Clinical Oral Investigations
https://doi.org/10.1007/s00784-022-04703-7

ORIGINAL ARTICLE

Eighteen-month clinical evaluation of a new universal adhesive applied in the "no-waiting" technique: a randomized clinical trial

Rossana Aboud Matos de Almeida[1] · Suellen Nogueira Linares Lima[1] · Maria Vitória Nassif[2] · Natanael Henrique Ribeiro Mattos[2] · Thalita Paris de Matos[2,3] · Rudys Rodolfo de Jesus Tavarez[1] · Andres Felipe Millan Cardenas[1] · Matheus Coelho Bandeca[1,2] · Alessandro D. Loguercio[3]

Received: 7 March 2022 / Accepted: 25 August 2022

Abstract

Objective The aim of this double-blind, randomized clinical trial was to evaluate the 6- and 18-month clinical performances of a new universal adhesive applied in the "no-waiting" (NW) technique to non-carious cervical lesions (NCCLs) using two evaluation criteria.

Materials and methods One hundred and seventy-six restorations were assigned to four groups according to the adhesive system, adhesive strategy, and application mode: Prime&Bond Active (PB) applied using the etch-and-rinse (ER) and self-etch (SE) strategies with 20 s applications and Clearfil Universal Bond Quick (CQ) applied using the ER and SE strategies with the NW technique. The composite resin restorations were evaluated at baseline and after 6 and 18 months using the World Dental Federation (FDI) and US Public Health Service (USPHS) criteria. The Friedman repeated measures analysis of variance and Wilcoxon test were used for statistical analyses ($\alpha = 0.05$).

Results No significant differences were observed among any of the groups or criteria after 6 months ($p > 0.05$). After 18 months, 10 restorations were lost ($p > 0.05$) (2 with PB-ER [95.5%; 95%CI: 92–100%], 4 with PB-SE [90.9%; 95%CI: 82–98%], 0 with CQ-ER [100%; 95%CI: 92–100%], and 4 with CQ-SE [90.9%; 82–98%]). The restorations performed with the SE strategy showed more marginal discrepancies than those performed with the ER strategy, mainly when the FDI criteria were used ($p < 0.05$). Those that used the PB-SE showed fewer marginal discrepancies than those that used the CQ-SE (FDI; $p < 0.05$). A few restorations showed marginal discrepancies after the USPHS analysis ($p > 0.05$).

Conclusions The results when using the CQ-SE and -ER strategies with the NW technique were similar to those when using the PB-SE and -ER strategies in standard applications to non-carious cervical lesions after 6 and 18 months of clinical evaluation.

Clinical relevance After 6 and 18 months, the application of Clearfil Universal Bond Quick with the "no-waiting" technique showed similar clinical performance compared to the standard application of Prime & Bond Active applied using the standard application time (20 s).

Trial registration ClinicalTrials.gov identifier RBR-5f9gps.

Keywords Universal adhesives · Non-carious cervical lesion · Clinical trial · Application time

Introduction

The most recently manufactured adhesives are universal or multimodal adhesives [1]. Manufacturers have made an effort to maintain the trend of simplifying the techniques by providing etch-and-rinse or self-etch adhesives in enamel/dentin adhesive systems, [2, 3] as well as indirect materials, mainly glass-rich ceramics, zirconia and metals [4, 5]. This versatility in terms of application is a result of the addition of specific functional monomers such as 10-metacriloxidecil

✉ Alessandro D. Loguercio
aloguercio@hotmail.com

[1] Department of Postgraduate Program in Dentistry, CEUMA University, Sao Luis, Maranhao, Brazil

[2] Department of Restorative Dentistry, School of Dentistry, Tuiuti University of Parana, Curitiba, Parana, Brazil

[3] Department of Restorative Dentistry, State University of Ponta Grossa, Rua Carlos Cavalcanti, 4748, Bloco M - Uvaranas, Ponta Grossa, Parana, Brazil

Published online: 06 September 2022

dihydrogen phosphate (10-MDP) [5]. Compared with other functional monomers, the chemical bond between 10-MDP and the dental substrate may play an important role in a stable and sustainable interface [6–8].

Several in vitro studies, in which the bond durability was tested, have demonstrated remarkable effectiveness when a universal adhesive contained 10-MDP [9–11]. In addition, clinical trials have shown that universal adhesives attain an adequate retention rate for composite restorations placed in non-carious cervical lesions [12–22]. Nevertheless, when outcomes such as marginal adaptation or marginal discoloration are evaluated, the results regarding the best technique to use when applying a universal adhesive (self-etch [SE] or etch-and-rinse [ER]) are inconclusive [3, 20–22].

Furthermore, following the same line of simplification, universal adhesives were recently launched in the market with a "no-waiting" time concept, in which it is possible to apply and light-cure adhesives without waiting [23]. Manufacturers claim that the addition of a new multifunctional hydrophilic acrylamide amide monomer (also known as rapid bond technology) [24] enhances the wetting of dentine, thereby reducing the application time [23–25]. Recently, several in vitro studies that tested the "no-waiting" concept in comparison with a 10-s application mode reported controversial results [25–28].

The "no-waiting" technique may be considered more of a marketing advantage than a real benefit, as the little time saved may not be relevant from a clinical point of view. However, it should be noted that a shorter application time may theoretically make the application less technique sensitive and reduce the risk of contamination during restoration [24, 25, 27]. Considering the fact that these materials appeared as part of a new tendency of time and technique simplification, clinical outcomes that examine this tendency should be deemed important.

Therefore, the aim of this double-blind randomized clinical trial was to evaluate the clinical behaviors of two universal adhesives when placed using different application techniques during 18 months of clinical evaluation. The null hypothesis was that the universal adhesive applied using the "no-waiting" technique for bonding to non-carious cervical lesions (NCCLs) using the ER and SE strategies would show similar retention levels over 18 months of clinical service when compared to the universal adhesive applied using the standard application time (20 s).

Materials and methods

Study design

The experimental design of this randomized, double-blind clinical trial followed the Consolidated Standards of Reporting Trials (CONSORT) statement [29]. Additionally, this study was registered in the Brazilian Clinical Trials Registry under the identification number RBR-5f9gps. All the procedures were performed in the clinic of the School of Dentistry at Ceuma University from September to October 2019.

The study participants were aware of the nature and aims of the research but were not informed about which tooth would receive the specific treatments under analysis.

Participant recruitment

A consent form for this study (protocol 3.078.493) was reviewed, approved, and issued by the University Ethics Committee for Investigations Involving Subjects. The participants were recruited from August 2019 to September 2019. No advertisements were used for participant recruitment. Those who qualified for the study were asked to participate in the order in which they reported to the screening session, thus forming a convenience sample. Informed written consent was obtained from all participants before starting treatment.

Sample size selection

The sample size calculation was performed using the online software http://www.sealedenvelope.com. For this purpose, the retention rate of a universal adhesive was used. Perdigão et al. [13] reported a 94% retention rate at an 18-month follow-up (retention). Therefore, using a bilateral test based on a power of 80% and statistical significance level set at 0.05, 44 restorations per group was the minimum sample size to detect a 20% group difference [30].

Eligibility criteria

Two calibrated dental students, using a mouth mirror, an explorer, and a periodontal probe, examined 39 participants to see if they met the inclusion and exclusion criteria (Fig. 1), thus constituting a convenience sample. All the participants (a) required good oral and general health, (b) were at least 18 years of age, (c) had at least 20 teeth under occlusion, and (d) had at least four non-carious cervical lesions to be restored on four separate teeth. These lesions had to have a minimum depth and extent of 1 mm and involve both enamel and dentin of vital non-mobile teeth, with at least 50% of their margins devoid of enamel [31].

Oral hygiene instructions were provided to the patients before the start of operative treatment. Inadequate oral hygiene, severe or chronic periodontitis, xerostomia, braces, or heavy bruxism habits were considered criteria for disqualification.

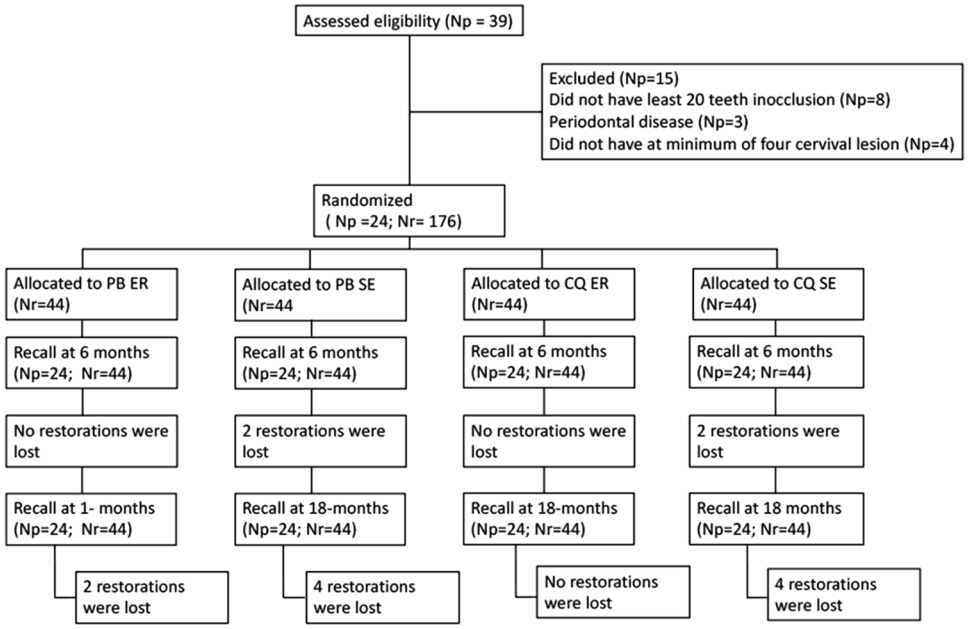

Fig. 1 Participant flow diagram in the different phases of the study design. Abbreviations: Np, number of participants; Nr, number of restorations

Allocation concealment and randomization

A participant who was not involved in the research protocol performed the randomization process by generating a random allocation sequence determined through the random.org/list website. The assigned groups were deposited on cards inside sequentially numbered opaque sealed envelopes. Each envelope was opened on the day of the restorative procedure to determine the assignment. The operator was not blinded to the restorative assignment; however, the patients and evaluators were blinded to the group assignment.

Restorative procedure

Dental prophylaxis was conducted using a suspension of pumice stone and water in a rubber cup prior to the procedures. The characteristics of the non-carious cervical lesions were evaluated before the implantation of the restorations. The degree of dentin sclerosis was evaluated according to the requirements described by Swift et al. [32]. The cavity dimensions (height, width, and depth) and cavity geometry were classified as < 45°, 45–90°, 90–135°, or > 135°. All the parameters were measured in millimeters and evaluated using profile photography. The attrition and antagonist tooth wear were observed and recorded. An exploratory probe was used to assess preoperative sensitivity, and an air jet was used for 10 s, 2 cm away from the tooth surface. All the features of the non-carious cervical lesions were marked to verify the standardization between the experimental groups.

Four restorations, one per group, were placed by a calibrated operator with more than 5 years of clinical experience in operative dentistry, supervised by the study director, in a clinic. The patients received a minimum of four restorations, one from each experimental group, in different lesions previously selected according to the inclusion requirements. Neither retentions nor bevels were prepared.

The tooth to be restored was isolated using cotton rolls and a retraction cord (Ultrapak 000, Ultradent Prod. South Jordan, UT, USA), and then, the non-carious cervical lesions received the Prime&Bond Active (PB; Dentsply Sirona, Milford, DE, USA) applied using the ER and SE strategies with the standard application (20 s) and the Clearfil Universal Bond Quick (CQ; Kuraray, Tokyo, Japan) applied using the ER and SE strategies with the "no-waiting" technique, which defined the four different groups. The compositions, application modes, and batch numbers of the adhesives used are listed in Table 1.

After the adhesive application, Filtek Z-350 XT (3 M Oral Care, St. Paul, MN, USA) resin composite was used in up to three increments, and each composite was light-cured for 30 s at an irradiance of 1000 mW/cm^2 (Valo, Ultradent Prod. South Jordan, UT, USA). All the restorations were finished with fine and extra-fine diamond burs (#2200F and #2200FF, KG Sorensen, Barueri, SP, Brazil) and polished with Jiffy points (Ultradent Prod. South Jordan, UT, USA) immediately after the placement of the restorations using green, yellow, and white sequences.

Clinical evaluation

Two experienced and calibrated dentists, not involved with the restoration procedures and therefore blinded to the group assignment, evaluated all the restorations once and independently using the World Dental Federation (FDI)

Table 1 Adhesive system, manufacturer, batch number, composition, and application mode

Material/manufacturer/batch number	pH	Composition*	Application technique**	
			Etch-and-rinse (ER)	Self-etch (SE)
Prime&Bond Active (PB)/Dentsply Sirona; Konstanz, Germany/1709000735	2.6	Phosphoric acid modified acrylate resins, PENTA, 10-MDP, multifunctional acrylate, bifunctional acrylate, acid acrylate, isopropanol, water, initiator, stabilizer	1. Apply Etchant for 15 s 2. Rinse for 10 s 3. Air dry to remove excess of water 4. Apply the adhesive for 20 s with vigorous agitation 5. Gently air thin for 5 s 6. Light-cure for 10 s (1000 mW/cm^2)	1. Apply the adhesive for 20 s with vigorous agitation 2. Gently air thin for 5 s 3. Light-cure for 10 s (1000 mW/cm^2)
Clearfil Universal Bond Quick (CQ)/Kuraray Noritake, Tokyo, Japan/2L0104	2.3	Bis-GMA, HEMA, 10-MDP, hydrophilic amide monomer, colloidal silica, silane coupling agent, sodium fluoride, camphorquinone, ethanol, water	7. Apply Etchant for 15 s 8. Rinse for 10 s 9. Air dry to remove excess of water 10 Apply the adhesive with vigorous agitation (no-waiting time) 11. Gently air thin for 5 s 12. Light-cure for 10 s (1000 mW/cm^2)	1. Apply the adhesive with vigorous agitation (no-waiting time) 2. Gently air thin for 5 s 3. Light-cure for 10 s (1000 mW/cm^2)

*_PENTA_ dipentaerythritol pentacrylate phosphate, _10-MDP_ 10-methacryloyloxydecyl dihydrogen phosphate, _HEMA_ 2-hydroxyethyl methacrylate, _Bis-GMA_ 2,2 bis[4-(2-hydroxy-3-methacrylyloxy-propoxy)-phenyl] propane, _10-MDP_ 10-methacryloyloxydecyl dihydrogen phosphate

**According to the manufacturer's instructions

[33] and classical US Public Health Service (USPHS) criteria [34, 35] at the baseline and after 6 and 18 months of clinical service. In a case of disagreement between the examiners, a consensus was reached by re-examination and discussion before the patient was dismissed [13, 36, 37]. Only clinically relevant measures for evaluating the performance of the adhesives were used and scored (Tables 2 and 3). Retention/fracture considered the primary clinical outcome, while marginal discoloration, marginal adaptation, dentin sensitivity, and recurrent caries considered secondary outcomes. A properly standardized case report form was used, and immediately after the parameters were recorded during the evaluation, this document was forwarded to the research team so that the evaluators were blinded to the group task during the follow-up evaluations. These variables were categorized using the following scoring criteria: (1) FDI criteria (clinically very good, clinically good, clinically sufficient/satisfactory, clinically unsatisfactory, and clinically poor) and (2) USPHS criteria (alpha, bravo, and charlie). The evaluators assessed all the restorations simultaneously and independently.

Statistical analysis

The intention-to-treat protocol following the Consolidated Standards of Reporting Trials (CONSORT) suggestion [29] was used for statistical analyses. Descriptive statistics were used to demonstrate the influence of the evaluation criteria. A statistical analysis was performed for each item (retention/fracture, marginal discoloration, marginal adaptation, postoperative sensitivity, and caries recurrence) and for each global parameter (FDI and USPHS). After 6 and 18 months, the differences between the classifications of the four groups were tested using Friedman's repeated analysis of variance classification ($\alpha = 0.05$), and the differences in each group (baseline and after 6 and 18 months) were evaluated using a Wilcoxon test ($\alpha = 0.05$).

For the primary outcome retention, we also calculated the risk ratio and relative risk of all the approaches relative to the most traditional approach (PB-ER). A 95% confidence interval was also reported. Inter-examiner agreement was measured using the Cohen's kappa statistic. For all the

Table 2 World Dental Federation (FDI) criteria used for clinical evaluation [33]

	Esthetic property	Functional properties		Biological properties	
	1. Staining margin	2. Fractures and retention	3. Marginal Adaptation	4. Postoperative (hyper) sensitivity	5. Recurrence of 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 problems with no adverse effects but not adjustable without damage to the tooth)	1.3 Moderate marginal staining, not esthetically	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 (dentine not exposed)
4. Clinically unsatisfactory (repair for prophylactic reasons)	1.4 Pronounced marginal staining; major intervention necessary for improvement	2.4 Chipping fractures which damage marginal quality; bulk fractures with or without partial loss (less than half of the restoration)	3.4.1 Gap > 250 µm or dentine/base exposed 3.4.2. chip fracture damaging margins 3.4.3 Notable enamel or dentine 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	5.5 Deep secondary caries or exposed dentine that is not accessible for repair of restoration	5.5 Deep secondary caries or exposed dentine that is not accessible for repair of restoration
Acceptable or not acceptable (*n*, % and reasons)	Aesthetic criteria	Functional criteria		Biological criteria	

Table 3 Modified United States Public Health Service (USPHS) [34, 35]

	Marginal staining	Retention	Fracture	Marginal adaptation	Postoperative sensitivity	Recurrence of caries
Alfa	No discoloration along the margin	Retained	None	Restoration is continuous with existing anatomic form	No postoperative sensitivity directly after the restorative process and during the study period	None evidence of caries contiguous with the margin
Bravo	Slight and superficial staining (removable, usually localized)	Partially retained	Small chip, but clinically acceptable	Detectable V-shaped defect in enamel only Catches explorer going both ways	–	–
Charlie	Deep staining cannot be polished away	Missing	Failure due to Bulk restorative fracture	Detectable V-shaped defect to dentin-enamel junction	Sensitivity present at any time during the study period	Evidence of presence of caries

statistical tests, we set a significance level of 5% (Statistical for Windows 7.0, Stat Soft Inc., Tulsa, OK, USA).

Results

Because they did not meet the inclusion criteria, 15 of the 39 patients examined for eligibility were excluded from the study. Thus, 24 individuals were selected (12 men and 12 women). One hundred and seventy-six restorations were placed, 44 in each group (Fig. 1). There was no loss of patients at the 6- and 18-month evaluations. Unfortunately, no examination results after 12 months could be obtained because of the first wave of the SARS-CoV-2 pandemic, which limited clinical examinations.

Table 4 presents all the details about the baseline related to the research subjects and characteristics of the restored lesions. The Cohen kappa statistics showed very good agreement between the examiners in the follow-ups at 6 and 18 months (0.94). All the study subjects were assessed at the baseline and follow-ups after 6 and 18 months.

Retention/fracture

The clinical evaluations after 6 months showed that five restorations were lost or fractured (three with PB-SE and two with CQ-SE). According to the evaluation criteria, the retention rates at 6 months (95% confidence interval [CI]) were 100% (92–100%) for PB-ER, 93.2% (82–98%) for PB-SE, 100% (92–100%) for CQ-ER, and 95.5% (85–99%) for CQ-ER ($p > 0.05$; Tables 6 and 7). There was no significant difference when the data of the results at 6 months for each group were compared with the baseline findings ($p > 0.05$; Tables 5 and 6).

The clinical evaluations after 18 months showed that ten restorations were lost or fractured (two with PB-ER, four with PB-SE, and four with CQ-SE). According to the evaluation criteria, the 18-month retention rates (95% CI) were 95.5% (92–100%) with PB-ER, 90.9% (82–98%) with PB-SE, 100% (92–100%) with CQ-ER, and 90.9% (82–98%) with CQ-SE, with no statistical difference identified between any pair of groups ($p > 0.05$; Tables 5 and 6). When the 18-month results for each group were compared with the baseline results, there was no significant difference ($p > 0.05$; Tables 5 and 6). Table 7 shows the absolute risk of retention/fracture for each of the groups, as well as the risk ratio in the PB-ER group. The fact that the 95% CI interval of the risk ratio crossed the null value of one meant that none of the results for the groups were different from those when using the most traditional approach of placing composites (PB-ER).

Marginal adaptation

When the FDI criteria were used for the 6-month evaluation results, 18 restorations were considered to have minor discrepancies (three with PB-ER, seven with PB-SE, two with CQ-ER, and six with CQ-SE; Table 5). Using the USPHS criteria, four restorations were scored as "bravo" (two with PB-SE and two with CQ-SE; $p > 0.05$; Table 6). No significant differences were found between the two groups during the 6-month evaluation using the two assessment criteria ($p > 0.05$; Tables 5 and 6).

When the FDI criteria were used for the 18-month evaluation results, 17 restorations were considered to have minor discrepancies (two with PB-ER, two with PB-SE, four with CQ-ER, and nine with CQ-SE; Table 5). A significant difference was detected between the CQ-ER and CQ-SE groups at the 18-month follow-up, and a significant difference was detected for the CQ-SE group when the baseline and 18-month evaluation results were compared ($p < 0.05$; Table 5). Using the USPHS criteria, only three restorations

Table 4 Characteristics of the research subjects and the non-carious cervical lesions (NCCLs) per group

Characteristics of research subjects	Number of participants			
Gender distribution				
Male	12			
Female	12			
Age distribution (years)				
20–29	00			
30–39	08			
39–49	08			
> 49	08			
Characteristics of Class-V lesions	Number of lesions			
	PB-ER	PB-SE	CQ-ER	CQ-SE
Shape (degree of angle)				
< 45	-	-	-	-
45–90	12	11	13	12
90–135	24	22	21	21
> 135	8	11	10	11
Cervico-incisal height (mm)				
< 1.5	10	9	11	7
1.5–2.5	22	24	22	28
2.5–4.0	9	10	9	8
> 4.0	3	-	1	1
Degree of sclerotic dentin				
1	23	23	21	19
2	18	18	19	22
3	3	3	4	3
4	-	-	-	-
Presence of antagonist				
Yes	44	44	44	44
No	-	-	-	-
Attrition facet				
Yes	18	16	18	15
No	26	28	26	29
Pre-operative sensitivity (spontaneous)				
Yes	1	1	-	3
No	43	43	44	41
Pre-operative sensitivity (air dry)				
Yes	26	28	29	31
No	18	16	15	13
Pre-operative sensitivity (touch)				
Yes	25	28	28	30
No	19	16	16	14
Tooth distribution				
Anterior				
Incisor	05	05	02	04
Canines	06	04	08	07
Posterior				
Premolar	24	24	20	24
Molar	9	11	14	9
Arc distribution				
Maxillary	24	31	29	29
Mandibular	20	13	15	15

were scored as "bravo" for marginal adaptation (three with CQ-SE; $p > 0.05$; Table 6).

Marginal discoloration

No restoration showed marginal discoloration during the clinical evaluation after 6 months for either criterion. Sixteen restorations were considered to have small discrepancies in the evaluation after 18 months when using the FDI and USPHS criteria (one with PB-ER, five with PB-SE, two with CQ-ER, and eight with CQ-SE; Table 5). A significant difference was found between the ER and SE groups during the evaluation after 18 months. When comparing the baseline and 18-month evaluation results, a significant difference was also detected for each SE group ($p < 0.05$; Table 5). When the USPHS criteria were used, only two restorations were scored as "bravo" (one with PB-SE and one with CQ-SE; $p > 0.05$; Table 6).

Other clinical parameters

No postoperative sensitivity was observed in any restoration during the 6- and 18-month evaluations using the FDI and USPHS criteria. No restoration showed the recurrence of caries after 6 and 18 months for either criterion (Tables 5 and 6).

Discussion

Clinicians desire not only a reduction in the number of application steps but also quicker application times for dental adhesives, which is the major appeal of the "no-waiting" concept [24, 28]. Some industries have launched universal adhesives for applications using this technique, one of which is CQ. The null hypothesis in the present study was accepted, and the results showed that when CQ was applied with the "no-waiting" technique to non-carious cervical lesions using the ER and SE strategies, the retention levels over 18 months of clinical service were similar to those when PB was applied using the standard application method (20 s).

It is widely accepted that clinical studies on non-carious cervical lesions are very reliable when evaluating the performances of adhesive systems, especially because retention is the most important aspect when a restoration performed on an non-carious cervical lesion is evaluated [38]. This is

Table 5 Number of evaluated restorations for each experimental group*classified according to the World Dental Federation (FDI) criteria [33]

FDI criteria	**	Baseline				6 months				18 months			
		PB-ER	PB-SE	CQ-ER	CQ-SE	PB-ER	PB-SE	CQ-ER	CQ-SE	PB-ER	PB-SE	CQ-ER	CQ-SE
Marginal staining	A	44	44	44	44	44	41	44	42	41	35	42	32
	B	–	–	–	–	–	–	–	–	01	05	02	07
	C	–	–	–	–	–	–	–	–	–	–	–	01
	D	–	–	–	–	–	–	–	–	–	–	-	–
	E	–	–	–	–	–	–	–	–	–	–	–	–
Fractures and retention	A	44	44	44	44	44	41	44	42	42	40	44	40
	B	–	–	–	–	–	–	–	–	–	–	–	–
	C	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	01	–	–	–	–	–	–
	E	–	–	–	–	–	02		02	02	01	–	02
Marginal adaptation	A	44	44	44	44	41	34	42	36	40	38	40	31
	B	–	–	–	–	03	06	02	06	02	02	04	06
	C	–	–	–	–	–	01	–	–	–	–	–	03
	D	–	–	–	–	–	–	–	–	–	–	–	–
	E	–	–	–	–	–	–	–	–	–	–	–	–
Post-operative (hyper-) sensitivity	A	44	44	44	44	44	42	44	42	42	40	44	39
	B	–	–	–	–	–	–	–	–	–	–	–	01
	C	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–
	E	–	–	–	–	–	–	–	–	–	–	–	–
Recurrence of caries	A	44	44	44	44	44	42	44	42	42	40	44	40
	B	–	–	–	–	–	–	–	–	–	–	–	–
	C	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–
	E	–	–	–	–	–	–	–	–	–	–	–	–

*_PB-ER_ Prime&Bond Active etch-and-rinse, _PB-SE_ Prime&Bond Active self-etch, _CQ-ER_ Clearfil Bond Quick etch-and-rinse, _CQ-SE_ Clearfil Bond Quick self-etch

**A = clinically very good; B = clinically good; C = clinically sufficient/satisfactory; D = clinically unsatisfactory; E = clinically poor

Table 6 Number of evaluated restorations for each experimental group* classified according to the Modified US Public Health Service (USPHS) criteria [34, 35]

USPHS criteria	**	Baseline				6 months				18 months			
		PB-ER	PB-SE	CQ-ER	CQ-SE	PB-ER	PB-SE	CQ-ER	CQ-SE	PB-ER	PB-SE	CQ-ER	CQ-SE
Marginal staining	A	44	44	44	44	44	41	44	42	42	39	44	38
	B	–	–	–	–	–	–	–	–	–	01	–	02
	C	–	–	–	–	–	–	–	–	–	–	–	–
Fractures and retention	A	44	44	44	44	44	41	44	42	42	40	44	40
	B	–	–	–	–	–	1	–	–	–	–	–	–
	C	–	–	–	–	–	02		02	02	01	–	02
Marginal adaptation	A	44	44	44	44	44	39	44	40	42	40	44	37
	B	–	–	–	–	–	02	–	02	–	–	–	03
	C	–	–	–	–	–	–	–	–	–	–	–	–
Post-operative (hyper-) sensitivity	A	44	44	44	44	44	41	44	42	42	40	44	40
	B	–	–	–	–	–	–	–	–	–	–	–	–
	C	–	–	–	–	–	–	–	–	–	–	–	–
Recurrence of caries	A	44	44	44	44	44	41	44	42	42	40	44	40
	B	–	–	–	–	–	–	–	–	–	–	–	–
	C	–	–	–	–	–	–	–	–	–	–	–	–

*_PB-ER_ Prime&Bond Active etch-and-rinse, _PB-SE_ Prime&Bond Active self-etch, _CQ-ER_, Clearfil Bond Quick etch-and-rinse, _CQ-SE_, Clearfil Bond Quick self-etch

**A = Alfa; B = Bravo; C = Charlie

Table 7 Absolute risk (95% CI) and relative risk (95% CI) for outcome retention/fracture for different groups after 18 months of clinical evaluation

	Absolute risk (95% CI)	Relative risk (95% CI)*
PB-ER	4.5 (1.2–15.1)	
PB-SE	9.1 (3.6–21.2)	− 1.0 (− 9.3–0.6)
CQ-ER	0.0 (0.0–8.0)	1.0 (0.0–0.0)
CQ-SE	9.1 (3.6–21.2)	− 1.0 (-9.3–0.6)

*Related to group: *PB-ER* Prime&Bond Active etch-and-rinse, *PB-SE* Prime&Bond Active self-etch, *CQ-ER* Clearfil Bond Quick etch-and-rinse, *CQ-SE* Clearfil Bond Quick self-etch

considered a true outcome because if the restoration is lost, none of the other parameters can be evaluated. Therefore, according to the results of the present clinical trial, when applied using both adhesive strategies, when CQ was applied using the "no-waiting" technique, it showed a very good clinical performance, with retention rates of 97.8% (100% for ER and 95.5% for SE) after 6 months and 95.5% (100% for ER and 90.9% for SE) after 18 months.

As indicated by the CQ manufacturer, in addition to 10-MDP, which provides chemical interaction for bond promotion [7, 39], the addition of a new multifunctional hydrophilic acrylamide amide monomer [24] reduces the 2-hydroxyethyl methacrylate (HEMA) content (2.5–10%) [40] compared to prior generations of adhesives. HEMA is a highly hydrophilic monomer that can be found in most adhesives on the market [41]. However, higher concentrations of HEMA may make the adhesive interface susceptible to water sorption and the long-term degradation of the adhesive properties [42].

In a recent study, Kuno et al. [25] claimed that the mechanical properties are improved, and the water sorption is decreased in the presence of a multifunctional amide monomer, when compared to an experimental version with the same composition as CQ, but with HEMA in place of this new monomer. According to these authors [25], the multifunctional amide monomer has a lower octanol/water partition coefficient (logPow = 0.7) than HEMA (logPow = 0.3), indicating greater hydrophilicity before polymerization [39]. Additionally, a lower octanol/water partition coefficient promotes a better and deeper infiltration of resin monomers into demineralized dentin, which, along with better polymerization, promotes the formation of a stable polymer network and induces stronger micromechanical interlocking [25–27]. All these features made it possible to minimize the adhesive bonding time dependency. In fact, in vitro studies showed that there were no benefits when the time was increased in terms of the resin–dentin bond strength with CQ [25, 27], even after water storage [43].

Of course, it is worth mentioning that PB also showed very good clinical performances with both adhesive strategies in the present study, with retention rates of 96.6% (100% for ER and 93.2% SE) after 6 months and 93.2% (95.5% for ER and 90.9% for SE) after 18 months of clinical service. This could be attributed to the fact that PB contains 10-MDP and is a HEMA-free adhesive [7, 39, 42]. According to the manufacturer, owing to its hydrophilic core and five double bonds per molecule, dipentaerythritol pentacrylate phosphate (PENTA) is an effective crosslinker agent that is responsible for increasing the wettability of PB. PENTA was used in different "Prime&Bond" adhesive generations (Dentsply Sirona), and despite the controversial results observed when previous generations of PENTA-containing adhesives were evaluated [22, 44, 45], in vitro studies have shown that PB has a higher resin–dentin bond strength than other universal adhesives [24, 46, 47]. This was one of the main reasons for using this material as a control in the present study. Another factor that could explain the excellent clinical performance of PB is the application time. The manufacturer of PB recommends an application time of 20 s instead of 10 s. It is well known that a longer application time results in better bonding to dentin [48, 49].

It is worth mentioning that the literature indicates that it is necessary to use a gold standard adhesive as a control group [50]. However, because gold standard adhesives are not simple adhesives, the presence of an additional hydrophobic coat in these materials could be a source of bias in the interpretation of the results. A recently published systematic review showed that there were no randomized clinical trials of non-carious cervical lesions to support the widespread concept that some adhesives (gold standard) are better than other competitive brands available in the dental market [51].

Regarding marginal adaptation, although no significant difference was observed in the clinical evaluation after 6 months, more marginal discrepancies in the enamel were observed, as well as marginal discoloration when both universal adhesives were used with the SE strategy compared to the ER strategy in the clinical evaluation after 18 months. It is well documented that the enamel etching depth is minimal when SE adhesives are applied, especially mild/ultra-mild adhesives (pH = 2.3 for CQ and pH = 2.6 for PB) [52–54].

However, there were larger marginal deviations with CQ-SE than with PB-SE, particularly when using a more sensitive criterion. In fact, it is well established that extending the application time of a mild/ultra-mild universal adhesive in the SE mode may be a viable alternative to phosphoric acid enamel etching [54–57]. Thus, the "no-waiting" technique could have been responsible for the shallow etching pattern on the enamel surface, leading to the premature marginal discrepancies.

Although different clinical trials have shown that the marginal discrepancies of restorations performed with universal adhesives in the SE mode usually develop rather rapidly [12–21], particularly when FDI criteria have been used

instead of USPHS criteria [12, 13, 15, 19, 20, 44], most marginal defects are easily solved with repolishing [58]. In the present study, two clinical criteria were used to evaluate restorations (USPHS and FDI criteria). For more than three decades, USPHS criteria have included a practical approach to assess the clinical performance of repair materials [33, 36, 59]. However, despite some signs of clinical degradation observed by clinicians, restorations are usually classified as very good when USPHS is used, which means that this criterion is not sufficiently discriminative to detect small changes in the clinical performances of adhesive restorations [33, 60]. This was the main reason for the development of the FDI criteria [33, 60]. Several clinical studies have shown that FDI provides a more sensitive and discriminative scale than the USPHS criteria [61]. However, despite these advantages of the FDI criteria, it was important to report the data for both criteria, mainly because several recently published clinical trials continued to use USPHS [18, 22]. Finally, an 18-month follow-up should be considered a medium-term evaluation, and clinical trials have greater value when published after a long-term follow-up. Thus, long-term monitoring studies are needed to test this hypothesis.

Conclusion

The clinical performance regarding the retention of CQ when using the "no-waiting" technique was similar that with the PB adhesive with the standard application, showing rather satisfactory results when applied to non-carious cervical lesions using the ER and SE strategies, as seen in clinical evaluations after 6 and 18 months.

Acknowledgements This study was performed by Rossana Aboud as partial fulfillment of her master's degree at the Universidade CEUMA, São Luís, MA, Brazil.

Funding This study was partially supported by the National Council for Scientific and Technological Development (CNPq) under grants 308286/2019–7 and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001.

Declarations

Ethics approval This clinical trial was approved (3.078.493) by the ethics and research committee of the CEUMA University. It was registered in the Brazilian Clinical Trials Registry (REBEC) under registration number RBR-5f9gps. All procedures performed on human participants obeyed the ethical standards of the institutional and/or national research committee and with the Declaration of Helsinki of 1964 and its subsequent changes or comparable ethical standards. Participants who met the eligibility criteria signed an informed consent form before enrolling in the study. Details that would reveal the identity of the subjects studied were not included.

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

Conflict of interest The authors declare no competing interests.

References

1. Alex G (2015) Universal adhesives: the next evolution in adhesive dentistry? Compend Contin Educ Dent 36:15–26 (**quiz 28, 40**)
2. Perdigao J, Loguercio AD (2014) Universal or multi-mode adhesives: why and how? J Adhes Dent 16:193–194. https://doi.org/10.3290/j.jad.a31871
3. Munoz MA, Luque I, Hass V, Reis A, Loguercio AD, Bombarda NH (2013) Immediate bonding properties of universal adhesives to dentine. J Dent 41:404–411. https://doi.org/10.1016/j.jdent.2013.03.001
4. Nagarkar S, Theis-Mahon N, Perdigao J (2019) Universal dental adhesives: current status, laboratory testing, and clinical performance. J Biomed Mater Res B Appl Biomater 107:2121–2131. https://doi.org/10.1002/jbm.b.34305
5. Matos AB, Trevelin LT, Silva B, Francisconi-Dos-Rios LF, Siriani LK, Cardoso MV (2017) Bonding efficiency and durability: current possibilities. Braz Oral Res 31:e57. https://doi.org/10.1590/1807-3107BOR-2017.vol31.0057
6. Yoshida Y, Nagakane K, Fukuda R, Nakayama Y, Okazaki M, Shintani H, Inoue S, Tagawa Y, Suzuki K, De Munck J, Van Meerbeek B (2004) Comparative study on adhesive performance of functional monomers. J Dent Res 83:454–458. https://doi.org/10.1177/154405910408300604
7. Yoshida Y, Yoshihara K, Nagaoka N, Hayakawa S, Torii Y, Ogawa T, Osaka A, Meerbeek BV (2012) Self-assembled nano-layering at the adhesive interface. J Dent Res 91:376–381. https://doi.org/10.1177/0022034512437375
8. Yoshihara K, Nagaoka N, Hayakawa S, Okihara T, Yoshida Y, Van Meerbeek B (2018) Chemical interaction of glycero-phosphate dimethacrylate (GPDM) with hydroxyapatite and dentin. Dent Mater 34:1072–1081. https://doi.org/10.1016/j.dental.2018.04.003
9. Munoz MA, Luque-Martinez I, Malaquias P, Hass V, Reis A, Campanha NH, Loguercio AD (2015) In vitro longevity of bonding properties of universal adhesives to dentin. Oper Dent 40:282–292. https://doi.org/10.2341/14-055-L
10. Vermelho PM, Reis AF, Ambrosano GMB, Giannini M (2017) Adhesion of multimode adhesives to enamel and dentin after one year of water storage. Clin Oral Investig 21:1707–1715. https://doi.org/10.1007/s00784-016-1966-1
11. Jacker-Guhr S, Sander J, Luehrs AK (2019) How "universal" is adhesion? Shear bond strength of multi-mode adhesives to enamel and dentin. J Adhes Dent 21:87–95. https://doi.org/10.3290/j.jad.a41974
12. Mena-Serrano A, Kose C, De Paula EA, Tay LY, Reis A, Loguercio AD, Perdigao J (2013) A new universal simplified adhesive: 6-month clinical evaluation. J Esthet Restor Dent 25:55–69. https://doi.org/10.1111/jerd.12005
13. Perdigao J, Kose C, Mena-Serrano AP, De Paula EA, Tay LY, Reis A, Loguercio AD (2014) A new universal simplified adhesive: 18-month clinical evaluation. Oper Dent 39:113–127. https://doi.org/10.2341/13-045-C
14. Lawson NC, Robles A, Fu CC, Lin CP, Sawlani K, Burgess JO (2015) Two-year clinical trial of a universal adhesive in total-etch and self-etch mode in non-carious cervical lesions. J Dent 43:1229–1234. https://doi.org/10.1016/j.jdent.2015.07.009

15. Loguercio AD, Luque-Martinez IV, Fuentes S, Reis A, Munoz MA (2018) Effect of dentin roughness on the adhesive performance in non-carious cervical lesions: a double-blind randomized clinical trial. J Dent 69:60–69. https://doi.org/10.1016/j.jdent.2017.09.011
16. Zanatta RF, Silva TM, Esper M, Bresciani E, Goncalves S, Caneppele T (2019) Bonding performance of simplified adhesive systems in noncarious cervical lesions at 2-year follow-up: a double-blind randomized clinical trial. Oper Dent 44:476–487. https://doi.org/10.2341/18-049-C
17. Oz FD, Ergin E, Canatan S (2019) Twenty-four-month clinical performance of different universal adhesives in etch-and-rinse, selective etching and self-etch application modes in NCCL - a randomized controlled clinical trial. J Appl Oral Sci 27:e20180358. https://doi.org/10.1590/1678-7757-2018-0358
18. Perdigao J, Ceballos L, Giraldez I, Baracco B, Fuentes MV (2020) Effect of a hydrophobic bonding resin on the 36-month performance of a universal adhesive-a randomized clinical trial. Clin Oral Investig 24:765–776. https://doi.org/10.1007/s00784-019-02940-x
19. Matos TP, Gutierrez MF, Hanzen TA, Malaquias P, de Paula AM, de Souza JJ, Hass V, Fernandez E, Reis A, Loguercio AD (2019) 18-month clinical evaluation of a copper-containing universal adhesive in non-carious cervical lesions: a double-blind, randomized controlled trial. J Dent 90:103219. https://doi.org/10.1016/j.jdent.2019.103219
20. Loguercio AD, de Paula EA, Hass V, Luque-Martinez I, Reis A, Perdigao J (2015) A new universal simplified adhesive: 36-Month randomized double-blind clinical trial. J Dent 43:1083–1092. https://doi.org/10.1016/j.jdent.2015.07.005
21. Atalay C, Ozgunaltay G, Yazici AR (2020) Thirty-six-month clinical evaluation of different adhesive strategies of a universal adhesive. Clin Oral Investig 24:1569–1578. https://doi.org/10.1007/s00784-019-03052-2
22. Ruschel VC, Stolf SC, Shibata S, Chung Y, Boushell LW, Baratieri LN, Walter R (2019) Three-year clinical evaluation of universal adhesives in non-carious cervical lesions. Am J Dent 32:223–228
23. Kuraray-noritake, (2017) Super stick, super quick! Br Dent J 222:904. https://doi.org/10.1038/sj.bdj.2017.518
24. Ahmed MH, De Munck J, Van Landuyt K, Peumans M, Yoshihara K, Van Meerbeek B (2019) Do universal adhesives benefit from an extra bonding layer? J Adhes Dent 21:117–132. https://doi.org/10.3290/j.jad.a42304
25. Kuno Y, Hosaka K, Nakajima M, Ikeda M, Klein Junior CA, Foxton RM, Tagami J (2019) Incorporation of a hydrophilic amide monomer into a one-step self-etch adhesive to increase dentin bond strength: effect of application time. Dent Mater J 38:892–899. https://doi.org/10.4012/dmj.2018-286
26. Sato T, Takagaki T, Ikeda M, Nikaido T, Burrow MF, Tagami J (2018) Effects of selective phosphoric acid etching on enamel using "no-wait" self-etching adhesives. J Adhes Dent 20:407–415. https://doi.org/10.3290/j.jad.a41359
27. Saito T, Takamizawa T, Ishii R, Tsujimoto A, Hirokane E, Barkmeier WW, Latta MA, Miyazaki M (2020) Influence of application time on dentin bond performance in different etching modes of universal adhesives. Oper Dent 45:183–195. https://doi.org/10.2341/19-028-L
28. Huang XQ, Pucci CR, Luo T, Breschi L, Pashley DH, Niu LN, Tay FR (2017) No-waiting dentine self-etch concept-Merit or hype. J Dent 62:54–63. https://doi.org/10.1016/j.jdent.2017.05.007
29. Schulz KF, Altman DG, Moher D, Group C (2010) CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. Obstet Gynecol 115:1063–1070. https://doi.org/10.1097/AOG.0b013e3181d9d421
30. Pocock SJ (1983) Clinical trials: a practical approach. New York: John Wiley & Sons, Chichester, 123–141
31. Loguercio AD, Reis A, Barbosa AN, Roulet JF (2003) Five-year double-blind randomized clinical evaluation of a resin-modified glass ionomer and a polyacid-modified resin in noncarious cervical lesions. J Adhes Dent 5:323–332
32. Swift EJ Jr, Perdigao J, Heymann HO, Wilder AD Jr, Bayne SC, May KN Jr, Sturdevant JR, Roberson TM (2001) Eighteen-month clinical evaluation of a filled and unfilled dentin adhesive. J Dent 29:1–6. https://doi.org/10.1016/s0300-5712(00)00050-6
33. Hickel R, Peschke A, Tyas M, Mjor I, Bayne S, Peters M, Hiller KA, Randall R, Vanherle G, Heintze SD (2010) FDI World Dental Federation: clinical criteria for the evaluation of direct and indirect restorations-update and clinical examples. Clin Oral Investig 14:349–366. https://doi.org/10.1007/s00784-010-0432-8
34. Perdigao J, Dutra-Correa M, Saraceni CH, Ciaramicoli MT, Kiyan VH, Queiroz CS (2012) Randomized clinical trial of four adhesion strategies: 18-month results. Oper Dent 37:3–11. https://doi.org/10.2341/11-222-C
35. Dalton Bittencourt D, Ezecelevski IG, Reis A, Van Dijken JW, Loguercio AD (2005) An 18-months' evaluation of self-etch and etch & rinse adhesive in non-carious cervical lesions. Acta Odontol Scand 63:173–178. https://doi.org/10.1080/00016350510019874
36. Cvar J, Ryge G (2005) Reprint of criteria for the clinical evaluation of dental restorative materials. 1971. Clin Oral Investig 9:215–232. https://doi.org/10.1007/s00784-005-0018-z
37. de Albuquerque EG, Warol F, Calazans FS, Poubel LA, Marins SS, Matos T, de Souza JJ, Reis A, de Oliveira BM, Loguercio AD (2020) A new dual-cure universal simplified adhesive: 18-month randomized multicenter clinical trial. Oper Dent 45:E255–E270. https://doi.org/10.2341/19-144-C
38. van Dijken JW (2013) A randomized controlled 5-year prospective study of two HEMA-free adhesives, a 1-step self etching and a 3-step etch-and-rinse, in non-carious cervical lesions. Dent Mater 29:e271–e280. https://doi.org/10.1016/j.dental.2013.08.203
39. Yoshihara K, Yoshida Y, Hayakawa S, Nagaoka N, Irie M, Ogawa T, Van Landuyt KL, Osaka A, Suzuki K, Minagi S, Van Meerbeek B (2011) Nanolayering of phosphoric acid ester monomer on enamel and dentin. Acta Biomater 7:3187–3195. https://doi.org/10.1016/j.actbio.2011.04.026
40. Kuraray-noritake (2019) CLEARFIL™ Universal Bond Quick Technical Brochure. https://www.kuraraynoritake.com/world/product/adhesives/pdf/universal_bond_quick_technical_brochure.pdf?fbclid=IwAR2Do-97LaqZYEA3OQ3G-wp_KCRXswPK6WKcY9BAJdL3gm4PuQQAzsfFrhI. Accessed Acces Date 2021
41. Van Landuyt KL, Snauwaert J, De Munck J, Peumans M, Yoshida Y, Poitevin A, Coutinho E, Suzuki K, Lambrechts P, Van Meerbeek B (2007) Systematic review of the chemical composition of contemporary dental adhesives. Biomaterials 28:3757–3785. https://doi.org/10.1016/j.biomaterials.2007.04.044
42. Takahashi M, Nakajima M, Hosaka K, Ikeda M, Foxton RM, Tagami J (2011) Long-term evaluation of water sorption and ultimate tensile strength of HEMA-containing/-free one-step self-etch adhesives. J Dent 39:506–512. https://doi.org/10.1016/j.jdent.2011.04.008
43. Ahmed MH, Yoshihara K, Mercelis B, Van Landuyt K, Peumans M, Van Meerbeek B (2020) Quick bonding using a universal adhesive. Clin Oral Investig 24:2837–2851. https://doi.org/10.1007/s00784-019-03149-8
44. Lopes LS, Calazans FS, Hidalgo R, Buitrago LL, Gutierrez F, Reis A, Loguercio AD, Barceleiro MO (2016) Six-month follow-up of cervical composite restorations placed with a new universal adhesive system: a randomized clinical trial. Oper Dent 41:465–480. https://doi.org/10.2341/15-309-C
45. Barceleiro MO, Lopes LS, Tardem C, Calazans FS, Matos TP, Reis A, Calixto AL, Loguercio AD (2022) Thirty-six-month follow-up of cervical composite restorations placed with an

MDP-free universal adhesive system using different adhesive protocols: a randomized clinical trial. Clin Oral Investig 26:4337–4350. https://doi.org/10.1007/s00784-022-04397-x
46. Gutierrez MF, Bermudez J, Davila-Sanchez A, Alegria-Acevedo LF, Mendez-Bauer L, Hernandez M, Astorga J, Reis A, Loguercio AD, Farago PV, Fernandez E (2019) Zinc oxide and copper nanoparticles addition in universal adhesive systems improve interface stability on caries-affected dentin. J Mech Behav Biomed Mater 100:103366. https://doi.org/10.1016/j.jmbbm.2019.07.024
47. Kumagai RY, Hirata R, Pereira PNR, Reis AF (2020) Moist vs over-dried etched dentin: FE-SEM/TEM and bond strength evaluation of resin-dentin interfaces produced by universal adhesives. J Esthet Restor Dent 32:325–332. https://doi.org/10.1111/jerd.12537
48. Burrer P, Dang H, Par M, Attin T, Taubock TT (2020) Effect of over-etching and prolonged application time of a universal adhesive on dentin bond strength. Polymers (Basel) 12. https://doi.org/10.3390/polym12122902
49. Hardan L, Orsini G, Bourgi R, Cuevas-Suarez CE, Nicastro M, Lazarescu F, Filtchev D, Cornejo-Rios E, Zamarripa-Calderon JE, Sokolowski K, Lukomska-Szymanska M (2022) Effect of active bonding application after selective dentin etching on the immediate and long-term bond strength of two universal adhesives to dentin. Polymers (Basel) 14. https://doi.org/10.3390/polym14061129
50. Van Meerbeek B, Yoshihara K, Van Landuyt K, Yoshida Y, Peumans M (2020) From Buonocore's pioneering acid-etch technique to self-adhering restoratives. A status perspective of rapidly advancing dental adhesive technology. J Adhes Dent 22:7–34. https://doi.org/10.3290/j.jad.a43994
51. Dreweck F, Burey A, de Oliveira DM, Fernandez E, Loguercio AD, Reis A (2021) Challenging the concept that OptiBond FL and Clearfil SE bond in NCCLs are gold standard adhesives: a systematic review and meta-analysis. Oper Dent 46:E276–E295. https://doi.org/10.2341/20-059-LIT
52. Perdigao J, Geraldeli S (2003) Bonding characteristics of self-etching adhesives to intact versus prepared enamel. J Esthet Restor Dent 15:32–41. https://doi.org/10.1111/j.1708-8240.2003.tb00280.x
53. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt KL (2011) State of the art of self-etch adhesives. Dent Mater 27:17–28. https://doi.org/10.1016/j.dental.2010.10.023
54. Loguercio AD, Munoz MA, Luque-Martinez I, Hass V, Reis A, Perdigao J (2015) Does active application of universal adhesives to enamel in self-etch mode improve their performance? J Dent 43:1060–1070. https://doi.org/10.1016/j.jdent.2015.04.005
55. Hirokane E, Takamizawa T, Kasahara Y, Ishii R, Tsujimoto A, Barkmeier WW, Latta MA, Miyazaki M (2021) Effect of double-layer application on the early enamel bond strength of universal adhesives. Clin Oral Investig 25:907–921. https://doi.org/10.1007/s00784-020-03379-1
56. Cardenas AM, Siqueira F, Rocha J, Szesz AL, Anwar M, El-Askary F, Reis A, Loguercio A (2016) Influence of conditioning time of universal adhesives on adhesive properties and enamel-etching pattern. Oper Dent 41:481–490. https://doi.org/10.2341/15-213-L
57. Suzuki T, Takamizawa T, Barkmeier WW, Tsujimoto A, Endo H, Erickson RL, Latta MA, Miyazaki M (2016) Influence of etching mode on enamel bond durability of universal adhesive systems. Oper Dent 41:520–530. https://doi.org/10.2341/15-347-L
58. Hickel R, Brushaver K, Ilie N (2013) Repair of restorations—criteria for decision making and clinical recommendations. Dent Mater 29:28–50. https://doi.org/10.1016/j.dental.2012.07.006
59. Ryge G (1980) Clinical criteria. Int Dent J 30:347–358
60. Hickel R, Roulet JF, Bayne S, Heintze SD, Mjor IA, Peters M, Rousson V, Randall R, Schmalz G, Tyas M, Vanherle G (2007) Recommendations for conducting controlled clinical studies of dental restorative materials. Science Committee Project 2/98--FDI World Dental Federation study design (Part I) and criteria for evaluation (Part II) of direct and indirect restorations including onlays and partial crowns. J Adhes Dent 9(Suppl 1):121–47
61. Marquillier T, Doméjean S, Le Clerc J, Chemla F, Gritsch K, Maurin JC, Millet P, Pérard M, Grosgogeat B, Dursun E (2018) The use of FDI criteria in clinical trials on direct dental restorations: A scoping review. J Dent 68:1–9. https://doi.org/10.1016/j.jdent.2017.10.007