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ORIGINAL ARTICLE

An 18-month clinical evaluation of three different universal adhesives used with a universal flowable composite resin in the restoration of non-carious cervical lesions

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Abstract

Objective The aim of this randomized, controlled prospective clinical trial was to evaluate and compare the performances of three different universal adhesives using a flowable universal composite resin in the restoration of non-carious cervical lesions (NCCLs) over an 18-month period.

Materials and methods Eighteen participants recieved 99 restorations from a single operator. NCCLs were divided into three groups according to adhesive systems used: Clearfil Universal Bond (CU), iBOND Universal (IU), and G-Premio Bond (GP). No enamel bevel was placed and no mechanical retention was created for the NCCLs. Prior to adhesive procedures, selective etching was performed with 37% phosphoric acid. Adhesive systems were applied following manufacturers' instructions and the lesions were restored with a flowable composite resin (G-ænial Universal Flo). Restorations were finished and polished immediately after placement and scored with regard to retention, marginal discoloration, marginal adaptation, sensitivity, surface texture, and color match using modified USPHS criteria after a week (baseline) and 6, 12, and 18 months. Descriptive statistics were performed using chi-square tests.

Results The 18-month recall rate was 88.8% and retention rates for CU, IU, and GP were 100%, 96.8%, and 100%, respectively. No restorations exhibited post-operative sensitivity and secondary caries. After 18 months, CU, IU, and GP groups showed similar alpha rates for marginal adaptation (CU 93.1%, IU 90%, GP 81.8%) and marginal discoloration (CU 100%, IU 90%, GP 87.9%). A total of ten (CU 2, IU 3, GP 5) restorations exhibited bravo scores for surface texture and three (CU 2, GP 1) restorations showed bravo score for color match. No statistical differences were found among the tested adhesives for any criteria evaluated ($p > 0.05$).

Conclusion The three adhesive systems demonstrated similar performances during the 18-month follow-up in the restoration of NCCLs.

Clinical relevance Universal adhesives could be used successfully in the restoration of NCCLs.

Keywords Universal adhesive · Non-carious cervical lesion · Selective etching

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Introduction

Adhesive dentistry has been in a state of constant evolution since it was first introduced by Buoncore in 1955 [1]. Adhesive systems should be capable of bonding to both enamel and dentin, although these structures differ in composition and natural variability. The composition of enamel is highly inorganic (96 wt% mineral, 1 wt% organic matrix, and 3 wt% water) whereas dentin is composed of 70 wt% inorganic, 20 wt% organic collagen, and water [2]. Smear layer and dentinal wetness also influence adhesive bonding. The creation and thickness of the smear layer interferes with the hybrid

layer, and dentin that is too wet or too dry affects bond strength [3]. Adhesive materials from different manufacturers have different compositions and applications, but the basic adhesion mechanism is the same: an exchange process between the dental structure and adhesive material. Minerals from hard tissue are replaced by resin monomers, effectively creating micromechanical bonding [4, 5].

Improved bonding efficiency of the adhesive is considered an important factor contributing to the longevity of composite resins. Clinicians are obviously interested in determining whether any prior application to the enamel surface results in improved short- and long-term performance of adhesive materials. Successful adhesion to hard tissues is necessary for placement of composite resins.

The two main categories of adhesive systems are etch&rinse adhesives and self-etch adhesives. Etch&rinse adhesives are divided into two subgroups: three-step and two-step etch&rinse types [4, 5]. The three-step etch&rinse strategy is considered the gold standard for adhesive systems bonding to hard tissues [4]. Etch&rinse systems are technically sensitive, and their protocol is likely to fail with moist or over-dried dentin [6]. Three-step etch&rinse adhesives were simplified to two-step etch&rinse adhesives, which combine the primer and adhesive in a single bottle.

Self-etch adhesives are divided into two subgroups: two-step and one-step self-etch adhesives. Self-etch adhesives have fewer steps and are less sensitive to technical problems compared with etch&rinse adhesives, as they eliminate the application of phosphoric acid and the rinsing process [4]. Over the years, adhesive systems' evolution progressed from two-bottle to one-bottle etch&rinse and self-etch systems. Although etch&rinse systems have technical sensitivity, they clearly have better clinical performance than do self-etch adhesives [7, 8]. Previous investigations reported that selective etching of enamel produced improved clinical performance [9–12].

Manufacturers have rapidly been working to develop bonding materials to ensure long-lasting restorations. The current philosophy of simplifying the application process, saving time, and eliminating the error potential of multiple steps has led to the manufacture of multi-mode adhesives, allowing the clinician to choose an adhesive according to its use. Nevertheless, some studies have indicated that simplification of etch&rinse and self-etch adhesives results in decreased clinical performance [13].

More recently, the introduction of universal adhesives has allowed clinicians to use adhesives according to their own judgment for specific clinical situations. Universal adhesives are based on the all-in-one concept of self-etch adhesives and can be used in three different modes (etch&rinse, self-etch, selective etching). Universal adhesives can also adhere to multiple substrates other than tooth surfaces, including resin composites, metals, zirconia, and silica-based ceramics [14]. A small number of studies have reported short-term results regarding the clinical success of universal adhesives [15, 16].

Non-carious cervical lesions (NCCLs) are seen in patients increasingly [17, 18] and generally need restorative procedures for protection. The loss of tooth structure in NCCLs can cause hypersensitivity and esthetic problems [19]. Many factors are involved in the formation of NCCLs, such as abrasion, erosion, and abfraction [20]. Composite resins are often preferred for the rehabilitation of these lesions because of their esthetic and physical properties. Restoration is needed to prevent further loss of healthy dental tissue. Additionally, NCCLs are considered appropriate lesions on which to test clinical effectiveness of adhesives because they provide only minimal microretention, and both enamel and dentin adhesion can be evaluated [20]. Although NCCLs are very common, their rehabilitation is not easy, and their durability is low with loss of retention and marginal adaptation [18, 21].

Thus, the aim of the present randomized investigation was to evaluate the clinical performance of three universal adhesives applied to NCCLs using a universal flowable composite resin over 18 months based on US Public Health Service (USPHS) criteria. The null hypothesis was that there would be no difference among the three universal adhesive systems placed with a flowable universal composite resin.

Materials and methods

Patient screening

One clinician enrolled patients fulfilling the inclusion criteria among a group of patients seeking routine dental care and recruited by the Hacettepe University School of Dentistry. Patients with severe periodontal disease; rampant, uncontrolled caries; xerostomia; serious medical problems preventing them from attending review visits; poor gingival health; heavy bruxism; or removable partial dentures were not included in the study. Patients who were undergoing bleaching treatment or orthodontic treatment were also excluded. All participants were at least 18 years old and had at least 20 teeth under occlusion. They were required to have at least three NCCLs that needed restoration in different teeth and that were similar in size (depth), ranging from 1 to 3 mm. None of the selected lesions was shallower than 1 mm or deeper than 3 mm. The cervico-incisal or cervico-occlusal height of the lesions was measured using a periodontal probe (32 lesions with 1.5–2.5 mm size and 67 lesions with > 2.5–4.0). Non-retentive lesions with a cavosurface margin involving at most 50% of the enamel were included. One clinician carried out assessments using an explorer, a mouth mirror, and a periodontal probe. Also, a cold test for sensitivity was performed to avoid including patients with severe

hypersensitivity. The patients were asked to scale their pain from 0 to 10 and were excluded if the pain rating was 7 or higher [22].

The ethics approval and patient consent form for the study were reviewed and approved by the Institutional Clinical Investigations Ethics Committee (Ethic No: KA 16066/08-65).

Restorative procedure

Eighteen participants who met the criteria were included in the study; their mean age was 47 years (age range 30–58 years) (Table 1). Patients were given oral hygiene instructions before operative treatments and received dental prophylaxis 1 week before procedures. The materials used in the study are listed in Table 2. All lesions were restored by the same clinician, who did not participate in the selection of patients for eligibility. Each patient received at least three restorations, and randomization of different adhesive systems was determined by computer-generated tables. Another clinician who was not involved in the research protocol prepared the details of the allocation. The allocation was revealed by choosing a number assigned to an adhesive in the tables (only the clinician who was not involved in the study could see these tables) [23]. A shade selection guide was used to determine the proper shade of the flowable composite resin (G-ænial Universal Flo, GC, Tokyo, Japan). All lesions were cleaned using a rotating rubber cup in a slow-speed handpiece with pumice, washed, and dried, but not desiccated before restoring. Adhesive procedures and restorations were placed according to manufacturers' recommendations:

Group CU ($n = 31$) After lesions were isolated by cotton rolls, enamel was etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein) for 30 s. Then, acid was rinsed and the lesion was gently dried with oil-free air spray. Cotton rolls were changed and Clearfil Universal Bond (Kuraray Dental, Tokyo, Japan) was applied with an applicator brush to the entire lesion and rubbed for 10 s. The adhesive was dried gently with oil-free air for more than 5 s until it did not move, and then light cured with a LED-curing unit (Radii Plus, SDI, Victoria, Australia) for 10 s.

Table 1 Distribution of treated research subjects and non-carious cervical lesions according to gender and age

Characteristics of research subjects	Number of patients	Number of NCCLs
Gender distribution (number of patients)		
Male	7	40
Female	11	59
Age distribution (years)/number of patients		
20–29	0	–
30–39	4	15
40–49	6	29
50–59	8	55
60–65	0	–

Group IU ($n = 33$) Lesions were isolated by cotton rolls and enamel was etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein) for 30 s. Then, the acid was rinsed, and the lesion was gently dried with oil-free air spray. Cotton rolls were changed, and iBOND Universal (Heraeus Kulzer GmbH, Hanau, Germany) was applied using an applicator brush to the entire lesion and rubbed for 20 s. The adhesive was air-dried gently with oil-free air flow until it did not move, and then light cured with a LED-curing unit (Radii Plus, SDI, Victoria, Australia) for 10 s.

Group GP ($n = 35$) Lesions were isolated by cotton rolls and enamel was etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein) for 30 s. Then, the acid was rinsed, and the lesion was gently dried with oil-free air spray. Cotton rolls were changed, and G-Premio Bond (GC Corporation, Tokyo, Japan) was applied with an applicator brush to the entire lesion, and then left undisturbed for 20 s. The adhesive was dried with air under maximum pressure for 5 s and light-cured with a LED-curing unit (Radii Plus, SDI, Victoria, Australia) for 10 s.

The flowable universal composite resin (G-ænial Universal Flo, GC Corporation, Tokyo, Japan) was placed using an incremental technique, with each increment light cured for 40 s. The LED light-curing unit was set at 1200 mW/cm^2. The intensity was checked regularly using a radiometer (Benlioğlu radiometer, Benlioğlu Dental, Ankara, Turkey) before each use. The restorations were contoured using flame-shaped fine finishing diamond burs (Diatech, Charleston, USA) in a slow-speed handpiece under water spray, and then polished with Optidisc discs (Kerr Coorporation, Orange, CA, USA).

Clinical evaluation

Patients were recalled at 1 week (baseline) and at 6, 12, and 18 months after placement. The restorations were checked for retention, marginal adaptation, marginal discoloration, surface texture, color match, and post-operative sensitivity according to USPHS [24, 25]. Two experienced examiners who were blinded to group assignment and not involved in the placement of the restorations evaluated the restorations. The calibration was conducted by reviewing ten photographs representative of each score for each criterion. Then, the examiners evaluated 10–15 teeth during two

Table 2 Materials used in the study

Material/manufacturer	Batch no.	Composition	Application
G-ænial Universal Flo/GC Corporation, Tokyo, Japan	1208012	UDMA Bis-MEPP TEGDMA Silicon dioxide (16 nm) Strontium glass (200 nm) Pigment Photo initiator	Place the dispensing tip as close as possible to the prepared cavity, and slowly push the plunger to syringe material. Light cure for 20 s. (LED) (1200 mW/cm^2)
Clearfil Universal Bond/Kuraray Dental, Tokyo, Japan	4T0015	MDP Bis-GMA HEMA Hydrophilic aliphatic dimethacrylate Colloidal silica Silane coupling agent DL-Camphorquinone Ethanol Water	Selective etch technique: Apply phosphoric acid etching gel (37%) to the enamel, leave it in place for 30 s, then rinse and dry. Apply bond to the entire cavity wall with the applicator brush and rub it for 10 s. Dry the entire cavity wall sufficiently by blowing mild air for more than 5 s until bond does not move. Light-cure bond with 1200 mW/cm^2 LED for 10 s
iBOND Universal/Heraeus Kulzer, Hanau, Germany	010021	Acetone 4-Methacryoxyethltrimellitic acid anhydride Diurethanedimethacrylate	Selective etch technique: Apply phosphoric acid etching gel (37%) to enamel and leave it in place for 30 s, then rinse and dry. Apply bond to the entire cavity wall with the applicator brush and rub it for 20 s. Dry the entire cavity wall sufficiently by blowing mild air for more than 5 s until bond does not move. Light-cure bond with 1200 mW/cm^2 LED for 10 s
G-Premio Bond/GC Corporation, Tokyo, Japan	160413A	MDP Acetone Dimethacrylate Phosphoric acid ester monomer Photoinitiator BHT MDTP	Selective etch technique: Apply phosphoric acid etching gel (37%) to enamel and leave it in place for 30 s, then rinse and dry Apply bond to the entire cavity wall with the applicator brush Leave undisturbed for 10 s after the end of application Dry thoroughly for 5 s with air under maximum air pressure Light-cure bond with 1200 mW/cm^2 LED for 10 s

UDMA urethanedimethacrylate, *MDP* 10-methacryloyloxydecyl dihydrogen phosphate, *Bis-GMA* bisphenol A diglycidylmethacrylate, *HEMA* 2-hydroxyethyl methacrylate, *BHT* butylated hydroxytoluene, *MDTP* methacryloyloxydecyl dihydrogen thiophosphate, *Bis-MEPP* bisphenol-A-ethoxylat dimethacrylat, *TEGDMA* triethylene glycol dimethacrylate

different appointments. Intraexaminer and interexaminer agreement of at least 85% was necessary before the beginning of the evaluation [26]. When disagreement occurred during an evaluation, a consensus was reached among the evaluators before the patient was dismissed.

Statistical analyses were carried out with IBM SPSS version 22.0 software (SPSS, Chicago, IL, USA). Pearson chi-square tests were used to compare universal adhesives for each recall. The differences in the ratings of the three materials were tested after 6, 12, and 18 months. The changes across different time points within each adhesive material were analyzed by the Cochran *Q* test. McNemar's test was used to compare the marginal adaptation and marginal discoloration scores of each adhesive with baseline scores by time. The level of significance was set at $p < 0.05$ for all tests.

Results

Ninety-nine flowable composite resin restorations were placed in 18 patients using the three universal adhesive systems. The distribution of NCCLs according to tooth type, arch, and adhesive systems used is given in Table 3. The majority of the restored teeth were premolars. Of the restorations, 66% were placed in premolars, and 27% (16 incisors, 11 canines) were placed in anterior teeth.

Recall rates were 100% for 6- and 12-month and 88.8% for 18-month evaluations. Clinical evaluation rates of the restorations are shown in Table 4. Retention was 100% for the Clearfil Universal Bond (CU) and G-Premio Bond (GP) groups at the 6-, 12-, and 18-month observations. At the 6-, 12-, and 18-month assessments, retention rates were 100%, 100%, and 96.8% for the iBOND Universal (IU) group,

Table 3 Distribution of NCCLs according to tooth type, arch, and adhesive systems used

	Tooth distribution				Arch distribution	
	Incisors	Canines	Premolars	Molars	Maxillary	Mandibular
Clearfil Universal Bond (CU)	3	6	18	2	16	15
iBOND Universal (IU)	6	3	23	1	13	20
G-Premio Bond (GP)	5	2	25	3	17	18
Total number of NCCLs	16	11	66	6	46	53

respectively. None of the restorations showed post-operative sensitivity or secondary caries at either the 6- or 12-month recall.

At the 6-month examinations, although two (5.7%) restorations for marginal adaptation and only one restoration (2.9%) for marginal discoloration showed a bravo score in the GP group, and two restorations (6.5%) from the CU group exhibited bravo scores for surface texture and color match, no significant differences were seen among the groups ($p > 0.05$).

At the 12-month evaluations, two [6.5%] CU restorations, three [9.1%] IU restorations, and five [9.1%] GP restorations showed bravo scores for marginal adaptation ($p = 0.560$). Three restorations (9.1%) from the IU group and three (8.6%) from the GP group were scored as bravo for marginal discoloration, but no significant differences were seen among the groups ($p = 0.096$). Two restorations (6.5%) in the CU group, three (9.1%) in the IU group, and five in the GP group exhibited bravo scores for surface texture ($p = 0.299$). Color match of restorations was very good, except in three restorations (two [6.5%] CU restorations, one [9.1%] GP restoration) that were scored as bravo ($p = 0.226$). However, no significant differences were seen among the groups regarding any of the criteria evaluated ($p > 0.05$).

At the 18-month evaluations, two patients were not available for examination. Two [6.9%] CU restorations, three [10%] IU restorations, and six [18.2%] GP restorations showed bravo scores for marginal adaptation ($p = 0.368$). Three restorations (10%) from the IU group and four restorations (12.1%) from the GP group were scored as bravo for marginal discoloration, but no significant differences were seen among the groups ($p = 0.060$). A total of ten (CU, two; IU, three; GP, five) restorations exhibited bravo scores for surface texture, and three (CU, two; GP, one) had bravo scores for color match. No significant differences were found among the tested adhesives for any criteria evaluated ($p > 0.05$).

McNemar's test showed a significant change in marginal adaptation in the GP group at the 12 ($p = 0.045$)- and 18-month ($p = 0.08$) observations. In addition, the GP group showed significant changes in surface texture after 12 and 18 months ($p < 0.05$).

Discussion

NCCLs have been used as a clinical model for evaluating the bonding efficacy of adhesive systems at non-retentive cavities. In this study, a randomized controlled prospective trial was conducted on the clinical effectiveness of universal adhesives using a universal flowable composite resin in NCCLs. To the extent of the authors' knowledge, there have been no studies in the literature that compare different universal adhesive systems in NCCLs using a universal flowable composite resin. None of the restorations exhibited post-operative sensitivity or secondary caries. Patients who had severe hypersensitivity were not included in the study, assuming this might influence the results for post-operative sensitivity. Similarly, another clinical trial evaluating 36-month results for etch&rinse adhesives in NCCLs excluded patients with severe hypersensitivity [27]. The clinical status of the restorations in terms of retention, marginal adaptation, marginal discoloration, surface texture, and color match was similar for all three adhesives. Therefore, the null hypothesis was accepted. The degree of discoloration was minimal, being of no concern to the patients. Additionally, color mismatch was not so great as to cause concern to patients. None of the patients reported post-operative sensitivity at recall visits.

Several studies conducted on NCCLs were performed primarily on premolars, as was the present investigation [27–29]. Nevertheless, no clinical study had evaluated whether the location (premolar, molar, or incisor) of restorations affects the outcomes of trials. In the present study, selective etching was preferred, and the enamel was conditioned with 37% phosphoric acid before application of universal adhesives in all groups, as the practice of etching the enamel prior to the application of an adhesive has been shown to increase enamel bonding efficiency [30, 31]. Van Meerbeek et al. [4] suggested that phosphoric acid etching of enamel produced effective sealing and protected the more vulnerable bond to dentin against degradation. A long-term study on NCCLs also found that the etching step influenced the clinical performance of restorations [32]. A systematic review assessed the average annual failure rates of adhesive systems in NCCLs. The results indicated that the three-step etch&rinse and two-step self-etch

Table 4 Clinical evaluation outcomes of different adhesive systems

Evaluation criteria	Score	Baseline			6 months *n* (%)			12 months *n* (%)			18 months *n* (%)		
		CU (*n* = 31)	IU (*n* = 33)	GP (*n* = 35)	CU (*n* = 31)	IU (*n* = 33)	GP (*n* = 35)	CU (*n* = 31)	IU (*n* = 33)	GP (*n* = 35)	CU (*n* = 29)	IU (*n* = 31)	GP (*n* = 33)
Retention	Alpha	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	35 (100)	29 (100)	30 (96.8)	33 (100)
	Bravo	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (3.2)	0 (0)
Marginal adaptation	Alpha	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	33 (94.3)	29 (93.5)	30 (90.9)	30 (85.7)	27 (93.1)	27 (90.0)	27 (81.8)
	Bravo	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (5.7)	2 (6.5)	3 (9.1)	5[a] (14.3)	2 (6.9)	3 (10.0)	6[a] (18.2)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Marginal discoloration	Alpha	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	34 (97.1)	31 (100)	30 (90.9)	32 (91.4)	29 (100)	27 (90.0)	29 (87.9)
	Bravo	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2.9)	0 (0)	3 (9.1)	3 (8.6)	0 (0)	3 (10.0)	4 (12.1)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Surface texture	Alpha	31 (100)	33 (100)	35 (100)	29 (93.5)	33 (100)	35 (100)	29 (93.5)	30 (90.9)	30 (85.7)	27 (93.1)	27 (90.0)	28 (84.8)
	Bravo	0 (0)	0 (0)	0 (0)	2 (6.5)	0 (0)	0 (0)	2 (6.5)	3 (9.1)	5[a] (14.3)	2 (6.9)	3 (10.0)	5[a] (15.2)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Color match	Alpha	31 (100)	33 (100)	35 (100)	29 (93.5)	33 (100)	35 (100)	29 (93.5)	33 (100)	34 (97.1)	27 (93.1)	30 (100)	32 (97)
	Bravo	0 (0)	0 (0)	0 (0)	2 (6.5)	0 (0)	0 (0)	2 (6.5)	0 (0)	1 (2.9)	2 (6.9)	0 (0)	1 (3)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Post-operative sensitivity	Alpha	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	35 (100)	29 (100)	30 (100)	33 (100)
	Bravo	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Secondary caries	Alpha	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	35 (100)	31 (100)	33 (100)	35 (100)	29 (100)	30 (100)	33 (100)
	Bravo	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Charlie	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

CU Clearfil Universal Bond, *IU* iBOND Universal, *GP* G-Premio Bond

USPHS US Public Health Service (Alpha: no discoloration along the margin. Bravo: slight and superficial staining (removable, usually localized), Charlie: deep staining cannot be polished away)

[a] Significant difference in comparison with baseline according to Cochran's *Q* test followed by McNemar's test ($p < 0.05$)

adhesives were the most effective, with 4.8% and 4.7% annual failure rates, respectively. Furthermore, simplified one-step self-etch adhesives had the highest annual failure rate, 8.1%. With regard to clinical procedures, any kind of simplification resulted in loss of bonding effectiveness due to hydrolysis and the elution of interface components. Although De Munck et al. [13] indicated that, after approximately 3 months, all categories of adhesive systems start to show mechanical and morphologic evidence of bond degradation, in the present study, CU exhibited no marginal discoloration at 18 months, and all CU restorations were scored as alpha for marginal adaptation after 6 months.

The universal adhesives used in the study contained MDP monomer, which can bond to calcium and build cross-linked complexes with collagen fibers in the hybrid layer [33]. Clinical trials conducted with adhesive systems containing MDP monomers have shown high success rates during 3 to 5 years of follow-up [10, 23, 27]. At the etched enamel substrate, chemical bonding of MDP monomers could significantly increase long-term enamel bonding [34]. In the present study, during the 12-month follow-up, no significant changes were observed on any measure.

The adhesive systems used in the present study had different pH values. The pH values of CU and IU were 2.3 and 1.8, respectively, which are classified as mild; on the other hand, GP had a pH value of 1.5, which is considered of intermediate strength [21, 35, 36]. However, the differences in pH values caused no clinically significant differences in the present study. Söderholm et al. [37] also reported that adhesives with different pH values showed no significant differences at 4-year follow-up.

Several factors affect the clinical performance of adhesive systems. Characteristics of the adhesive resin, such as the solvents, may play an important role. IU and GP contain acetone, whereas CU has ethanol/water as a solvent. High-vapor-pressure solvents such as acetone and ethanol are frequently used in adhesive systems. These solvents can achieve effective bonding by promoting wetting of the dentin structure. Additionally, the type and concentration of solvents have important impacts on the ability of adhesive systems to tolerate water. Ethanol plays a crucial role in the infiltration by the resin monomers of the wet collagen network and facilitates the evaporation of excess water by forming water/ethanol aggregates [38, 39]. Careful air-drying of the adhesive is necessary to remove excess solvent before light curing of the adhesive because excess solvent impairs adhesive bonding by lowering the mechanical properties of the adhesive and increasing degradation over time [2, 40]. The ethanol concentration of CU is less than 20%; however, the acetone concentrations of IU and GP are between 25 and 50%. Previous studies suggested that solvent content affects the bond strength of adhesive systems [41–43]. An in vitro study [44] found that when the acetone content of the adhesive increased, the microtensile bond strength decreased from the highest value of 64 MPa (37% acetone) to 38 MPa (67% acetone). Although no significant difference was detected among groups in the present study, the low ethanol concentration of CU in the present study might explain the better clinical outcome of CU, which showed no marginal discoloration at 18 months. Furthermore, the evaporation behaviors of acetone and ethanol differ in terms of boiling temperature and vapor pressure, which might affect the long-term results of the materials used [45]. Acetone-based systems are likely to be thinner after evaporation than are ethanol-based systems, and thinner adhesive layers become more susceptible to degradation. Additionally, thin layers of adhesives are more sensitive to polymerization inhibition by oxygen. Furthermore, acetone-based systems are more sensitive to air-drying, as they cannot re-expand the shrunken collagen fibrils [46]. However, ethanol-based systems are good at re-expanding collagen matrix and produce higher bond strengths in dentin [47].

A clinical trial found that after 36 months, an acetone-based adhesive system had lower retention rates than did an ethanol-based adhesive system [27]. In the present study, after 18 months, ethanol/water-based CU showed no marginal discoloration, whereas acetone-based IU and GP demonstrated marginal discolorations in seven restorations (IU, three; GP, four). Marginal discoloration of acetone-based adhesive systems similar to that seen in the present study is quite commonly reported in the literature [8, 27, 48, 49]. A recent clinical trial found that, in etch&rinse mode, an ethanol-containing universal adhesive demonstrated similar results to the present study at the 18- and 36-month follow-ups in retention, marginal discoloration, and marginal adaptation [23]. In addition, an in vitro study showed that an ethanol/water-based adhesive had significantly higher shear bond strength compared to an acetone-based adhesive [50]. In the present study, CU showed slight changes in marginal adaptation in 6.5% of the evaluated restorations, whereas IU (9.1%) and GP (14.3%) (acetone-based adhesives) demonstrated higher bravo scores. However, no significant differences between groups were observed.

Another characteristic of adhesives that may cause degradation is water sorption ability. Swelling of the polymers reduces frictional forces between polymer chains and decreases the mechanical properties of adhesives, causing discoloration at marginal interfaces. This situation can also lead to the formation of marginal gaps and secondary caries [51]. Water sorption ability is affected by existing monomers in adhesives. Different adhesive systems contain different monomers, affecting bond strength and durability. The hydroxyl group in Bis-GMA has a higher cohesive energy density than does urethane, which forms weaker hydrogen bonds. Due to the lower energy needed in the urethane group, the links of hydrogen bridges are established more easily, favoring greater water gain and, conversely, easier loss of water molecules.

The presence of more UDMA in the composition of the ethanol/water-based adhesive system may explain the greater gain and loss of mass when compared with other adhesive systems [52]. Although the adhesives in the present study contained different monomers, no significant differences were detected among groups. Twelve months of follow-up may not be long enough to determine the effects of different monomers and water sorption in adhesive systems.

To the best of our knowledge, few studies have evaluated universal adhesives clinically, and none has yet compared different universal adhesives. Loguercio et al. [23] compared Single Bond Universal in different application modes and reported that only one restoration was lost in etch&rinse groups during 3 years of observations. Lawson et al. [7] reported that Single Bond Universal showed no retention loss in etch&rinse mode over 3 years of evaluations. These investigations showed high retention rates (100% [7], 98% [23]) at the 3-year evaluation, as did the current study.

Previous researchers have used different types of composite resins [18] such as microhybrid [29, 53] and nano-hybrid composite resins [7, 23] in the restoration of NCCLs. Additionally, Celik et al. [54] reported results with a self-adhering flowable composite resin. Unfortunately, the self-adhering composite resin showed unacceptable clinical results, with a survival rate of just 33% at 6 months. Besides, another clinical trial which compared two flowable composite resins (N'Durance Dimer Flow and Filtek Supreme XTE Flow) on NCCLs demonstrated that both flowable composite resins performed similarly and successful after a 5-year evaluation [55].

In the present study, two restorations from the CU group showed slight changes in surface texture at the 6-month evaluation. After 18 months, ten restorations demonstrated bravo scores for surface texture, and three restorations scored bravo regarding color match. The universal flowable composite resin used in the study did not show any unacceptable degradation. Most flowable composite resins on the market demonstrate low viscosity, whereas the universal flowable composite resin used in the present study seemed to have high viscosity, allowing the clinician to imitate the anatomical form during manipulation and restoration. After application of the flowable composite resin to the lesion, the clinician could create the proper shape using instruments, and the composite resin did not flow away as other flowable composite resins do. Additionally, the finishing procedure of the restorations became easy and quick because there was no need to reshape before polishing.

In the present study, the restorations were observed for a short length of time. Further evaluations will be carried out to evaluate the performance of these adhesives after longer clinical service.

Conclusions

Within the limitations, this preliminary report on an 18-month evaluation of three universal adhesives concluded that:

(1) Clearfil Universal Bond, iBOND Universal, and G-Premio Bond demonstrated good retention, and none of the restorations exhibited post-operative sensitivity;
(2) The three universal adhesives tested showed minor differences in terms of marginal adaptation, marginal discoloration, surface texture, and color match; but,
(3) The three universal adhesives tested presented acceptable clinical results at the 18-month evaluation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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