Dental Materials 40 (2024) 619–628

Contents lists available at ScienceDirect

Dental Materials

journal homepage: www.elsevier.com/locate/dental

Clinical evaluation of posterior restorations over wet and dry dentin using an etch-and-rinse adhesive: A 36-month randomized clinical trial

Claudia C. González [a], Romina Ñaupari-Villasante [a], Andrea Dos Santos de Castro [b], Luján Mendez-Bauer [c], Andrés Dávila-Sanchez [d], Paulina Aliaga-Sancho [d], Mario Felipe Gutierrez [e,f], Alessandra Reis [a], Alessandro D. Loguercio [a,*]

[a] Department of Restorative Dentistry, School of Dentistry, State University of Ponta, Ponta Grossa, PR, Brazil
[b] School of Dentistry, Tuiuti University, Santo Inácio, Curitiba, Paraná, Brazil
[c] Research Department, Faculty of Dentistry, Francisco Marroquím University, Guatemala city, Guatemala
[d] Universidad San Francisco de Quito USFQ, Department of Restorative Dentistry and Dental Materials, School of Dentistry, Quito, Ecuador
[e] Universidad de los Andes, Facultad de Odontología, Santiago, Chile
[f] University of Chile, Institute for Research in Dental Sciences, Faculty of Dentistry, Santiago, Chile

ARTICLE INFO

Keywords:
Dentin
Dental adhesive
Composite restoration
Clinical trial
Dental bonding

ABSTRACT

Objectives: To evaluate the clinical performance of posterior restorations over wet and dry dentin with an etch-and-rinse adhesive after 36 months of clinical service.
Methods: Forty-five participants were recruited, each one had at least two posterior teeth that needed restoration. Ninety restorations were placed on Class I or Class II cavities. For the restoration protocol, a simplified etch-and-rinse adhesive (Adper Single Bond 2) was applied over wet (WD) or dry dentin (DD) and later restored with a bulk-fill composite (Filtek Bulk Fill) under rubber dam isolation. Each restoration was evaluated using the World Dental Federation (FDI) criteria after 6, 12, and 36 months of clinical service, regarding the following principal restoration characteristics: postoperative sensitivity, marginal discoloration, marginal adaptation, fracture of material and retention, and recurrence of caries. Kruskal Wallis analysis of variance rank ($\alpha = 0.05$) and Kaplan-Meier survival analysis were used for statistical analysis.
Results: After 36 months of clinical evaluation, no significant difference between groups was observed in each FDI criterion ($p > 0.05$). Twenty restorations (WD=10, DD=10) showed minor marginal staining, and twenty-two restorations (WD=11, DD=11) presented small marginal adaptation defects ($p > 0.05$). Four restorations were lost (WD = 2, DD = 2) and the fracture rates (95% confidence interval) were 94.9% for each one, without significant difference between wet and dry dentin ($p > 0.05$).
Significance: The degree of dentin moisture does not seem to affect the clinical performance of a simplified etch-and-rinse adhesive in posterior restorations when the adhesive is applied vigorously over the dentine surface.

1. Introduction

In recent decades, direct resin composite restorations have been considered one of the most popular choices of treatment among dentists because of their low cost, minimal intervention, esthetics, and very good clinical performance [1], being performed with both incremental and bulk-fill resin composites [2]. However, the annual failure rate of direct composite restorations of posterior teeth is around 2%, being secondary caries and fractures, as the main reasons for failure [3]. Some factors that affect restoration longevity are not only associated with the materials themselves but also with the patient's habits and tooth-related factors, such as caries risk and restoration size; as well as associated with the operator skills and decision-making for the restorative procedures [4].

Regarding restorative procedures, the adhesive technique is considered one of the most important issues for achieving restoration longevity, because of the sensitivity of the technique and the influence of clinicians' skills, knowledge, and ability to carry out bonding protocols [5]. In this regard, adhesive protocols could be classified according to the bonding technique such as self-etch and etch-and-rinse, depending

* Correspondence to: Faculdade de Odontologia, UEPG, Avenida General Carlos Cavalcanti, 4748, Ponta Grossa CEP 84010-330, PR, Brazil.
E-mail address: aloguercio@hotmail.com (A.D. Loguercio).

https://doi.org/10.1016/j.dental.2024.02.009
Received 18 November 2023; Received in revised form 30 January 2024; Accepted 12 February 2024
Available online 18 February 2024

on the use or not of phosphoric acid in dentin. This acid is responsible for removing the smear layer to expose the collagen network, allowing the adhesive monomer infiltration, then creating the hybrid layer [6]. It has been reported that collagen fibers can collapse after the post-etching dry, jeopardizing the hybrid layer formation, and as many clinicians believe it may leave voids allowing the movement of dental fluid causing postoperative sensitivity (POS) [7–9]. Thus, demineralized dentin loses interfibrillar spaces between fibers blocking monomer infiltration, resulting in low values of bond strength. Therefore, maintaining dentin moisture has been considered an alternative for better adhesive performance [10].

In vitro studies have shown controversial results about the influence of dentin moisture over the bonding performance of adhesive systems after acid etching dry, suggesting that the effectiveness of this technique may be related to the adhesive composition and application mode (active or passive application) [11–18]. In this context, the presence of residual water in the adhesive interface, which is a factor for the phase separation of the hydrophobic monomers, could jeopardize the adhesive interface integrity [19,20]. Additionally, the difficulty in achieving the right degree of dentin surface wetness, as, most of the time, there are no objective criteria to establish the ideal moisture level.

Regarding the evidence from clinical trials, some studies were performed on non-carious cervical lesions (NCCLs), and have shown that the dentin moisture level (wet or dry) did not influence the clinical performance of etch-and-rinse adhesives after a short time evaluation [21–23]; as well as with universal adhesives applied in the etch-and-rinse mode after short- [24], mid- [25–27], and long-term evaluation [28,29].

Given the notable regional variations in dentin wetness and permeability between occlusal dentin (typically associated with posterior restorations) and buccal dentin (commonly found in NCCLs), it becomes imperative to investigate the impact of dentin moisture levels (wet or dry) on the overall clinical efficacy of posterior resin composite restorations. Previous studies that assessed the influence of dentin moisture levels after acid etching on posterior composite restorations, showed no significant difference when the demineralized dentin was kept wet or dry [30,31]. However, those results came from short-term clinical evaluations. Considering that composite restoration failures tend to manifest after an extended time, it is imperative to undertake clinical investigations with prolonged follow-ups to confirm the previous findings.

Thus, the aim of this double-blind, split-mouth randomized controlled clinical trial was to assess the clinical outcomes of employing both wet and dry adhesive techniques, using a simplified etch-and-rinse adhesive in posterior restorations over a 36-month follow-up. The null hypotheses tested in this study were that there is no significant difference in a) the postoperative sensitivity of posterior restorations when using the wet and dry adhesive technique with an etch-and-rinse adhesive after 36 months of clinical service, and in b) the secondary outcomes (marginal staining, marginal adaptation, fracture of material and retention, and recurrence of caries) of posterior restorations using the wet and dry adhesive technique with an etch-and-rinse adhesive when evaluated using the FDI criteria after 36 months of clinical service.

2. Method and Materials

2.1. Ethical approval and protocol registration

The ethics committee involving human subjects, from the State University of Ponta Grossa (PR/Brazil), reviewed and accepted the protocol and consent given for this study (protocol #2.583.973). All participants were informed about the study's objectives and nature and signed a consent form, before their inclusion in the study. This clinical study was registered in the Clinical Trials Registry (#RBR-69d7cz) and was conducted and reported following the Consolidated Standards of Reporting Trials (CONSORT) statement [32].

2.2. Trial design, settings, and location of data collection

This was a double-blinded (patient and examiner), split-mouth randomized clinical trial. This study was conducted at the clinics of the School of Dentistry of the State University of Ponta Grossa (PR/Brazil) from June 2018 to December 2018, and the 36-month follow-up was performed from July 2021 to December 2021.

2.3. Participants recruitment

All participants were recruited as they appeared for screening sessions at the dental clinic of the State University of Ponta Grossa (PR/Brazil), thus forming a sample of convenience. Written advertisement was also placed on the university's walls.

2.4. Eligibility criteria

Sixty-three participants were examined by two calibrated dental residents to check if they met the inclusion criteria, using an explorer, an intra-oral mirror, and a periodontal probe. Afterward, 45 participants were selected and recruited after accepting the terms of the research (Fig. 1). All participants had to be in good general health, be older than 18 years old, have an acceptable oral hygiene level according to the Simplified Oral Hygiene Index (OHI-S) [33], have at least 20 teeth under occlusion with at least two molars with carious lesions that require restoration, or deficient posterior restoration in need of replacement.

Participants with extremely poor oral hygiene (OHI-S more than 3) [33], severe or chronic periodontitis (teeth with probing pocket depth more than 4 mm with bleed on probing and clinical attachment loss more than 3 mm in more than 4 teeth) [34], dental prostheses, severe bruxism, parafunctional habits, or continuous use of anti-inflammatory or analgesic medication were excluded of the study. Also, participants with known allergies to resin-based materials or any other material used in this study, with bleaching treatment and pregnant or breastfeeding women were excluded. Consequently, each one of the selected participants signed a consent form accepting their role in the study.

2.5. Characteristics of the teeth cavities to be included

The teeth intended for restoration had to be in occlusion with its natural antagonist tooth and adjacent teeth. The dental cavities had to be Class I or Class II (involving the occlusal surface) of a depth of 3 mm or greater, evaluated using a bitewing radiograph and ruler, in vital teeth. Teeth requiring endodontic treatment (evaluated by radiography and by cold pulpal sensitivity test (Roeko-Endo-Frost, Coltene/Whaledent, Langenau, Germany) were excluded.

2.6. Sample size

The primary outcome of this study was postoperative sensitivity (POS) after posterior resin composite restoration. Sample size calculation was based on the risk of POS of 30% in deep and large restorations [35–37] using $\alpha = 0.05$ with a power of 80% in a two-sided test, and to detect a difference of 20% between groups when applying the adhesive to dry dentin. Considering a 20% dropout rate, the minimal sample size was 45 restorations per group.

2.7. Randomization sequence, allocation, and blinding

The randomization process was performed using the software at the website http://www.sealedenvelope.com, by a staff member who did not participate in the research protocol. The randomization was done on an intra-individual basis so that each subject ended up with two restorations, each one of each research group. Details of the allocated groups were recorded in cards inside opaque sequentially numbered sealed envelopes. Each envelope was opened on the day of the restorative

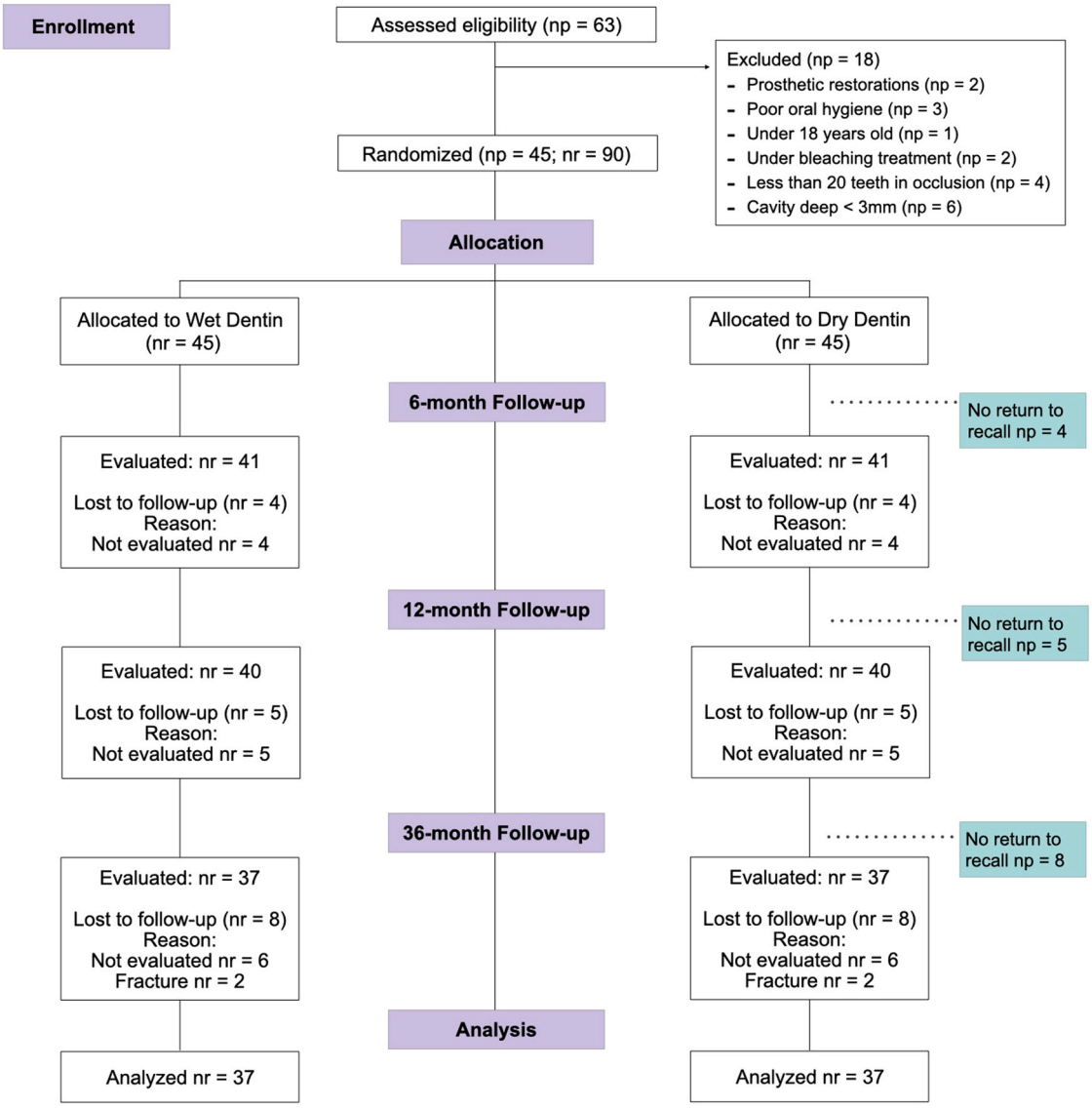

Fig. 1. Participant flow diagram in the different phases of the study design. Abbreviations: np – number of participants; nr – number of restorations.

procedure, guaranteeing the concealment of the random sequence, and preventing selection bias.

The operator who placed each restoration on the participants was the only one aware of the procedure because they needed to know details on how to perform each restoration. This means that only participants and examiners were blinded to the group allocation in a double-blind, randomized clinical trial design.

2.8. Baseline characteristics of the selected teeth

The features of the posterior teeth were evaluated before restoration placement. Some of the features were cavity depth, attrition facets, and the presence of an antagonist (Table 1).

2.9. Interventions: restorative procedure

For calibration purposes, the study director trained three resident dentists (ASC, LMB, MFG) with more than three years of clinical experience in restorative dentistry and not involved in the previous evaluation of patients, to restore all teeth. The calibration process included practical demonstrations (in vitro and in vivo) where the study director placed one restoration for each group to identify all the restoration steps. Subsequently, each operator placed four restorations (both in vitro and in vivo), two of each group, under the supervision of the study director, in a clinical setting. During this procedure, any discrepancies were discussed and resolved before the start of the study. At this point, the operators were considered calibrated to perform the restorative procedures.

Before restorative procedures, the operators cleaned all lesions with pumice for plaque and salivary pellicle removal, rinsing, and drying. Color match was determined using a shade guide of the resin composite used. Subsequently, local anesthesia (3% mepivacaine Mepisv, Nova DFL, Rio de Janeiro, RJ, Brazil) was applied and the rubber dam isolation was performed. No additional retention or bevel was performed in the cavities.

Cavity preparation began with a spherical diamond bur (#1013–1017, KG Sorensen, Barueri, SP, Brazil) placed on a high-speed handpiece with air-water irrigation. Only caries-infected dentin and defective restorations were removed. For Class II cavities a sectional matrix system Palodent (Dentsply Caulk, Milford, DE, USA) was used and proximal wedges were placed and adapted to obtain the proximal contour of the restoration [38]. In none of these prepared cavities was placed a liner or base. The cavity dimensions were measured in the proximal (Class II) or occlusal (Class I), in millimeters (height, width,

Table 1
Baseline characteristics of all subjects, cavities, and arch distribution.

Distribution	Number of participants	
Gender	16	
Female	29	
Male		
Age distribution	28	
20-29	07	
30-39	06	
40-49	04	
> 49		
Characteristics of cavities and arch distribution	Number of research subjects	
Presence of antagonist	Dry dentin	Wet dentin
Yes	45	45
No	00	00
Attrition facet		
Yes	03	03
No	42	42
Arc distribution		
Maxillary	21	23
Mandibular	24	22
Cavity depth		
3 mm	10	13
4 mm	25	21
> 4 mm	10	11
Black classification		
I	35	32
II	10	13
Number of restored surfaces		
1	33	30
2	12	11
3	00	04
4	00	00
Reasons for restoration		
Marginal fracture	01	00
Esthetic reasons	17	20
Marginal discoloration	00	01
Bulk fracture	00	00
Primary/secondary caries lesions	28	23

and depth) using a periodontal probe (#6 Satin Steel Handled, Hu-friedy mfg, Chicago, IL, USA).

At this moment, the envelopes were opened, and the operators discovered which adhesive technique they would use for each cavity. The adhesive protocol began with a 34% phosphoric acid Scotchbond Universal Etchant (3M Oral Care, St. Paul, MN, USA) applied for 15 s on dentin and enamel. Then, the cavity was rinsed with an air-dry syringe for 10 s. Later, for the dry dentin group, the surface was dried for 10 s with a 2 cm distance between the tip of the syringe and the surface. Generally, the prepared surface dentin was completely dry, without any moisture. For the wet dentin group, excess water was removed using gentle air-drying for 4 s, at the same 2 cm distance from the tip of the syringe to the dentin surface. Leaving a visibly shiny and moist surface.

One drop of the adhesive Adper Single Bond 2 (3M Oral Care, St. Paul, MN, USA) was applied on a microbrush (Cavibrush, FGM Dental Products, Joinville, SC, Brazil) after the adhesive bottle was shaken. The microbrush was rubbed on all surface dentin for both wet and dry groups. After that using an air syringe, a light air-drying was applied for 5 s. Followed, by light-curing (Radii Cal SDI, Vitoria, Australia) for 10 s (1,000 mW/cm^2), as manufacturer indications. For each restoration, the composite Filtek Bulk Fill Posterior Restorative (3M Oral Care, St. Paul, MN, USA) was used in a single increment and light cured for 30 s (1,000 mW/cm^2). The irradiance was evaluated before each restoration with a radiometer (Hilux Led Max Curing light meter, First Medica, Greensboro, NC, USA). After removal of the metal matrix, proximal regions of Class II restorations were additionally polymerized buccally and lingually/palatally for 10 s. Once, restorations were finished, occlusal adjustment was executed with final polishing using fine-grained FF diamond tips (KG Sorensen, Barueri, SP, Brazil) and Astropol rubber cups (Ivoclar Vivadent, Schaan, Liechtenstein). Proximal contacts were checked with dental floss and adjusted with sanding strips (3M Oral Care, St. Paul, MN, USA) if needed. Batch numbers, composition of materials, and adhesive/restorative procedures used in the study are described in Table 2.

2.10. Clinical evaluation

Two calibrated blinded dentists (CCG, RÑV), who were not part of the restoration procedure, examined each restoration. For their proper calibration, the examiners observed 10 photographs that were representative of each score for each criterion under the supervision of the study director. Then they evaluated 10 to 15 subjects each on two consecutive days. These subjects had posterior restorations and did not participate in this project. An inter-examiner and intra-examiner agreement of at least 85% was necessary before beginning the evaluation.

For a proper evaluation, examiners performed dental prophylaxis with pumice and water over the teeth's surface before evaluation. Clinical evaluation was performed using a dental explorer and intraoral mirror. The proximal marginal adaptation of Class II restorations was evaluated using dental flossing and bitewing radiography when examiners considered it necessary.

The standardized procedure for examination included intraoral

Table 2
Material composition, adhesive, and restorative procedures.

Material [Batch Number]	Composition (*)	Dry dentin adhesive procedure	Wet dentin adhesive procedure
Scotchbond Universal Etchant (3 M Oral Care, St. Paul, MN, USA) [643399]	Orthophosphoric acid 34%	1. Acid etchant was applied for 15 s on dentin and enamel. 2. Rinse for 10 s	
Adper Single Bond 2 (3 M Oral Care, St. Paul, MN, USA) [N771968]	BisGMA, HEMA, dimethacrylates, ethanol, water, photoinitiator system, methacrylate functional copolymer of polyacrylic and polyalkenoic acids	3. Air-dried surface for 10 s at 2 cm distance (dentin without moisture signs). 4. One drop of adhesive was vigorously rubbed on all surfaces. 5. Light air-drying for 5 s 6. Light-cured for 10 s (1000 mW/cm^2)	3. Air-dried surface for 4 s at 2 cm distance (dentin visibly shiny and moist).
Filtek Bulk Fill Posterior Restorative (3 M Oral Care, St. Paul, MN, USA) Shades A2 and A3 [N68566]	Organic Matrix: AUDMA, UDMA, and 1,12-dodecane-DMA Fillers: non-agglomerated/non-aggregated 20 nm silica filler, a non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, aggregated zirconia/silica cluster filler (comprised of 20 nm silica to 4 to 11 nm zirconia particles), and ytterbium trifluoride filler of 100 nm particles; 76.5 wt 58.4 vol% Other components: camphorquinone.	7. Single increments of 4-5 mm were placed and light-cured (1000 mW/cm^2) for 40 s in each restoration	

*Bis-GMA: bisphenol A- glycidyl methacrylate; HEMA: 2- Hydroxylethyl methacrylate; AUDMA: aromatic urethane dimethacrylate; UDMA: urethane dimethacrylate.

digital photographs of each restoration and a paper case report at each recall time, so they were kept blind to previous evaluations during the follow-up recalls. The restorations were evaluated by World Federation criteria (FDI) [39,40] and U.S. Public Health Service (USPHS) [41] criteria at baseline and after 6, 12, and 36 months of clinical service. Clinically relevant measures for evaluation of adhesive performance were used and scored (postoperative sensitivity, marginal adaptation, marginal staining, fracture of material and retention, and recurrence of caries). Color match and surface staining were also recorded if it was observed. These variables were ranked according to FDI criteria into clinically very good [VG], clinically good [CG], clinically sufficient/satisfactory [SS], clinically unsatisfactory but repairable [UN], and clinically poor (replacement required) [PO] [39,40]. They were ranked as well for the USPHS criteria into Alfa [excellent/very good], Bravo [acceptable], and Charlie [not acceptable] [41]. Examiners evaluated all the restorations and gave their scores individually. If any disagreement occurred, examiners had to reach a consensus before the participant left.

All restorations scored as clinically unsatisfactory or poor by FDI criteria at once recall were accounted as a cumulative failure at the next follow-up evaluation. Each failed restoration was replaced with a new composite resin restoration [39]. These new restorations were not included as part of the study for further evaluation. Participants' restorations whose evaluation was not possible to be performed, as well as excluded restorations, were considered lost to follow-up.

2.11. Statistical analysis

The statistician was blinded to the type of study groups. The statistical analysis followed the intention-to-treat protocol, according to CONSORT's suggestion [32]. Descriptive statistics were used to describe the distributions of the evaluated criteria. For statistical purposes, the FDI criteria were dichotomized into two categories: no necessity of intervention (clinically very good, clinically good, and clinically sufficient/satisfactory) or necessity of intervention (clinically unsatisfactory but repairable, and clinically poor where replacement is required) [42]. Missing outcome data due to missing participants was analyzed following the Imputed Case Analysis approach, where all missing participants in each intervention were assumed to have experienced the event (failure) [43].

For the outcomes, postoperative sensitivity, marginal staining, marginal adaptation, and recurrence of caries, the differences between the two groups' ratings after 6, 12, and 36 months were tested by Kruskal Wallis analysis of variance and Mann- Whitney test ($\alpha = 0.05$) (Statistica StatSoft Inc., Tulsa, Ok, USA). For the outcome fracture of material and retention success rates of both groups, Kaplan-Meier analysis was used [42], and the Hazard Ratios (HR) and 95% confidence intervals were also estimated. The long-rank test was used to compare the survival distributions of restorations ($\alpha = 0.05$). The absolute and relative risks of all approaches were calculated, and the 95% confidence interval was reported (MedCal Software, Version 19.1, Ostend, Belgium). Additionally, the distribution of failed restorations between groups and operators was analyzed by the Chi-square test ($\alpha = 0.05$).

3. Results

In total sixty-three participants were screened for eligibility, and 18 participants were excluded from the study for not meeting the inclusion criteria. Therefore, ninety restorations were placed on 45 participants, 16 females and 29 males (Table 1). Each participant had two restorations for the experimental groups ($n = 45$) in a split-mouth design. The restorative procedure was applied precisely as planned, and no modification was performed. All baseline cavity characteristics were considered for all restorations, as described in Table 1. In each one of the follow-ups, restorations were examined, and taken pictures (Fig. 1). The level of agreement between inter and intra-examiners was calculated using the Cohen *kappa* statistics showing 0.86 and 0.75, respectively.

All participants attended to one-week recall. For the 6- and 12-month follow-up 4 and 5 participants did not attend to recalls, respectively. Afterward, for the 36-month follow-up, only 6 participants did not attend to examination due to loss of contact, discontinued intervention, or moved to another city (Fig. 1). Tables 3 and 4 display all the data regarding follow-up times. However, only the 36-month data are described here.

3.1. Postoperative (hyper-) sensitivity

After the 36-month evaluation, none of the restorations for both experimental groups (DD and WD) reported postoperative sensitivity. All restorations scored clinically very good, on the FDI or USPHS criterion ($p > 0.05$, Tables 3 and 4).

3.2. Marginal staining

According to the FDI criteria, after 36 months of clinical evaluation, 20 posterior restorations (10 for WD and 10 for DD; Table 3) showed minimal marginal staining and no significant differences between both groups when the criteria were dichotomized into two categories: clinically acceptable and clinically not acceptable ($p > 0.05$). According to the USPHS criteria, after 36 months of clinical evaluation, 11 posterior restorations (6 for WD and 5 for DD; Table 4) showed marginal staining, with no significant differences between both groups ($p > 0.05$).

3.3. Marginal adaptation

According to the FDI, after the 36-month recall, 22 restorations (11 for WD and 11 for DD) showed minor marginal adaptation discrepancies (Table 3). After the criteria were dichotomized into two categories: clinically acceptable and clinically not acceptable, no significant difference was detected between any pair of groups at the 36-month recall ($p > 0.05$, Table 3). According to the USPHS criteria, after 36 months of clinical evaluation, 13 posterior restorations (7 for WD and 6 for DD; Table 4) showed marginal discrepancies, with no significant differences between both groups ($p > 0.05$).

3.4. Fracture and retention

After 36 months of clinical evaluation, four restorations were fractured (WD = 2; DD = 2; Tables 3 and 4). According to the FDI/USPHS criteria, the 36-month fracture of material and retention rate absolute risk (95% confidence interval) was 94.9% (95% CI 83.1 – 98.6) for both groups (Table 5). In Fig. 2, the Kaplan-Meier curves did not show significant differences (Long-rank test, $p = 1.00$) among the time and survival probability. The survival curves are shown overlaid. The paired comparisons among the DD vs WD as the hazard ratios are shown in Table 5, without significant difference (HR = 1.08; 95% CI 0.69 – 1.70), since the 95% CI interval of the hazard ratio crosses the null value of 1. Furthermore, the distribution of failed restorations between groups and operators is detailed in Table 6, revealing no significant differences ($p > 0.05$).

3.5. Recurrence of caries

No recurrence of caries was found during the 36-month recall. All restorations for (DD and WD) scored as clinically very good in the FDI or USPHS criterion ($p > 0.05$, Tables 3 and 4).

4. Discussion

In this 36-month double-blind randomized clinical trial, posterior restorations with wet or dry dentin using a simplified ethanol-based etch-and-rinse adhesive system, showed similar POS, regardless of

Table 3
Number of Evaluated Restorations for Each Experimental Group Classified According to the World Dental Federation (FDI) [39,40].

FDI Criteria	(*)	Baseline		6 months		12 months		36 months	
		Dry Dentin	Wet Dentin	Dry Dentin	Wet Dentin	Dry Dentin	Wet Dentin	Dry Dentin	Wet Dentin
Postoperative (hyper-) sensitivity	A	45	45	41	41	40	40	35	35
	B	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-	-
Marginal staining	A	45	45	38	38	33	33	25	25
	B	-	-	02	02	04	05	04	05
	C	-	-	01	01	03	02	06	05
	D	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-	-
Marginal adaptation	A	45	45	41	40	37	36	24	24
	B	-	-	-	01	03	04	04	05
	C	-	-	-	-	-	-	07	06
	D	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-	-
Fracture of material and retention	A	45	45	40	39	39	37	35	35
	B	-	-	01	02	01	03	-	-
	C	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	02	02
Recurrence of caries	A	45	45	41	41	40	40	35	35
	B	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-	-

(*) A: Clinically very good; B: Clinically good; C: Clinically sufficient; D: Clinically unsatisfactory; E: Clinically poor

Table 4
Number of Evaluated Restorations for Each Experimental Group Classified According to the USPHS [41].

USPHS Criteria	(*)	Baseline		6 months		12 months		36 months	
		Dry Dentin	Wet Dentin	Dry Dentin	Wet Dentin	Dry Dentin	Wet Dentin	Dry Dentin	Wet Dentin
Postoperative (hyper-) sensitivity	Alpha	45	45	41	41	40	40	35	35
	Bravo	-	-	-	-	-	-	-	-
	Charlie	-	-	-	-	-	-	-	-
Marginal staining	Alpha	45	45	38	38	33	33	29	30
	Bravo	-	-	02	02	05	05	06	05
	Charlie	-	-	01	01	02	02	-	-
Marginal adaptation	Alpha	45	45	40	39	37	36	28	29
	Bravo	-	-	01	02	03	04	07	06
	Charlie	-	-	-	-	-	-	-	-
Fracture	Alpha	45	45	40	38	39	37	35	35
	Bravo	-	-	01	02	01	03	-	-
	Charlie	-	-	-	01	-	-	02	02
Retention	Alpha	45	45	41	40	40	40	35	35
	Bravo	-	-	-	-	-	-	-	-
	Charlie	-	-	-	01	-	-	-	-
Recurrence of caries	Alpha	45	45	41	41	40	40	35	35
	Bravo	-	-	-	-	-	-	-	-
	Charlie	-	-	-	-	-	-	-	-

(*) Alpha: Excellent; Bravo: Acceptable; Charlie: No acceptable

Table 5
Absolute risk (95% Cl), relative risk (95% CI), and hazard ratio (95% CI) for outcome fracture of material and retention for the two groups after 36 months of clinical evaluation.

	Absolute risk (95% CI)	Relative risk (95% CI)*	Hazard ratio (95% CI)*
Wet dentin	94.9 (83.1-98.6)	1.0 (0.2 – 6.7)	1.08 (0.69 to 1.70)
Dry dentin	94.9 (83.1-98.6)		

(*) Related to wet dentin

being spontaneous or provoked. Thus, the first null hypothesis was accepted. The evaluated restorations in both groups demonstrated the absence of POS, as per both FDI (categorized as clinically excellent/very good) and USPHS criteria (categorized as Alpha), thereby minimizing the difference in the criteria's sensitivity to detect POS.

Based on the hydrodynamic theory, dentin hypersensitivity is caused by open dentinal tubules that enable communication between the oral environment and the pulp-dentin complex. Normally, fluid within these tubules faces constant external pressure. Various stimuli can lead to a rapid increase in fluid flow, triggering pulp receptors and causing sharp pain [44]. Furthermore, the shrinkage stress from composite resin polymerization, along with ensuing cuspal deflection, could contribute to the development of potential POS [45]. In this sense, some restorative material characteristics could influence the low POS observed in this

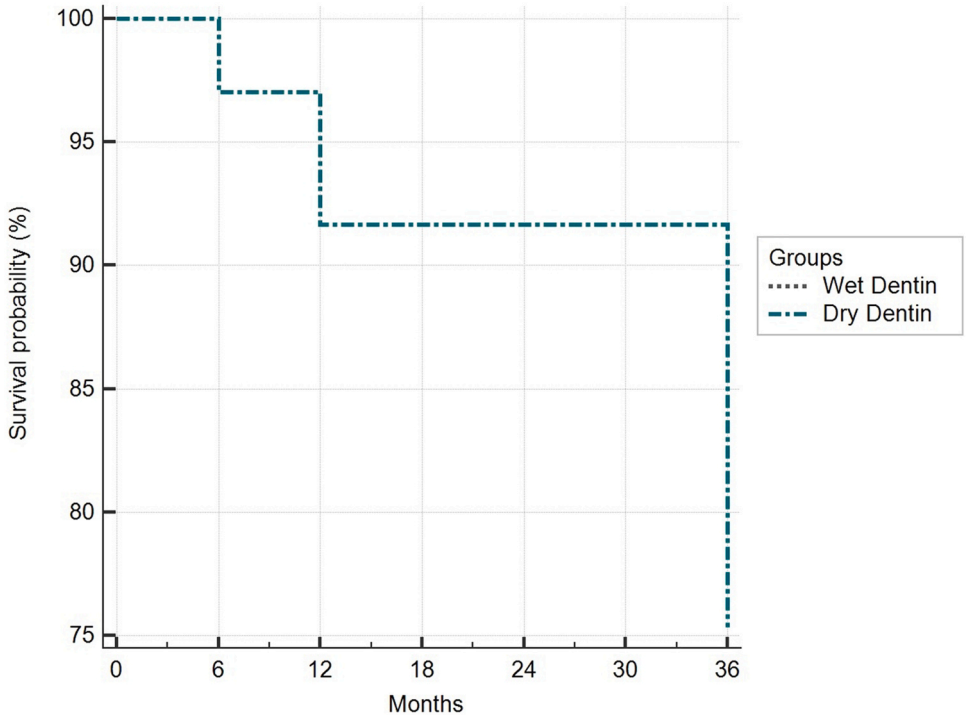

Fig. 2. Survival curves for wet and dry dentin. The survival curves overlaid because the same numbers of failed restorations were observed in both groups.

Table 6
Distribution of failed restorations between operators at 36 months of clinical evaluation.

Failed restorations per operator*						
	Operator 1		Operator 2		Operator 3	
No failed	28		21		25	
Failed	02		01		01	
Failed restorations per operator per group* *						
	Operator 1		Operator 2		Operator 3	
	Dry dentin	Wet dentin	Dry dentin	Wet dentin	Dry dentin	Wet dentin
No failed	14	14	11	10	12	13
Failed	01	01	-	01	01	-

(*) $\chi 2 = 0.22$; p-value = 0.64; (**) $\chi 2 = 0.05$; p-value = 0.82;

study. Bulk-fill composites have an acceptable depth of cure, degree of conversion, and polymerization shrinkage stress [46], which may be related to low polymerization shrinkage stress in the adhesive interface, reducing POS risk [47]. This is so true, that several clinical trials about posterior restorations performed with bulk-fill composites have reported a lack or low incidence of POS after a short- [30,31,48–54], mid- [55,56], and long-term clinical evaluation [57,58].

On the other hand, it has been suggested that POS could be caused not only by occlusal discrepancies, and cusp deformation but also by the deficient adhesive monomer infiltration in the collagen network after the acid-etching step, resulting in air voids able to stimulate the pulpal complex [8]. An alternative to overcome this problem is the active adhesive application, which showed an increase in the retention rates in restorations in NCCls when compared to the passive application [23,59]. This occurs because applying resin monomers under pressure compresses the demineralized dentin substrate, and draws the adhesive into the demineralized collagen network when the pressure is subsequently released [13,60], thus reducing the air voids and risk of POS. However, it is worth mentioning that the influence of the acid-etching step on the risk and intensity of POS on posterior restorations has not been confirmed yet [61].

In posterior restorations there are different substrates at interfaces to bond, dentin and enamel (Class II) and enamel (Class I); and it is well known that the bonding performance of adhesive systems and hybrid layer stability in both substrates is different [62]. Bonding to dentin is considered a challenging procedure due to the dynamic hydrophilic organic structure prone to hydrolytic and endogenous enzymatic degradation over time [63], leading to marginal defects and eventual restoration failure. In this context, keeping dentin wet to avoid the collapse of collagen fibrils after acid etching air-dry, was proposed as a standard protocol to facilitate a proper hybridization, and improve the interface integrity [20]. However, this study showed that keeping dentin wet or dry did not influence the marginal adaptation and marginal staining of posterior restorations after 36 months. Actually, the minimal marginal discrepancies observed were not considered failures and were ranked as clinically acceptable, just requiring monitoring or refurbishment of the restoration [42].

This clinical performance regardless of dentin moisture level could be explained by two main reasons. First, due to the adhesive composition. Adper Single Bond 2 presents a polyalkenoic acid copolymer in its chemical composition, a functional polymer that ionically bonds to the calcium in hydroxyapatite, providing better stability to moisture, establishing hydrogen bonds with the water absorbed on the hydroxyapatite [6,64], thus resulting in a very good clinical performance as was also observed on NCCLs [65–68]. And second, due to the active application mode of the adhesive since rubbing motion on dentin, besides promoting better monomer infiltration, also increases the solvent removal and reduces the amount of residual water in the collagen mesh, avoiding jeopardizing the monomers' degree of conversion, increasing the physical and mechanical properties of the hybrid layer [13,69], thus reducing its degradation over time, showing minimal marginal defects.

Taking into account that the majority of the margins in posterior restorations are in enamel, the adhesion to this substrate is critical for the prevention of marginal discoloration and proper sealing [3]. In this sense, polyalkenoic acids of Adper Single Bond 2 also perform a chemical bonding to enamel through the ionic bonding to hydroxyapatite, playing a crucial role in achieving improved marginal sealing [70],

added to the adhesion achieved with previous phosphoric acid etching that leads to enamel microporosities and the adhesive micromechanical interlocking [8]. Additionally, the active application of the adhesive appears to reinforce their bonding performance due to increasing the solvent evaporation and better conditioning pattern, which consequently, improve the adhesive infiltration in enamel [71]. Altogether may explain why the moisture level may not be relevant at dentin/enamel interfaces bonded with this simplified etch-and-rinse adhesive.

Indeed, the percentage of clinical success related to marginal adaptation (69%) or margins without discoloration (71%) in the current study was comparable to that reported in other studies evaluating the same adhesive system in posterior restorations, with marginal adaptation ranging from 66% to 82% and marginal without discoloration ranging from 53% to 99% [72–74]. However, comparing outcomes from different studies can be challenging, primarily due to variations in evaluation criteria. For example, while the current study employed both criteria, some studies [72–74] solely relied on the modified USPHS criteria, which is less sensitive and precise in detecting minimal discrepancies or failures than FDI, especially in assessing marginal adaptation and marginal staining [75]. This suggests that, in the current study, early defects could be identified, whereas in other studies [72–74], might have occurred but remained unnoticed.

Furthermore, no difference in fracture of material and retention loss of posterior restorations was observed between wet and dry dentin in the current study after 36 months. Previous studies performed in NCCLs with different adhesive systems found no difference in the retention rate between both dentin moisture levels even after long-term evaluation [26,28,29]. Taking into account that clinical trials conducted on NCCLs are considered the ideal study design to evaluate the adhesive procedure due to the challenging characteristics of these lesions without macro-mechanical retention compared to Class I and II cavities [76], it could be expected a good clinical performance on posterior restorations regardless the dentin moisture, as it was observed in the short-term evaluation [30,31]. In addition, the mechanical and physical properties of the bulk-fill composite in terms of degree of conversion, fracture strength, and polymerization stress, could be other factors for the low number of restorations with failures related to fracture [77]. It is worth mentioning that the fracture of material/retention rate of the current study was around 95%, similar to the 93% [38] and 90% [78] after the same follow-up.

Regarding the recurrence of caries, none of the evaluated restorations in wet or dry dentin showed failures after 36 months of clinical service. These results follow previous literature comparing wet and dry dentin on NCCLs after a mid- [25–27], and long-term evaluation [28,29]. However, it is worth mentioning that this clinical behavior was expected since the recurrence of caries is related to patients with high caries activity that could even develop carious lesions within three years [79], therefore, it is possible to assume that the caries experience of the participant sample of the current study was low [80].

As previously observed, regarding the secondary clinical parameters of marginal staining, marginal adaptation, fracture and retention, and recurrence of caries, the results of the present study suggest that both dentin moisture levels (wet or dry) perform similar clinical behavior on posterior restorations after 36 months. Therefore, the second null hypothesis was also accepted. Thus, based on the results of the present study, there is no sufficient evidence to confirm the influence of wet or dry dentin on restoration longevity. Thus, clinical decisions should be focused on factors such as procedure time or technical sensitivity, since controlling dentin moisture could be difficult to standardize and reproduce [81].

Although there was no difference in clinical performance of both groups in any of the criteria evaluated in the present study, it is interesting to describe the reasons why some failures occurred. The few restorations that exhibited failure (four in total) in the present study were associated with fractures at the marginal ridge of Class II cavities, which could be considered a characteristic issue of composite restorations in posterior teeth [58]. This may be linked to limitations in the mechanical properties of composites, such as lower fracture toughness, flexural strength, and fatigue resistance [82], when compared to indirect materials. Additionally, tooth- and patient-related factors, such as bruxism and parafunctional habits [83,84], could contribute. However, the former should be considered the most significant reason for the failures, given that patients with bruxism and parafunctional habits were excluded from the present study.

As a limitation of the present study, this is a mid-term evaluation (36-month clinical follow-up). In addition, it is noteworthy that more than 60% of the restorations in the current study were Class I restorations. Given that Class II restorations present a higher risk of failure compared to Class I restorations when using regular viscosity composites [85], it is recommended that future clinical studies investigate the clinical performance of bulk-fill composites in cavities with increased complexity.

5. Conclusion

After 36 months, the dentin moisture level (wet or dry) did not influence the clinical performance of an etch-and-rinse adhesive associated with a bulk-fill composite restoration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study was partially supported by National Council for Scientific and Technological Development (CNPq) under grants 304817/2021-0 and 308286/2019-7 and Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior - Brasil (CAPES) - Finance Code 001.

References

[1] Demarco FF, Corrêa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. Dent Mater 2012;28:87–101. https://doi.org/10.1016/j.dental.2011.09.003.
[2] Kunz PVM, Wambier LM, Kaizer MDR, Correr GM, Reis A, Gonzaga CC. Is the clinical performance of composite resin restorations in posterior teeth similar if restored with incremental or bulk-filling techniques? A systematic review and meta-analysis. Clin Oral Invest 2022;26:2281–97. https://doi.org/10.1007/s00784-021-04337-1.
[3] Heintze SD, Loguercio AD, Hanzen TA, Reis A, Rousson V. Clinical efficacy of resin-based direct posterior restorations and glass-ionomer restorations - an updated meta-analysis of clinical outcome parameters. Dent Mater 2022;38:e109–35. https://doi.org/10.1016/j.dental.2021.10.018.
[4] Demarco FF, Cenci MS, Montagner AF, de Lima VP, Correa MB, Moraes RR, et al. Longevity of composite restorations is definitely not only about materials. Dent Mater 2023;39:1–12. https://doi.org/10.1016/j.dental.2022.11.009.
[5] Ferracane JL. Resin composite–state of the art. Dent Mater 2011;27:29–38. https://doi.org/10.1016/j.dental.2010.10.020.
[6] Van Meerbeek B, Yoshihara K, Van Landuyt K, Yoshida Y, Peumans M. From Buonocore's pioneering acid-etch technique to self-adhering restoratives. A status perspective of rapidly advancing dental adhesive technology. J Adhes Dent 2020;22:7–34. https://doi.org/10.3290/j.jad.a43994.
[7] Tay FR, Gwinnett AJ, Pang KM, Wei SH. Resin permeation into acid-conditioned, moist, and dry dentin: a paradigm using water-free adhesive primers. J Dent Res 1996;75:1034–44. https://doi.org/10.1177/00220345960750040601.
[8] Perdigão J. Current perspectives on dental adhesion: (1) Dentin adhesion - not there yet. Jpn Dent Sci Rev 2020;56:190–207. https://doi.org/10.1016/j.jdsr.2020.08.004.
[9] Stape THS, Uctasli M, Cibelik HS, Tjäderhane L, Tezvergil-Mutluay A. Dry bonding to dentin: Broadening the moisture spectrum and increasing wettability of etch-and-rinse adhesives. Dent Mater 2021;37:1676–87. https://doi.org/10.1016/j.dental.2021.08.021.
[10] Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, et al. State of the art etch-and-rinse adhesives. Dent Mater 2011;27:1–16. https://doi.org/10.1016/j.dental.2010.10.016.
[11] Nakajima M, Kanemura N, Pereira PN, Tagami J, Pashley DH. Comparative microtensile bond strength and SEM analysis of bonding to wet and dry dentin. Am J Dent 2000;13:324–8.

[12] Reis A, Loguercio AD, Carvalho RM, Grande RH. Durability of resin dentin interfaces: effects of surface moisture and adhesive solvent component. Dent Mater 2004;20:669–76. https://doi.org/10.1016/j.dental.2003.11.006.
[13] Reis A, Pellizzaro A, Dal-Bianco K, Gones OM, Patzlaff R, Loguercio AD. Impact of adhesive application to wet and dry dentin on long-term resin-dentin bond strengths. Oper Dent 2007;32:380–7. https://doi.org/10.2341/06-107.
[14] Leite M, Costa CAS, Duarte RM, Andrade AKM, Soares DG. Bond strength and cytotoxicity of a universal adhesive according to the hybridization strategies to dentin. Braz Dent J 2018;29:68–75. https://doi.org/10.1590/0103-6440201801698.
[15] Tsujimoto A, Shimatani Y, Nojiri K, Barkmeier WW, Markham MD, Takamizawa T, et al. Influence of surface wetness on bonding effectiveness of universal adhesives in etch-and-rinse mode. Eur J Oral Sci 2019;127:162–9. https://doi.org/10.1111/eos.12596.
[16] Sugimura R, Tsujimoto A, Hosoya Y, Fischer NG, Barkmeier WW, Takamizawa T, et al. Surface moisture influence on etch-and-rinse universal adhesive bonding. Am J Dent 2019;32:33–8.
[17] Nonato RF, Moreira PHA, Silva DOD, Ferreira MWC, Reis A, Cardenas AFM, et al. Long-term evaluation of bonding performance of universal adhesives based on different dentinal moisture levels. J Adhes Dent 2022;24:395–406. https://doi.org/10.3290/j.jad.b3559027.
[18] Saeed NA, Tichy A, Shimada Y. Bonding of universal adhesives to bur-cut dentin: effect of double application and dentin moisture level. Dent Mater J 2022;41:724–30. https://doi.org/10.4012/dmj.2021-310.
[19] Spencer P, Wang Y. Adhesive phase separation at the dentin interface under wet bonding conditions. J Biomed Mater Res 2002;62:447–56. https://doi.org/10.1002/jbm.10364.
[20] Tjäderhane L. Dentin bonding: can we make it last? Oper Dent 2015;40:4–18. https://doi.org/10.2341/14-095-bl.
[21] Perdigão J, Carmo AR, Geraldeli S, Dutra HR, Masuda MS. Six-month clinical evaluation of two dentin adhesives applied on dry vs moist dentin. J Adhes Dent 2001;3:343–52.
[22] Perdigão J, Carmo AR, Geraldeli S. Eighteen-month clinical evaluation of two dentin adhesives applied on dry vs moist dentin. J Adhes Dent 2005;7:253–8.
[23] Zander-Grande C, Ferreira SQ, da Costa TR, Loguercio AD, Reis A. Application of etch-and-rinse adhesives on dry and rewet dentin under rubbing action: a 24-month clinical evaluation. J Am Dent Assoc 2011;142:828–35. https://doi.org/10.14219/jada.archive.2011.0272.
[24] Perdigão J, Kose C, Mena-Serrano AP, De Paula EA, Tay LY, Reis A, et al. A new universal simplified adhesive: 18-month clinical evaluation. Oper Dent 2014;39:113–27. https://doi.org/10.2341/13-045-c.
[25] Loguercio AD, de Paula EA, Hass V, Luque-Martinez I, Reis A, Perdigão J. A new universal simplified adhesive: 36-Month randomized double-blind clinical trial. J Dent 2015;43:1083–92. https://doi.org/10.1016/j.jdent.2015.07.005.
[26] de Albuquerque EG, Warol F, Tardem C, Calazans FS, Poubel LA, Matos TP, et al. Universal simplified adhesive applied under different bonding technique's: 36-month randomized multicentre clinical trial. J Dent 2022;122:104120. https://doi.org/10.1016/j.jdent.2022.104120.
[27] Barceleiro MO, Lopes LS, Tardem C, Calazans FS, Matos TP, Reis A, et al. 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 Invest 2022. https://doi.org/10.1007/s00784-022-04397-x.
[28] de Paris Matos T, Perdigão J, de Paula E, Coppla F, Hass V, Scheffer RF, et al. Five-year clinical evaluation of a universal adhesive: a randomized double-blind trial. Dent Mater 2020;36:1474–85. https://doi.org/10.1016/j.dental.2020.08.007.
[29] Ñaupari-Villasante R, Matos TP, de Albuquerque EG, Warol F, Tardem C, Calazans FS, et al. Five-year clinical evaluation of universal adhesive applied following different bonding techniques: a randomized multicenter clinical trial. Dent Mater 2023;39:586–94. https://doi.org/10.1016/j.dental.2023.04.007.
[30] Castro AS, Maran BM, Gutiérrez MF, Martini EC, Dreweck FD, Mendez-Bauer L, et al. Dentin moisture does not influence postoperative sensitivity in posterior restorations: a double-blind randomized clinical trial. Am J Dent 2020;33:206–12.
[31] Castro AS, Maran BM, Gutierrez MF, Chemin K, Mendez-Bauer ML, Bermúdez JP, et al. Effect of dentin moisture in posterior restorations performed with universal adhesive: a randomized clinical trial. Oper Dent 2022;47:E91–e105. https://doi.org/10.2341/20-215-c.
[32] Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. Bmj 2010;340:c332. https://doi.org/10.1136/bmj.c332.
[33] Greene JC, Vermillion JR. The simplified oral hygiene index. J Am Dent Assoc 1964;68:7–13. https://doi.org/10.14219/jada.archive.1964.0034.
[34] Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, et al. Periodontitis: consensus report of workgroup 2 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. Suppl 1: S173-s82 J Periodo 2018;89. https://doi.org/10.1002/jper.17-0721.
[35] Briso AL, Mestrener SR, Delício G, Sundfeld RH, Bedran-Russo AK, de Alexandre RS, et al. Clinical assessment of postoperative sensitivity in posterior composite restorations. Oper Dent 2007;32:421–6. https://doi.org/10.2341/06-141.
[36] Perdigão J, Geraldeli S, Hodges JS. Total-etch versus self-etch adhesive: effect on postoperative sensitivity. J Am Dent Assoc 2003;134:1621–9. https://doi.org/10.14219/jada.archive.2003.0109.
[37] Wegehaupt F, Betke H, Solloch N, Musch U, Wiegand A, Attin T. Influence of cavity lining and remaining dentin thickness on the occurrence of postoperative hypersensitivity of composite restorations. J Adhes Dent 2009;11:137–41.
[38] Loguercio AD, Rezende M, Gutierrez MF, Costa TF, Armas-Vega A, Reis A. Randomized 36-month follow-up of posterior bulk-filled resin composite restorations. J Dent 2019;85:93–102. https://doi.org/10.1016/j.jdent.2019.05.018.
[39] Hickel R, Roulet JF, Bayne S, Heintze SD, Mjör IA, Peters M, et al. Recommendations for conducting controlled clinical studies of dental restorative materials. Clin Oral Investig 2007;11:5–33. https://doi.org/10.1007/s00784-006-0095-7.
[40] Hickel R, Peschke A, Tyas M, Mjör I, Bayne S, Peters M, et al. FDI world dental federation - clinical criteria for the evaluation of direct and indirect restorations. Update and clinical examples. J Adhes Dent 2010;12:259–72. https://doi.org/10.3290/j.jad.a19262.
[41] Perdigão J, Dutra-Corrêa M, Saraceni CH, Ciaramicoli MT, Kiyan VH, Queiroz CS. Randomized clinical trial of four adhesion strategies: 18-month results. Oper Dent 2012;37:3–11. https://doi.org/10.2341/11-222-c.
[42] Hickel R, Mesinger S, Opdam N, Loomans B, Frankenberger R, Cadenaro M, et al. Revised FDI criteria for evaluating direct and indirect dental restorations-recommendations for its clinical use, interpretation, and reporting. Clin Oral Invest 2023;27:2573–92. https://doi.org/10.1007/s00784-022-04814-1.
[43] Spineli LM, Fleming PS, Pandis N. Addressing missing participant outcome data in dental clinical trials. J Dent 2015;43:605–18. https://doi.org/10.1016/j.jdent.2015.03.007.
[44] Brannstrom M. Dentin sensitivity and aspiration of odontoblasts. J Am Dent Assoc 1963;66:366–70. https://doi.org/10.14219/jada.archive.1963.0104.
[45] Oliveira LRS, Braga SSL, Bicalho AA, Ribeiro MTH, Price RB, Soares CJ. Molar cusp deformation evaluated by micro-CT and enamel crack formation to compare incremental and bulk-filling techniques. J Dent 2018;74:71–8. https://doi.org/10.1016/j.jdent.2018.04.015.
[46] Miletic V, Pongprueksa P, De Munck J, Brooks NR, Van Meerbeek B. Curing characteristics of flowable and sculptable bulk-fill composites. Clin Oral Investig. 2017;21:1201–12. https://doi.org/10.1007/s00784-016-1894-0.
[47] Rizzante FAP, Mondelli RFL, Furuse AY, Borges AFS, Mendonça G, Ishikiriama SK. Shrinkage stress and elastic modulus assessment of bulk-fill composites. J Appl Oral Sci 2019;27:e20180132. https://doi.org/10.1590/1678-7757-2018-0132.
[48] Costa T, Rezende M, Sakamoto A, Bittencourt B, Dalzochio P, Loguercio AD, et al. Influence of adhesive type and placement technique on postoperative sensitivity in posterior composite restorations. Oper Dent 2017;42:143–54. https://doi.org/10.2341/16-010-c.
[49] Balkaya H, Arslan S. A two-year clinical comparison of three different restorative materials in class ii cavities. Oper Dent 2020;45:E32–e42. https://doi.org/10.2341/19-078-c.
[50] Torres CR, Jurema AL, Souza MY, Di Nicoló R, Borges AB. Bulk-fill versus layering pure ormocer posterior restorations: a randomized split-mouth clinical trial. Am J Dent 2021;34:143–9.
[51] Rodrigues NS, de Souza LC, Cunha DA, Souza NO, Silva P, Santiago SL, et al. Postoperative sensitivity of composite replacement of amalgam restoration: a randomized clinical trial. Oper Dent 2022;47:481–91. https://doi.org/10.2341/19-295-c.
[52] Maghaireh GA, Albashaireh ZS, Allouz HA. Postoperative sensitivity in posterior restorations restored with self-adhesive and conventional bulk-fill resin composites: a randomized clinical split-mouth trial. J Dent 2023;137:104655. https://doi.org/10.1016/j.jdent.2023.104655.
[53] Hanzen TA, de Paula AM, Grokoski E, de Oliveira ILM, Arana-Gordillo LA, de Melo Monteiro GQ, et al. Glutaraldehyde-based desensitizer does not influence postoperative sensitivity and clinical performance of posterior restorations: a 24-month randomized clinical trial. Dent Mater 2023;39:946–56. https://doi.org/10.1016/j.dental.2023.08.179.
[54] Barceleiro MO, Tardem C, Albuquerque EG, Lopes LS, Marins SS, Poubel LA, et al. Can composite packaging and selective enamel etching affect the clinical behavior of bulk-fill composite resin in posterior restorations? 24-month results of a randomized clinical trial. J Appl Oral Sci 2023;31:e20220323. https://doi.org/10.1590/1678-7757-2022-0323.
[55] Durão MA, de Andrade AKM, do Prado AM, Veloso SRM, Maciel LMT, Montes M, et al. Thirty-six-month clinical evaluation of posterior high-viscosity bulk-fill resin composite restorations in a high caries incidence population: interim results of a randomized clinical trial. Clin Oral Investig 2021;25:6219–37. https://doi.org/10.1007/s00784-021-03921-9.
[56] Cieplik F, Hiller KA, Buchalla W, Federlin M, Scholz KJ. Randomized clinical split-mouth study on a novel self-adhesive bulk-fill restorative vs. a conventional bulk-fill composite for restoration of class II cavities - results after three years. J Dent 2022;125:104275. https://doi.org/10.1016/j.jdent.2022.104275.
[57] Loguercio AD, Ñaupari-Villasante R, Gutierrez MF, Gonzalez MI, Reis A, Heintze SD. 5-year clinical performance of posterior bulk-filled resin composite restorations: a double-blind randomized controlled trial. Dent Mater 2023. https://doi.org/10.1016/j.dental.2023.10.018.
[58] Schoilew K, Fazeli S, Felten A, Sekundo C, Wolff D, Frese C. Clinical evaluation of bulk-fill and universal nanocomposites in class II cavities: five-year results of a randomized clinical split-mouth trial. J Dent 2023;128:104362. https://doi.org/10.1016/j.jdent.2022.104362.
[59] Zander-Grande C, Amaral RC, Loguercio AD, Barroso LP, Reis A. Clinical performance of one-step self-etch adhesives applied actively in cervical lesions: 24-month clinical trial. Oper Dent 2014;39:228–38. https://doi.org/10.2341/12-286-c.
[60] Loguercio AD, Stanislawczuk R, Mena-Serrano A, Reis A. Effect of 3-year water storage on the performance of one-step self-etch adhesives applied actively on dentine. J Dent 2011;39:578–87. https://doi.org/10.1016/j.jdent.2011.06.005.

[61] Reis A, Dourado Loguercio A, Schroeder M, Luque-Martinez I, Masterson D, Cople Maia L. Does the adhesive strategy influence the post-operative sensitivity in adult patients with posterior resin composite restorations? A systematic review and meta-analysis. Dent Mater 2015;31:1052–67. https://doi.org/10.1016/j.dental.2015.06.001.
[62] Perdigão J, Araujo E, Ramos RQ, Gomes G, Pizzolotto L. Adhesive dentistry: current concepts and clinical considerations. J Esthet Restor Dent 2021;33:51–68. https://doi.org/10.1111/jerd.12692.
[63] Breschi L, Maravic T, Cunha SR, Comba A, Cadenaro M, Tjäderhane L, et al. Dentin bonding systems: from dentin collagen structure to bond preservation and clinical applications. Dent Mater 2018;34:78–96. https://doi.org/10.1016/j.dental.2017.11.005.
[64] Sezinando A, Perdigão J, Ceballos L. Long-term in vitro adhesion of polyalkenoate-based adhesives to dentin. J Adhes Dent 2017;19:305–16. https://doi.org/10.3290/j.jad.a38895.
[65] Loguercio AD, Bittencourt DD, Baratieri LN, Reis A. A 36-month evaluation of self-etch and etch-and-rinse adhesives in noncarious cervical lesions. quiz 35-7 J Am Dent Assoc 2007;138:507–14. https://doi.org/10.14219/jada.archive.2007.0204.
[66] Burrow MF, Tyas MJ. Clinical evaluation of three adhesive systems for the restoration of non-carious cervical lesions. Oper Dent 2007;32:11–5. https://doi.org/10.2341/06-50.
[67] Reis A, Loguercio AD. A 36-month clinical evaluation of ethanol/water and acetone-based etch-and-rinse adhesives in non-carious cervical lesions. Oper Dent 2009;34:384–91. https://doi.org/10.2341/08-117.
[68] Matos TP, Hanzen TA, Almeida R, Tardem C, Bandeca MC, Barceleiro MO, et al. Five-year randomized clinical trial on the performance of two etch-and-rinse adhesives in noncarious cervical lesions. Oper Dent 2022;47:31–42. https://doi.org/10.2341/20-103-c.
[69] Loguercio AD, Loeblein F, Cherobin T, Ogliari F, Piva E, Reis A. Effect of solvent removal on adhesive properties of simplified etch-and-rinse systems and on bond strengths to dry and wet dentin. J Adhes Dent 2009;11:213–9.
[70] Fukuda R, Yoshida Y, Nakayama Y, Okazaki M, Inoue S, Sano H, et al. Bonding efficacy of polyalkenoic acids to hydroxyapatite, enamel and dentin. Biomaterials 2003;24:1861–7. https://doi.org/10.1016/s0142-9612(02)00575-6.
[71] Loguercio AD, Muñoz MA, Luque-Martinez I, Hass V, Reis A, Perdigão J. Does active application of universal adhesives to enamel in self-etch mode improve their performance? J Dent 2015;43:1060–70. https://doi.org/10.1016/j.jdent.2015.04.005.
[72] de Andrade AK, Duarte RM, Medeiros e Silva FD, Batista AU, Lima KC, Pontual ML, et al. 30-Month randomised clinical trial to evaluate the clinical performance of a nanofill and a nanohybrid composite. J Dent 2011;39:8–15. https://doi.org/10.1016/j.jdent.2010.09.005.
[73] Sundfeld RH, Machado LS, Pita DS, Franco LM, Sundfeld D, Sundefeld ML, et al. Three-year clinical evaluation of class i restorations in posterior teeth. Effects of two adhesive systems. Compend Contin Educ Dent 2016;37:e1–4.
[74] Yazici AR, Antonson SA, Kutuk ZB, Ergin E. Thirty-six-month clinical comparison of bulk fill and nanofill composite restorations. Oper Dent 2017;42:478–85. https://doi.org/10.2341/16-220-c.
[75] Marquillier T, Doméjean S, Le Clerc J, Chemla F, Gritsch K, Maurin JC, et al. The use of FDI criteria in clinical trials on direct dental restorations: a scoping review. J Dent 2018;68:1–9. https://doi.org/10.1016/j.jdent.2017.10.007.
[76] Van Meerbeek B, Peumans M, Poitevin A, Mine A, Van Ende A, Neves A, et al. Relationship between bond-strength tests and clinical outcomes. Dent Mater 2010;26:e100–21. https://doi.org/10.1016/j.dental.2009.11.148.
[77] Cidreira Boaro LC, Pereira Lopes D, de Souza ASC, Lie Nakano E, Ayala Perez MD, Pfeifer CS, et al. Clinical performance and chemical-physical properties of bulk fill composites resin -a systematic review and meta-analysis. Dent Mater 2019;35:e249–64. https://doi.org/10.1016/j.dental.2019.07.007.
[78] Sekundo C, Fazeli S, Felten A, Schoilew K, Wolff D, Frese C. A randomized clinical split-mouth trial of a bulk-fill and a nanohybrid composite restorative in class II cavities: three-year results. Dent Mater 2022;38:759–68. https://doi.org/10.1016/j.dental.2022.04.019.
[79] van de Sande FH, Opdam NJ, Rodolpho PA, Correa MB, Demarco FF, Cenci MS. Patient risk factors' influence on survival of posterior composites. 78s-83s J Dent Res 2013;92. https://doi.org/10.1177/0022034513484337.
[80] Kopperud SE, Tveit AB, Gaarden T, Sandvik L, Espelid I. Longevity of posterior dental restorations and reasons for failure. Eur J Oral Sci 2012;120:539–48. https://doi.org/10.1111/eos.12004.
[81] Reis A, Loguercio AD, Favoreto M, Chibinski AC. Some myths in dentin bonding: an evidence-based perspective. J Dent Res 2023;220345221146714. https://doi.org/10.1177/00220345221146714.
[82] Heintze SD, Ilie N, Hickel R, Reis A, Loguercio A, Rousson V. Laboratory mechanical parameters of composite resins and their relation to fractures and wear in clinical trials-A systematic review. Dent Mater 2017;33:e101–14. https://doi.org/10.1016/j.dental.2016.11.013.
[83] Opdam NJ, van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, et al. Longevity of posterior composite restorations: a systematic review and meta-analysis. J Dent Res 2014;93:943–9. https://doi.org/10.1177/0022034514544217.
[84] van Dijken JWV, Pallesen U. Bulk-filled posterior resin restorations based on stress-decreasing resin technology: a randomized, controlled 6-year evaluation. Eur J Oral Sci 2017;125:303–9. https://doi.org/10.1111/eos.12351.
[85] Da Rosa Rodolpho PA, Rodolfo B, Collares K, Correa MB, Demarco FF, Opdam NJM, et al. Clinical performance of posterior resin composite restorations after up to 33 years. Dent Mater 2022;38:680–8. https://doi.org/10.1016/j.dental.2022.02.009.