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Effect of Dentin Moisture in Posterior Restorations Performed with Universal Adhesive: A Randomized Clinical Trial

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Clinical Relevance

Dentin moisture seems not to be important for the postoperative sensitivity or clinical performance of posterior bulk-fill composite restorations, when a universal adhesive was applied.

SUMMARY

Objectives: This double-blind, randomized clinical trial evaluated the influence of dentin moisture on postoperative sensitivity (POS), as well as, on clinical performance in posterior bulk-fill composite restorations, using a universal adhesive, until 12 months after clinical service.

Methods and Materials: In accordance with a split-mouth design, 45 patients received posterior restorations, restored with a bulk-fill resin

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http://doi.org/10.2341/20-215-C

composite (Filtek Bulk Fill, 3M Oral Care) and a universal adhesive used in etch-and-rinse mode (SBU; Single Bond Universal Adhesive), which were applied on dry or moist dentin, with a cavity depth of at least 3 mm. Three operators placed 90 Class I/Class II restorations. Patients were evaluated for spontaneous and stimulated POS in the baseline, and after 48 hours, 7 days, and at 6 and 12 months. In addition, secondary parameters (marginal discoloration, marginal adaptation, fracture, and recurrent caries) were evaluated by World Dental Federation (FDI) criteria after 7 days and at 6 and 12 months. Statistical analyzes were performed using the Chi-square, Fisher exact, Friedman, Kruskall–Wallis, and Mann–Whitney tests (α=0.05).

Results: No significant spontaneous and stimulated POS was observed when SBU was applied in dry and moist dentin (p>0.05). A significant and higher risk of spontaneous POS (20.0%; 95%CI 10.9-33.82 for dry dentin and 22.22%; 95%CI 12.54-36.27 for moist dentin) occurred up to 48 hours after restoration placement for the dry and moist dentin groups (p<0.02). However, the POS intensity was mild up to 48 hours with no significant difference between dry and moist dentin groups (p>0.79). When secondary parameters were evaluated, no significant differences between the groups were observed.

Conclusion: Dentin moisture did not influence POS in posterior bulk-fill composite restorations when associated with a universal adhesive applied in etch-and-rinse mode.

INTRODUCTION

Direct resin composite restorations in posterior teeth have increased worldwide,[1] either due to the prohibitions related to the use of mercury-based materials such as amalgam[2] or due to the increased aesthetic needs of the population.[3] In this sense, a recent literature review showed that composite resin restorations are considered as the material of choice in dental schools around the world for restoring occlusal and occluso-proximal cavities in permanent teeth.[4]

Unfortunately, several clinical studies indicated that reported postoperative sensitivity (POS) after posterior resin composite restorations remains a challenge in dentistry.[5,6] The POS is related to many factors, such as the cavity preparation procedure, adhesive approach, type of resin composite used, and placement technique.[7-11]

However, one of the most important factors related to the POS is the anecdotal clinical perception that use of phosphoric acid on dentin (when etch-and-rinse adhesives are applied) significantly increase the POS.[12] After etching and rinsing the dentin, the removal of the smear layer and the opening of the dentinal tubules increases the dentin permeability and their hydraulic conductance.[13] After the adhesive system application, if the resin monomers did not correctly infiltrate in the demineralized dentin, voids occurred in the hybrid layer. Several studies showed that voids frequently occurred when the dentin was kept dry after phosphoric acid etching.[14,15] These unfilled spaces may allow dentin fluid movement, especially under external stimuli. This, in turn, sensitizes the nerve endings in the dentin tubules, and it may cause POS.[16]

The wet-bonding technique is a very simple technique to improve adhesive infiltration.[16] In this technique, if the dentin demineralized matrix is kept fully hydrated by the clinician during the adhesive procedure, it will not cause a collapse of collagen fibrils, and free space will be available for resin infiltration.[14,15] Due to the intrinsically wet nature of dentin, it is necessary to use ethanol- or acetone-based adhesives.[15,17] Therefore, in the last three decades, wet-bonding has been the most popular technique to maintain an adequate degree of moisture for an etch-and-rinse adhesive.[18]

However, the popularity of wet-bonding techniques changed with the emergence of a new generation of adhesives called universal or multimode adhesives.[19,20] These adhesives are single-bottle adhesive systems similar to self-etch adhesives but include several acidic functional monomers, including 10-methacryloyloxydecyl dihydrogen phosphate (MDP) the most known among them. Functional monomers promote chemical bonding between the enamel and dentin and the indirect materials, such as glass ceramics, zirconia and metals, following a manufacturing of one product for application in different clinical situations.[21,22]

To guarantee that MDP provides stable and durable interfaces, all universal adhesives must contain water, because water is essential for ionizing the acidic functional monomers that make self-etching possible.[17,23] Although, the exact amount of water content of the universal adhesives was not disclosed by the manufacturers, several studies have already claimed that universal adhesives contain approximately 10–25 wt% of water.[24-27]

Due to the self-capacity of water to reexpand the air-dried and collapsed collagen mesh, for adhesive resin infiltration,[13] keeping the dentin dry or moist after the phosphoric acid application does not make a

difference in the universal adhesive's bonding quality, which was observed in several recently published *in vitro* studies.[25-28] Furthermore, recent clinical studies in noncarious cervical lesions have shown that universal adhesive systems are less sensitive to dry and moist dentin, because no significant differences in terms of clinical performance (retention, marginal adaptation, or discoloration) were observed when MDP-based universal adhesives were evaluated through 3 years of follow-up.[29-33] However, all previously published clinical trials were performed on noncarious cervical lesions. Unfortunately, there is a huge regional variability of permeability, cavity format, and dentin moisture in the dentin of posterior restorations compared to the dentin walls of noncarious cervical lesions.[34] Therefore, it is very important to evaluate the effect of degree of dentin moisture (dry or moist) and the subsequent effect on the clinical performance of an MDP-based universal adhesive in posterior resin composite restorations.

Thus, this double-blind, randomized clinical trial evaluated the influence of dentin moisture on spontaneous and stimulated POS in posterior resin composite restorations using a universal adhesive applied in etch-and-rinse mode, after 48 hours, 7 days, and 6 and 12 months. In addition, the marginal discoloration, marginal adaptation, fracture, and recurrence of caries were evaluated by World Dental Federation (FDI) criteria after 6 and 12 months. The null hypotheses were: (1) dentin moisture does not influence the spontaneous and stimulated POS evaluated at different times (48 hours, 7 days, and 6 and 12 months) when compared to a universal adhesive applied in etch-and-rinse mode on dry dentin. (2) Dentin moisture does not influence the other evaluated clinical parameters (marginal staining, fracture, marginal adaptation, and the recurrence of caries) at different times (6 and 12 months) when compared to a universal adhesive applied in etch-and-rinse mode and used on dry dentin.

METHODS AND MATERIALS

Ethics Approval and Protocol Registration

The State University of Ponta Grossa Ethics Committee on Involving Human Subjects reviewed and approved the protocol and consent form for this study (protocol 1.752.848). Written informed consent was obtained from all participants prior to starting the treatment. The experimental design followed the Consolidated Standards of Reporting Trials (CONSORT) statements.[35] This was a randomized, double-blind clinical trial, registered in the Clinical Trials Registry. The restorations were placed in the clinics of the State University of Ponta Grossa from October 2017 to December 2018. We informed all participants about the nature and the objectives of the study, but they were not aware of what tooth received the specific treatments under evaluation.

Participant Recruitment

Patients were recruited as they sought treatment in the clinics of the State University of Ponta Grossa School of Dentistry. Those who qualified for the study were recruited in the order in which they reported for the screening session, thus forming a convenience sample. Participants were recruited through written advertisements placed on the university's walls.

Sample Size

The sample size calculation was based on the absolute risk of spontaneous POS in posterior resin composite restorations. According to the literature, the risk of POS was approximately 30% in deep and large restorations.[7,9-11] Using an α of 0.05, a power of 80%, and a two-sided test, the minimal sample size was 45 restorations in each group (considering 20% loss) to detect a 20% difference between groups with the adhesive in dry dentin.

Eligibility Criteria

Two pretrained dentists examined 63 participants to check if the subjects met the inclusion and exclusion criteria (Figure 1). The evaluations were performed using an intraoral mirror, an explorer, and a periodontal probe. Participants had to be in good general health, at least 18 years old, and present at least 20 teeth under occlusion and at least two carious lesions and/or indication of replacement restorations (fracture, secondary caries, and temporary restoration) in different hemiarches with depths $\geq$ 3 mm, which were diagnosed using an interproximal radiograph. As much as possible, we always tried to select participants with two cavities in the same hemiarch, the same cavity type, and the same number of cavity surfaces to be restored.

Participants with dental prostheses, extremely poor oral hygiene, severe or chronic periodontitis, severe bruxism, parafunctional habits, continuous use of medication that may alter the perception of pain (analgesic, anti-inflammatory, etc.), and patients undergoing bleaching treatments or who were pregnant were excluded. Based on preestablished criteria, we selected 45 subjects who volunteered for this study (Figure 1).

Randomization Sequence Generation, Allocation Concealment, and Blinding

A staff member not involved in the research protocol performed the randomization process within subjects through http://www.sealedenvelope.com. Details of the allocated group were recorded on cards contained in sequentially numbered and sealed opaque envelopes. A staff member who was not involved in any of the clinical trial phases prepared these. The allocation assignment was revealed by opening the envelope on the day of the restorative procedure to guarantee the concealment of the random sequence and to prevent selection bias. The operator who implemented the interventions was not blinded to the procedure. However, the participants and the examiners were blinded to the group assignment.

Baseline Characteristics of the Selected Teeth and Calibration Procedure

The same three trained and calibrated dentists involved in the selection of participants carried out the restorative procedures. The features of the posterior restorations were evaluated prior to the placement of the restorations. Features, such as the presence of antagonist and attrition facets were observed and recorded. Patients were assessed for their risk of caries, and parafunctional habits, such as bruxism, for each patient were estimated by means of clinical and sociodemographic information, taking in account the incipient caries lesions and a history of caries and parafunctional habits.

Spontaneous preoperative sensitivity was evaluated prior to examination as well as the different preoperative sensitivity stimuli (air, cold, heat, vertical, and horizontal touch). To measure the sensitivity by air, air-drying was applied for 10 seconds from a dental syringe placed 2 cm from the surface of the tooth; the percussion sensitivity was measured with percussive load applied vertically on the occlusal aspect of the tooth and horizontally (vestibular area) on the buccal aspect of the tooth with the blunt end of a mouth mirror handle, as well as in the contralateral tooth; cold stimulation was conducted through the application of a swab with Endo Ice (Maquira, Maringá, PR, Brazil) applied to the vestibular face in the cervical region of the restored tooth; and heat stimulation was applied to the tooth surface with a gutta-percha stick (Dentsply, Sirona, Charlotte, NC, USA).[36]

Spontaneous preoperative sensitivity was evaluated through the intensity of tooth sensitivity measurement through the Visual Analogue Scale (VAS) and the NRS (Numerical Rating Scale). The VAS scale consists of a 10-cm linear scale with the words "no pain" at one end and "unbearable pain" on the other. The NRS consists of five verbal points with the 0 meaning "no pain" and 4 meaning "severe pain".

For the calibration procedure step, the study director placed one restoration for each group to identify all the steps involved in the protocol. Then, three operators placed another four restorations for each group under the supervision of the study director in a clinical setting. Any discrepancies of the restorative protocol were identified and discussed with the operator prior to starting the study. At this point, the operators were considered trained to perform the restorative procedures. The calibrated operators restored all teeth under the supervision of the study director.

Interventions: Restorative Procedure

The interventions were standardized by a detailed protocol, which is briefly summarized below. A preliminary dental prophylaxis of the tooth surface was performed with pumice and water in a rubber cup, with the aim of removing the salivary pellicle and any remaining dental plaque, followed by rinsing and drying. Using a shade guide, the proper shade of the resin composite was determined. Local anesthesia was applied with a 3% mepivacaine solution (Mepisv, Nova DFL, Rio de Janeiro, RJ, Brazil), and all restorations were placed under rubber dam isolation. The operators did not prepare any additional retention or bevel in the cavities.

All subjects received a minimum of two restorations, one from each experimental group, in different cavities previously selected according to the inclusion criteria. The cavity dimensions in millimeters (height, width, and depth) and the cavity geometry were also recorded. The cavity design was performed using a spherical diamond bur (#1013-1017; KG Sorensen, Barueri, SP, Brazil) mounted in a high-speed handpiece with an air–water spray. It was only applied for the removal of defective restorations or for the elimination of carious tissues (caries-infected dentin). No liner or base was used. For restoration of class II cavities, a sectional matrix system (Palodent, Dentsply Sirona) was preferentially used. However, circumferential matrix systems were used when a good adaptation could not be obtained with the sectional matrix system.

Then, an application of 34% phosphoric acid (Scotchbond Universal Etchant, 3M Oral Care, St. Paul, MN, USA) was conducted for 15 seconds in dentin/enamel, followed by rinsing with a dental syringe for 10 seconds. Afterward, in the groups assigned for dry dentin, all dentin surfaces were dried for 10 seconds at a distance of 2 cm between the tip of the air syringe and the dentin surface. At the end, the dentin surface was

Table 1: *Adhesive System and Resin Composite: Composition and Application Mode*

Adhesive System and Resin Composite	Composition/Batch Number[a]	Application in Etch-and-Rinse Mode		
Single Bond Universal Adhesive (3M Oral Care, St Paul, MN, USA)	1. Scotchbond Universal Etchant (643399): 34% phosphoric acid 2. Adhesive (691954): Methacryloyloxydecyl dihydrogen phosphate, phosphate monomer, dimethacrylate resins, hydroxyethyl methacrylate, methacrylate-modified polyalkenoic acid copolymer, filler, ethanol, water, silane, camphorquinone	Apply Etchant for 15 seconds. Rinse for 10 seconds.	Dry dentin: Air dry (10 seconds) to remove excess of water and keep dentin completely dry Wet dentin: Air dry (2-4 seconds) to remove only excess of water and keep dentin visible moist	Apply the adhesive for 20 seconds with vigorous agitation. Gently stream of air for 5 seconds. Light-cure for 10 seconds (1000 mW/cm^2)
Filtek Bulk Fill Posterior Restorative (3M Oral Care) Shade A2 and A3	Resin Matrix: AUDMA (urethane aromatic dimethacrylate)/ UDMA/1,12-dodecane-DMA (12-dodecane dimethacrylate) (N68566) Fillers: Combination of a non-agglomerated/ non-aggregated 20 nm silica filler, a non-agglomerated/ non-aggregated 4 to 11 nm zirconia filler, an aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles) and a ytterbium trifluoride filler consisting of agglomerate 100 nm particles; 76.5 wt%, 58.4 vol%. Photoinitiator: Camphorquinone	Insert in the cavity bulk increases of up to 4-5 mm in thickness, and light-cure each area of the surface of the restoration with 1000 mW/cm^2 for 30 seconds.		

[a] *According to the manufacturer's instructions.*

completely dry, without any signs of moisture. In the groups assigned for moisture dentin, only the excess water in the dentin surface was removed through air-drying for 2-4 seconds at a distance of 2 cm between the tip of the air syringe and the dentin surface. At the end, the entire dentin surface was shiny, because moisture was visible (Table 1).[29-31]

The Single Bond Universal Adhesive (SBU; 3M Oral Care, also known as Scotchbond Universal in some countries) was shaken, and a small drop was put in a microbrush (Cavibrush, FGM, Joinville, SC, Brazil). Then, the microbrush was rubbed onto the surface of the dentin under manual pressure, followed by thinning with gentle air-drying for 5 seconds. At the end, the entire surface was light cured (Radii Cal, SDI, Victoria, Australia) for 10 seconds (1000 mW/cm^2; Table 1). The resin composite Bulk Fill (3M Oral Care) was used in a single increment and photoactivated for 30 seconds (1000 mW/cm^2; Radii Cal, SDI, Victoria, Australia). After finishing the restorations, the occlusal adjustment was carried out, and followed by finishing and a final polishing with fine-grained diamond tips FF (KG Sorensen, Barueri, SP, Brazil) and polishing with rubber bowls (Astropol, Ivoclar Vivadent, Schaan, Liechtenstein).

Examination After Restorative Procedure

Spontaneous POS was the primary clinical outcome analyzed, and it was assessed at 48 hours, 7 days, and 6 and 12 months, using the VAS and NRS, as

Table 2: *World Dental Federation (FDI) Criteria Used for Clinical Evaluation (Hickel and others)*[37,38]

	Functional Properties				
	1. Fracture	**2. Marginal Adaptation**	**3. Contact Point/ Food Impact**	**4. Radiographic Exam**	**5. Patient View**
1. Clinically very good	Restoration retained, no fractures/ cracks	Harmonious outline, no gaps, no discoloration	Normal contact point (floss or 25 µm)	No pathology, harmonious transition between restoration/ tooth	Entirely satisfied
2. Clinically good (after correction very good	Small hairline crack	Marginal gap (50 µm) or small marginal fracture removable by polishing	Slightly too strong but no disadvantage	Acceptable cement excess present or positive/negative step present at margin <150 µm	Satisfied
3.Clinically sufficient / satisfactory (minor shortcomings with no adverse effects but not adjustable without damage to the tooth)	Two or + larger hairline cracks and/ or chipping (not affecting the marginal integrity)	Gap < 150 µm not removable or several small enamel or dentin fractures	Slightly too weak, no indication of damage to tooth, gingivae or periodontal structures	Marginal gap < 200 µm; negative steps visible with no adverse effects. Noticed or poor radiopacity of filling material	Minor criticism due to aesthetic shortcomings; some lack of chewing comfort or; Time consuming procedure and/or similar; No adverse clinical effects
4. Clinically unsatisfactory (repair for prophylactic reasons)	Chipping fractures which damage marginal quality; bulk fractures with or without partial loss (- than ½ of the restoration)	Gap > 250 µm or dentin/ base exposed; chip fracture damaging margins or notable enamel or dentin wall fracture	Too weak (100 µm metal blade can pass) and possible damage (food impaction). Repair possible	Marginal gap >250 µm; cement excess accessible but not removable or; negative steps >250 µm and repairable	Desire for improvement (reshaping of anatomic form or refurbishing etc.)
5. Clinically poor (replacement necessary)	Partial or complete loss of restoration	Filling is loose but in situ	Too weak and/ or clear damage (food impaction) and/or pain/ gingivitis)	Secondary caries, large gaps; apical pathology or; Fracture/loss of restoration or tooth	Completely dissatisfied and/oral adverse effects including pain
Acceptable or not acceptable (n, % and reasons			Functional criteria		

previously described. The stimulated POS was also evaluated (secondary outcomes) at 7 days, 6 months, and 12 months. At each time, the restoration was evaluated for sensitivity caused by air application, vertical and horizontal percussion, and cold and heat stimulation, as described in the initial evaluation. The

Table 2: *World Dental Federation (FDI) Criteria Used for Clinical Evaluation (Hickel and others) (cont.)*[37,38]

	Esthetic Properties		Biological Properties	
	6. Marginal Staining	**7. Color Stability and Translucency**	**8. Postoperative (Hyper-) Sensitivity**	**9. Recurrence of Caries**
1. Clinically very good	Good color match No difference in shade and translucency	No marginal staining	No hypersensitivity	No secondary or primary caries
2. Clinically good (after correction very good	Minor deviations	Minor marginal staining (under dry conditions) is present	Low hypersensitivity for a limited period of time	Very small and localized demineralization. No operative treatment required
3.Clinically sufficient / satisfactory (minor shortcomings with no adverse effects but not adjustable without damage to the tooth)	Clear deviation but acceptable. Does not affect aesthetics: (more opaque; translucent; dark or bright)	Moderate marginal or surface staining not noticeable from a speaking distance	Premature/slightly more intense or delayed/ weak sensitivity; no subjective complaints, no treatment needed	Larger areas of demineralization, but only preventive measures necessary (dentin not exposed)
4. Clinically unsatisfactory (repair for prophylactic reasons)	Localized - clinically unsatisfactory but can be corrected by repair (too opaque; translucent; dark or bright)	Localized marginal staining is present and not removable by polishing. The aesthetic properties of the dentition are affected.	Premature/ very intense; extremely delayed/weak with subjective complaint or negative Sensitivity Intervention necessary but not replacement	Caries with cavitation (localized and accessible and can be repaired
5. Clinically poor (replacement necessary)	Unacceptable, replacement necessary	Generalized/ profound marginal discoloration is present. Replacement is necessary	Very intense, acute pulpitis or non-vital. Endodontic treatment is necessary	Deep secondary caries or exposed dentin
Acceptable or not acceptable (n, % and reasons	Aesthetic criteria		Biological criteria	

final values of spontaneous POS were divided into two categories: percentage of patients who reported POS at least once during treatment (absolute risk) and overall POS intensity over 48 hours, 7 days, 6 months, and 12 months. Furthermore, in the 6- and 12-month return visits, the clinical outcomes, such as marginal staining, fracture, marginal adaptation, and recurrence of caries, were evaluated using the World Dental Federation (FDI)[37, 38] criteria (Table 2).

Statistical Analysis

The statistician was blinded to the type of study groups, and the statistical analyses followed the intention-to-treat protocol according to CONSORT suggestions.[35] Participants who experienced at least one event of POS in each evaluation time (48 hours, 7 days, and 6 and 12 months) were considered as have POS. The risk of spontaneous and stimulus (air, cold, heat, horizontal, and vertical percussion) POS between the groups in each time were compared using the Chi-square test and

Fisher exact test. The risk of spontaneous POS among different times for each group were compared with the Friedman repeated measures analysis of variance by rank.

The intensities of spontaneous POS in each group for different evaluation times (48 hours and 7 days) were evaluated using the Friedman repeated measures analysis of variance by rank and Mann–Whitney tests (VAS) and one-way repeated measures, and Tukey test (NRS). The intensity of spontaneous POS in each time for both the groups was evaluated using the Mann–Whitney test (VAS) and *t*-test for dependent variables (NRS).

Additionally, the risks of POS according to cavity characteristics were compared using the Chi-square test. Statistical analyses for each item and overall parameter (FDI criteria) were performed. The differences in the ratings of the two groups and each group at baseline, after 6 months and after 12 months were tested with the Wilcoxon rank sum test repeated measures analysis of variance by rank (α=0.05). In all statistical tests, the alpha was set at 5% (Statistica for Windows 7.0, StatSoft Inc, Tulsa, OK, USA).

Characteristics of the Participants and Cavities

No modifications were performed in the experimental protocols, and they were implemented exactly as planned. Twenty-seven women and 18 men participated in this study. The mean age of the participants was 30.0 ± 8.20 years. Ninety restorations were placed, 45 for each group. The restorations were distributed into class I (75) and class II (15) cavities (Table 3). The homogeneity of cavity characteristics between the study groups can be seen in Table 3. Seven participants did not attend the 6 and 12 months recall, because they moved to another city (Figure 1).

RESULTS

POS Evaluation

A higher risk and intensity of spontaneous POS for both groups occurred up to 48 hours after restoration placement, with statistically significant differences for other evaluation times (Table 4, p<0.02; Table 5, p>0.01) However, no statistically significant difference was found for the risk and intensity of spontaneous POS in each period when dry and moist dentins were compared (Tables 4 and 5; p>0.58). It is noteworthy that, in a 1-week evaluation period, the intensity of spontaneous POS was considered mild when measured through the VAS and NRS scales (Table 5).

After 1 week, 6 months, and 12 months, a few participants reported experiencing stimulus POS, with

Table 3: *Characteristics of the Research Subjects, Dental Arches and Cavities Per Group*

Characteristics of Research Subjects		
Gender Distribution	**Number of Subjects**	
Male	18	
Female	27	
Age Distribution (years)		
20-29	29	
30-39	10	
40-49	4	
>49	2	
Characteristics of Dental Arches and Cavities	**Number of Restorations**	
Presence of Antagonist	**Dry Dentin**	**Moist Dentin**
Yes	44	45
No	1	0
Attrition Facet		
Yes	3	3
No	42	42
Arch Distribution		
Maxillary	19	20
Mandibular	26	25
Cavity Depth		
3 mm	16	14
4 mm	21	21
>4 mm	8	10
Black Classification		
I	37	38
II	8	7
Number of Restored Surfaces		
1	35	38
2	10	7
3	0	0
4	0	0
Reasons for Restoration		
Marginal fracture	1	0
Esthetic reasons	18	17
Marginal discoloration	0	0
Bulk fracture	7	8
Primary/Secondary caries lesion	19	20

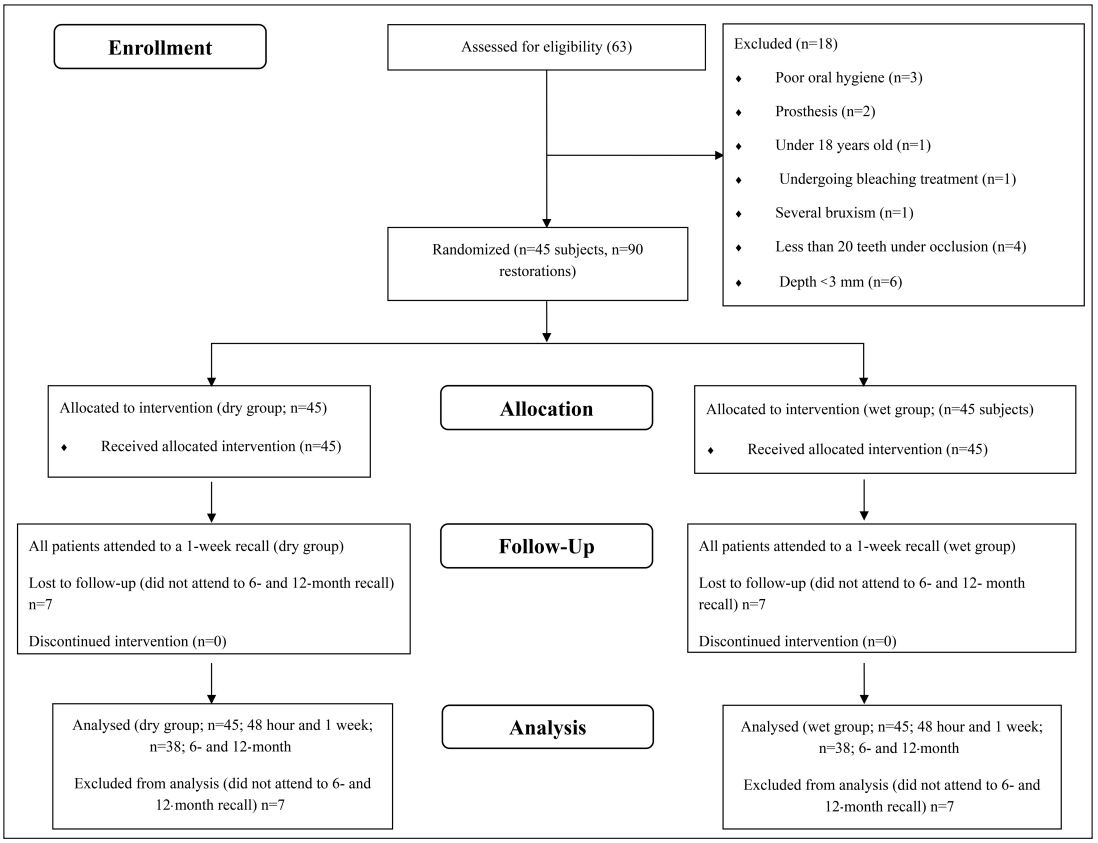

Figure 1. *Participant flow diagram in the different phases of the study design. Np, number of participants; Nr, number of restorations.*

no statistically significant difference when dry and moist dentin were compared (Table 6; $p>0.59$). However, no participants needed to take oral medication to reduce POS. When the cavities' characteristics were evaluated, the type of cavity, the number of surfaces, and the cavity depth did not show any significant differences (Table 7; $p>0.58$).

Other Clinical Parameters

Fourteen restorations showed small marginal discrepancies after the 12-month recall, with no statistical difference between the dry and moist dentin groups (Table 8; $p=1.0$). Five restorations showed some marginal fractures after the 12-month recall,

Table 4: *Number of Patients with Spontaneous POS/Total During 12 Months of Follow-up, as well as the Absolute Risk of POS*

Time Assessment		Dry Dentin[a]		Moist Dentin		*p*-value[b]
		Number of Patients with POS/Total	Absolute Risk (95%CI)	Number of Patients with POS/Total	Absolute Risk (95%CI)	
Preoperative	Baseline	1/45	2.22(0.39-11.57) A	3/45	6.67 (2.29-17.86) a	0.6
Postoperative	Up to 48 hours	9/45	20(10.9-33.82) B	10/45	22.22 (12.54-36.27) b	1.0
	7 days	3/45	6.67(2.29-17.86) A	2/45	4.44 (1.23-14.83) a	1.0
	6 months	2/38	5.26(1.46-17.29) A	0/38	0.00 (0.00-9.18) a	1.0
	12 months	2/38	5.26(1.46-17.29) A	1/38	0.00 (0.47-13.49) a	1.0

[a]*Different uppercase (dry dentin) and lowercase letters (moist dentin) indicate significant differences among time assessment (Friedman test;* p<*0.05).*
[b]*Chi-square or Fisher exact test (*p<*0.05).*

Table 5: *Intensity of Spontaneous POS Experienced by Patients During 7 Days of Follow-Up*

Time Assessment	Visual Analogue Scale[a]		*p*-value[c]	Numerical Rate Scale[b]		*p*-value[c]
	Dry Dentin	Moist Dentin		Dry Dentin	Moist Dentin	
Up to 48h	5 (4.7) B	3.5 (2-5) B	0.62	5.2 (2.9) b	3.8 (2.17) b	0.54
7 days	1 (1.2) A	1 (1-2) A	1.0	1.1 (1.1) a	1.2 (1.3) a	1.0

[a]*Mean and standard deviation; different lowercase letters indicate significant differences among time assessment (1-way repeated measures ANOVA and Tukey test;* p*<0.05).*

[b]*Median and interquartile range; different uppercase letters indicate significant differences among time assessment (Friedman test and Mann–Whitney test;* p*<0.05).*

[c]*Chi-square or Fisher exact test (*p*<0.05).*

with no statistical difference between the groups (Table 8; p=0.72). Five restorations showed some marginal discolorations after the 12-month recall. Once again, no statistical difference between dry and wet dentin groups was observed (Table 8; p=0.45). No restorations had recurrent caries at the 12-month recall (Table 8; p=1.0).

DISCUSSION

The present randomized clinical trial evaluated POS, as well as the clinical performance of posterior bulk-fill resin composite restorations, associated with a universal adhesive applied in the etch-and-rinse mode in dry and moist dentin. The results of the present study showed that keeping the demineralizing dentin dry or moist did not significantly increase the spontaneous and stimulated POS in resin composite posterior restorations, leading us to accept the first null hypothesis. To the extent of the authors' knowledge, this is the first study that evaluated the effect of dentin moisture on the clinical performance of resin composite in posterior restorations using a universal adhesive.

Several *in vitro* studies have shown that it is necessary to keep the dentin moist to achieve a proper adhesive infiltration in the demineralized dentin and, consequently, allow adequate sealing and high immediate bond strength values.[13-16] On the other hand, low bond strength values were achieved when adhesive systems were applied in dry dentin, mainly

Table 6: *Number of Patients who Experienced Provoked Pre- and Postoperative/Total to Different Stimulus in the Baseline and 7 Days Follow-Up*

Time Assessment/Stimulus		Dry Dentin		Moist Dentin		*p*-value[a]
		Number of Patients with POS/Total	Absolute Risk	Number of Patients with POS/Total	Absolute Risk	
Preoperative	Air	1/45	2.22 (0.30-11.57)	2/45	4.44 (1.23-14.83)	1.0
	Cold	25/45	55.56 (4118-6906)	26/45	57.78 (43.3-71.03)	0.83
	Heat	4/45	8.89 (3.51-20.73)	5/45	11.11 (4.34-23.5)	0.97
	Horizontal percussion	2/45	4.44 (1.23-14.83)	1/45	2.22 (0.30-11.57)	1.0
	Vertical percussion	3/45	6.67 (2.29-17.86)	4/45	8.89 (3.51-20.73)	0.69
Postoperative (7 days)	Air	2/45	4.44 (1.23-14.83)	1/45	2.22 (0.30-11.57)	1.0
	Cold	8/45	17.78 (9.29-31.33)	10/45	22.22 (12.54-36.27)	0.59
	Heat	2/45	4.44 (1.2-14.83)	1/45	2.22 (0.30-11.57)	1.0
	Horizontal percussion	1/45	2.22 (0.30-11.57)	2/45	4.44 (1.23-14.83)	1.0
	Vertical percussion	2/45	4.44 (1.23-14.83)	2/45	4.44 (1.23-14.83)	1.0

[a]*Chi-square or Fisher exact test (*p*<0.05).*

Table 7: *Number of Patients (%) who Experienced Spontaneous Postoperative Sensitivity up to 48 Hours Follow-up According to the Characteristics of Dental Arches and Cavities*

Characteristics	Number of Sensitive Teeth (%)		*p*-value[a]
	No	Yes	
Cavity Depth			
3 mm	25 (83.3)	5 (16.6)	0.58
More of 3 mm	46 (76.6)	14 (23.4)	
Black Cavity			
Class I	59 (78.6)	16 (21.4)	1.0
Class II	12 (80)	3 (20)	
Number of Restored Surfaces			
1 or 2 faces	71 (78.8)	19 (21.11)	1.0
3 or 4 faces	0	0	

[a]*Chi-square test and Fisher exact test.*

because there was shrinkage of collagen fibrils after the drying procedure.[13-16]

However, universal adhesives seemed to have a different behavior when applied in dry and moist dentin.[25,27,28,39,40] Universal adhesives can be used as a self-etch system, and the addition of water in their composition is important, because it ionizes the acidic groups, allowing the formation of hydronium ions, which etch hydroxyapatite.[41] The water content of the universal adhesives is strongly related to the pH, because

Table 8: Number of Evaluated Restorations for Dry and Moist Dentin Classified According to the World Dental Federation (FDI) Criteria (Hickel and others)[37,38]

FDI Criteria	Score[a]	Baseline		6 Months		12 Months	
		Dry	Wet	Dry	Wet	Dry	Wet
Marginal Adaptation	VG	45	45	36	38	32	30
	GO	—	—	1	—	4	6
	SS	—	—	1	—	2	2
	UN/PO	—	—	—	—	—	—
Marginal Staining	VG	45	45	32	36	35	36
	GO	—	—	5	1	3	2
	SS	—	—	1	1	—	—
	UN/PO	—	—	—	—	—	—
Fractures	VG	45	45	37	36	36	35
	GO	—	—	1	2	2	3
	SS	—	—	—	—	—	—
	UN/PO	—	—	—	—	—	—
Recurrence of Caries	VG	45	45	38	38	38	38
	GO	—	—	—	—	—	—
	SS	—	—	—	—	—	—
	UN/PO	—	—	—	—	—	—

[a]*VG, clinically very good; GO, clinically good; SS, clinically sufficient/satisfactory; UN, clinically unsatisfactory; PO, clinically poor.*

the water is essential for ionizing the acidic functional monomers, thus making self-etching possible.[17,41]

According to the manufacturer, SBU contains approximately 10% of water.[42] Perdigão and others[39] were the first to evaluate the effect of dry and moist dentin on the performance of SBU. The authors showed that the ultramorphology evaluation of the adhesive–dentin interface observed similar hybrid layer formation when SBU was applied in dry or moist dentin. The authors speculated that the water contained in SBU may be able to plasticize the collapsed collagen network, allowing for re-expansion and reopening of the interfibrillar spaces for the infiltration of resin monomers.[43] These results were recently confirmed through several studies.[25,27,28] For instance, Choi and others[25] and Tsujimoto and others[28] showed that the immediate bond strength and bond fatigue strength of SBU did not show any significant difference when dentin was kept dry or moist.[25,28]

In addition, a second component of SBU, the presence of polyalkenoic acid copolymer, could be partially responsible for the similar clinical results observed in the present study. Actually, according to Sezinando and others[44], the presence of polyalkenoic acid copolymer in the SBU showed better immediate and 6-month bond strength results, when compared to an experimental SBU without this component. However, according to the manufacturer, the use of polyalkenoic acid copolymer provides a better moisture stability.[45,46] Therefore, we hypothesized that, due to the presence of polyalkenoic acid copolymer in the SBU, this adhesive is less sensitive to moisture variations, when dry or moist dentin conditions were simulated,[45,46] as occured in the present study. Future clinical studies need to be done to confirm this hypothesis.

All these characteristics of SBU help to explain the similarity of immediate POS, as well as POS after several times of evaluation, when the universal adhesive was applied in the dry or moist dentin. However, it's important to mention that the spontaneous and stimulus POS was very low after 1 week, as previously demonstrated in recent clinical studies that evaluated the same commercial brand.[47,48] These results agree with a recent published meta-analysis of clinical studies,[12] indicating that POS generated immediately after placement of a restoration appears to be the result of trauma produced by restorative procedures, but usually this problem disappears after 1 week.[10,47]

The percentage of POS in the present study was higher to that compared to a nonrandomized clinical study run by Guggenberger and others.[49] However, that data was only published as an abstract, which prevents us from evaluating the methodology and the underlying risk of bias of the study. Several important technical details (the type of cavity restored, resin composite, rubber dam use, finishing, and polishing procedure, etc) and study features (randomization, allocation concealment, blinding, outcome measurement, management of missing data, publication of the study protocol, etc) are not available for evaluation. All these characteristics are likely responsible for the differences between the present results and the results reported in that abstract.

Usually, the POS measured by randomized and independent clinical trials [10,47,48] are higher than the percentage of POS measured by the studies conducted by manufacturers. The risk of POS sensitivity of bulk-fill composites, when associated to universal adhesives in randomized clinical trials, are quite variable in the literature. For instance, Tardem and others[47] and Yazici and others[50] showed lower rates of POS (2%-4%) than the present study. On the other side, the results of the present study are similar to Costa and others[10] and Afifi and others,[51] as they reported risk rates of 19% and 26%, respectively. Several methodological differences could explain these different results. Reis and others,[12] in a systematic review of POS in posterior restorations, observe a great variation among the way researchers assess the POS. This fact makes difficult the comparison between results of difference randomized clinical trials, and efforts need to be done to standardize the measurement of POS in posterior restorations.

It is worth mentioning that the enamel was also kept wet in the moist dentin group. In the past, dentists were taught to dry enamel vigorously after rinsing off the acid etchant in order to check for an adequately etched aspect of enamel.[36] This was not a concern when a universal adhesive was used, because, even with dry or moist enamel, some studies showed that there are not differences in terms of immediate and long-term bond strength as well as bond fatigue strength with the enamel.[27,28] Actually, no significant differences in terms of marginal discrepancies were observed at the 12-month follow-up when enamel or dentin margins were kept dry or moist, as well as other parameters, leading the authors to partially accept the second null hypothesis.

Furthermore, no significant difference was observed when dry and moist dentin were compared after 6 and 12 months of clinical evaluation, when other clinical parameters (fracture and recurrence of caries) were compared, leading the authors to partially accept the second null hypothesis. The present and previous studies indicate that the use of a bulk-fill resin composite could be considered an interesting alternative to restore posterior teeth. Unfortunately, the results of the present study are difficult to compare

with the previous literature, because this is the first study to evaluate the effect of dentin moisture on the clinical performance of a universal adhesive associated with a bulk-fill composite. However, some studies showed similar clinical performance when evaluating SBU applied in moist dentin in posterior restorations in comparison with the present ones.[47,48]

In general, the results of the present study in posterior resin composite restorations are similar to clinical studies of noncarious cervical lesions when SBU was evaluated.[29-31] In these studies, no significant clinical differences were observed when universal adhesive systems were applied in the etch-and-rinse mode in dry and moist dentin for 3 years after follow-up.[29-31] Despite all clinical differences, the results of the present study are in agreement with previous ones showing excellent clinical performances of SBU when posterior restorations, as performed in the present study, are compared with noncarious cervical restorations in terms of morphological and physiological differences.[34,50]

Regarding the characteristics of the cavities, it was possible to show that the risk of spontaneous POS was not correlated with the complexity of the restoration (class I or II and the number of restored surfaces), which was previously observed in several studies.[7,9,51] Although it is expected that more extensive cavities (cavities with more surfaces involved) showed more POS when compared with more simple cavities, there is not a consensus in the literature,[7,9,51] because a fewer number of restorations has been evaluated. Related to the cavity depth, the same controversial results were found.[47,52] Future systematic reviews of clinical studies in posterior restorations need to be evaluate the effect of these variables (number of restored surfaces and cavity depth) to confirm the hypothesis.

There are some limitations in the present clinical study. Only short-term (6- and 12-month) follow-up results were described. Future long-term clinical evaluation needs to be done to confirm the effect of dry or moist dentin on other clinical parameters (marginal adaptation, marginal discoloration, fracture, and recurrence of caries, among others). In this study, only a universal adhesive was evaluated. Unfortunately, as each universal adhesive contains a specific composition, these results could not be extrapolated for all universal adhesives, specifically those with less water in their compositions.[25,27,28] Similarly, some studies showed that, if an over-wet dentin was simulated, the adhesive performance of SBU was affected.[26,53] However, the authors believe that the results of the present study will encourage researchers to investigate the same concept for other universal adhesive systems, and then a body of evidence will be produced around the concept of wet/dry dentin bonding for universal adhesives. Therefore, to increase the external validity of the concept herein demonstrated for other adhesive systems, other randomized clinical trials are recommended.

CONCLUSIONS

The moisture of dentin did not influence POS or the clinical performance in posterior bulk-fill composite restorations when associated with an MDP-containing universal adhesive applied in etch-and-rinse mode.

Acknowledgements

The authors acknowledge Mohamed Mahmoud Bazeed, associate professor of Oral Medicine and Periodontology Department, Faculty of Dentistry, Mansoura University, Egypt, for performing thescaling procedures in this study.

Regulatory Statement

The local Ethics Committee on Involving Human Subjects reviewed and approved the protocol and consent form for this study (State University of Ponta Grossa). The approval code issued for this study is 1.752.848. This was a randomized, double-blind clinical trial, registered in the Clinical Trials Registry (REBEC) under identification number RBR-83CD7J.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 10 April 2021)

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