dihydrogen phosphate monomer, which is responsible for the chemical bonding between the adhesive and the dentin, creating a stable interface even without micromechanical retention.[29] This monomer also contains a phosphate radical in its molecule that, together with the carboxylate radical from the polyalkenoate copolymer in the universal adhesive, reacts with the calcium from hydroxyapatite to create stable bonds, termed "hydroxyapatite nanolayering."[3,29] This nanolayering is essential for bonding, not only to dentin, but also to enamel, and might explain the good performance of this adhesive on enamel even without selective etching, as shown by the results of retention and marginal adaptation and discoloration (Table 6). The pH of the universal adhesive tested is claimed to be around 2.7 to 3.0.[14,29] This is claimed to be ultramild, and it is not strong enough to provide adequate etching of the enamel. This effective bond to enamel at two years has been previously reported.[3,13,27,29] The retention rate and marginal adaptation have been acceptable immediately and after 18 months. However, differences between the techniques have been reported after 36 months.[14]

The participants in this research were predominately women, aged between 41 and 60 years old, and with dentin sclerosis category 1 (Table 4). Canines and premolars were the most affected teeth, which is consistent with a previous report.[30] Due to its small occlusal surface and location in the arch, the premolar undergoes load concentration during mastication. This overload can be transmitted to the cervical region of reduced enamel volume, promoting microcracks and initiating the NCCL. Also, hypersensitivity was rarely reported, the lesion height was less than 4 mm, and the lesion angle was between 90° and 135°. The data do not confirm the evolution of the lesion or a relation to patient lifestyle.

The restoration of NCCLs should include an analysis of the etiologic factors and their removal, when possible. Not removing unwanted occlusal forces on the restored teeth will also decrease the success rate, factors clinicians should be aware of when treating patients. The Single Bond Universal, in both bonding strategies used in this study, proved to be useful compared with the etch-and-rinse and self-etch conventional adhesives for a two-year period. However, more extended evaluations are necessary to establish its long-term performance.

CONCLUSION

This two-year clinical evaluation demonstrated that the universal adhesive system tested, Scotchbond Universal, performed similarly in restoring NCCLs with minimal dentin sclerosis in both strategies used compared with the etch-and-rinse (Single Bond) or self-etching (Clearfil SE Bond) systems.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the São Paulo State University. The approval code for this study is: 095374/2013.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature

or kind in any product, service, and/or company that is presented in this article.

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