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Randomized Prospective Clinical Trial of Class II Restorations Using Low-shrinkage Flowable Resin Composite

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Clinical Relevance

Class II restorations using low-shrinkage resin composites showed satisfactory clinical performance after one year.

SUMMARY

Purpose: The aim of this prospective, randomized, split-mouth clinical trial was to evaluate postoperative sensitivity, clinical performance, and interproximal contacts after using different restorative systems.

Methods and Materials: Fifty-three subjects each received three class II restorations according to the restorative systems: conventional resin composite (PA: Peak Universal+Amelogen Plus, Ultradent), low-shrinkage flowable and nanoparticulate resin composites (ABF: Adper Single Bond 2+Filtek Bulk Fill Flow+ Filtek Z350XT, 3M ESPE), and low-shrinkage flowable and microhybrid resin composites (XST: XP Bond+SDR+TPH3, Dentsply). Postoperative sensitivity was assessed at 24 hours, seven days, 90 days, and six months. The clinical performance and interproximal contacts were evaluated at baseline, six months, and one year. Friedman, Wilcoxon, Kruskal-Wallis, and Mann-Whitney tests were used to evaluate postoperative sensitivity and interproximal contacts. The equality test of two proportions and logistic regression analysis were used to assess the clinical performance.

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Results: No statistically significant differences were observed among groups for postoperative sensitivity. The highest spontaneous sensitivity was reported at 24 hours. ABF was the only group that did not present a reduction in cold sensitivity. Color, marginal discoloration, and superficial staining showed differences among the groups. XST did not show superficial staining after one year. No differences were observed among groups in relation to interproximal contacts. XST resulted in the loss of interproximal contact after one year.

Conclusions: Different types of restorative systems do not influence postoperative sensitivity; however, ABF maintained cold sensitivity over time. Marginal discoloration occurred for all groups but occurred earliest for PA. XST presented a reduction of interproximal contact after one year of evaluation.

INTRODUCTION

Resin composites have increased in popularity in the clinical practice of dental professionals. The replacement of amalgam restorations with resin composite has been frequent, especially for esthetic reasons.[1] Despite the development of adhesive and restorative materials, posterior resin composite restorations still require extreme technical accuracy for their best performance. The use of incremental techniques, combined with photoactivation protocols, makes the restorative procedure relatively time consuming. Nevertheless, this care has been determined as essential for achieving restorative success.[2]

Posterior restorations, especially those involving proximal surfaces, still represent a challenge for the dental professional when re-establishing the contour and interproximal contact to resemble those of natural teeth[3] since the most common restorative failures are observed in this region.[4] Polymerization shrinkage stress is one of the causes of these failures, generating tension at the adhesive interface and compromising the bonding integrity over time.[5] In addition, polymerization stresses make cavity margins more susceptible to leakage and the development of carious lesions.[6]

Therefore, there is a growing tendency to use materials that generate lower stress at the restorative interface[7] while allowing restorations to be performed in a considerably shorter time with the advantage of reducing the technical sensitivity of the operative technique. Low-shrinkage flowable resin composites present a main advantage of minimal shrinkage stress during polymerization, with a high level of flow in the cavity, to facilitate handling of the material.[7] These materials are presented as a restorative alternative for class II cavities because they can quickly replace lost dental tissue by inserting single increments of up to 4 mm thick.[8-10]

Clinical studies with conventional resin composites indicate that up to 30% of patients report some discomfort or pain after receiving a restoration in posterior teeth, which is more common in class II restorations.[11,12] This sensitivity has been attributed to the stresses caused by the contraction of the resinous restorative material, leading to possible failures of marginal sealing,[13,14] which may favor the movement of fluids in the dentin-pulp complex or cause pulp injury.[15]

Currently, there are a few randomized clinical trials in the literature that have evaluated low-shrinkage resin composites with regard to the occurrence of postoperative sensitivity,[16,17] clinical performance of the material,[17-19] and maintenance of interproximal contact.

Thus, the objective of this study was to evaluate postoperative sensitivity, clinical performance, and interproximal contact after the placement of direct resin composite restorations in class II cavities, using three different restorative strategies. The null hypotheses tested were that there would be no difference among the three restorative systems at each evaluation period for the clinical parameters described above and that there would be no differences for the same restorative strategy at the different evaluation periods.

METHODS AND MATERIALS

Study Design

This clinical trial was a prospective, randomized, double-blind (volunteers and examiners), and split-mouth model. It was carried out after gaining approval from the local ethics committee (approval code: 1,235,100), and it was registered (#RBR-3gg3mg) and conducted according to CONSORT guidelines (Figure 1). Three restorative systems were used: conventional resin composite - considered the control group (PA: Peak Universal+Amelogen Plus, Ultradent, South Jordan, UT, USA), low-shrinkage flowable and nanoparticulate resin composites (ABF: Adper Single Bond 2+Filtek Bulk Fill Flow+Filtek Z350XT, 3M ESPE, St Paul, MN, USA), and low-shrinkage flowable and microhybrid resin composites, (XST: XP Bond+SDR+TPH3, Dentsply,

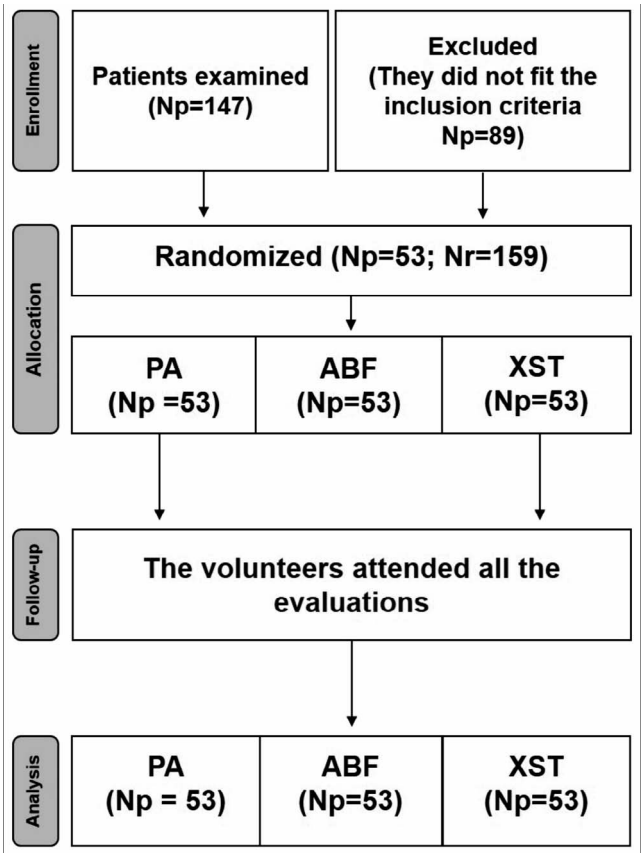

Figure 1. *Flowchart of patients. Np, number of patients; Nr, number of restorations.*

Milford, DE, USA). The two last restorative systems were considered the test groups.

Patient Selection

The sample power for two proportions, when considering 95% success achieved for the control group and 80% for the test group, indicated that an experimental sample with 159 restorations had a high power of 98.3%.

The following inclusion criteria were used: patients presenting at least three unsatisfactory class II restorations that were at least 3 mm deep in a vital permanent premolar or molar of the maxilla or mandible with an adjacent tooth, patients who were at least 18 years old, patients with good periodontal health, and patients with no clinical history of allergies to dental products. The exclusion criteria were the following: pregnant or lactating women, patients receiving orthodontic treatment, a tooth without an antagonist, active and untreated periodontal disease, endodontically treated teeth, dental mobility, history of previous tooth sensitivity, or subjects undergoing any kind of treatment using analgesic or anti-inflammatory drugs.

Fifty-three subjects were selected from the local undergraduate clinic, and patients were submitted to clinical and radiographic examination after signing the informed consent form.

Calibration and Randomization

Two calibrated operators (residents), with clinical experiences of 19 years and one year, were trained by a faculty member specializing in restorative dentistry to perform the restorative procedures. For calibration, each operator performed two restorations for each group from patients who were not selected for the research. The operators were identified on the procedure sheets. Visible plaque index (VPI), gingival bleeding index (GBI), and the decayed, missing, and filled teeth (DMFT) index were assessed at baseline. The subjects then received oral hygiene instructions, and initial photographs were taken.

All subjects received local anesthesia prior to restorative procedures. The randomization was performed by putting numbers in a sealed envelope and drawing which restorative procedure would be performed on each of the selected teeth. Each subject received three restorations, one from each group.

Restorative Procedures

The cavity preparations were performed using spherical diamond burs (#1015-1017, KG Sorensen, Barueri, Brazil) that were replaced after every three procedures. When there was carious tissue, smooth spherical carbide burs (#1/2-4, Dentsply Maillefer, Ballaigues, Switzerland) were also used in a slow speed hand piece.

Prophylaxis with pumice and water was carried out, and rubber dam isolation was performed in all restorations. In order to evaluate the depth of the preparation in mm, a periodontal probe was used (#6 Satin Steel Handle, Hu-Friedy, Chicago, IL, USA) to measure the greatest depth of the preparation. This was done to limit the use of the low-skrinkage resin composites to the maximum thickness of 4-mm depth as well as to preserve 2 mm of space for inserting the covering resin on the occlusal surface. This measurement was performed in all preparations, even in those that would receive the restorations using the incremental technique.

Then 35% phosphoric acid gel (Ultra-Etch, Ultradent) was used for 30 seconds on enamel and 15 seconds on dentin. Thereafter, the preparation was

Table 1: *Products (Material, Manufacturer, Composition, and Mode of Application) Used in This Study*

Group	Material	Manufacturer	Composition	Application
Control PA	Peak Universal	Ultradent (South Jordan, UT, USA)	Ethyl alcohol and 2-hydroxyethyl methacrylate	Dentin was dried, and the adhesive was applied with a microbrush by rubbing on the cavity for 10 s. Adhesive was air-dried for 10 s and photoactivated for 10 s.
	Amelogen Plus		Organic matrix: Bis-GMA, TEGDMA. Filler: silica dioxide and silicate particles (76% wt)	Oblique 2-mm increments were inserted and photoactivated for 20 s. The last increment was photoactivated for 40 s.
Test ABF	Adper Single Bond 2	3M ESPE (St Paul, MN, USA)	Water, ethanol, Bis-GMA, HEMA, UDMA, bisphenol A glycerolate, silica nanofillers treated with acid copolymer, dimethacrylate	Dentin was left slightly moist. The adhesive was applied with a microbrush and air-dried for 5 s. A second layer of the adhesive was applied and air-dried for 5 s. Photoactivation was performed for 20 s.
	Filtek Bulk Fill Flow		Organic matrix: Bis-GMA, Bis-EMA, UDMA, procrylat. Filler: ytterbium trifluoride filler with a range of particle sizes from 0.1 to 5.0 microns and zirconia/silica with a particle size range of 0.01 to 3.5 μm (64.5% wt)	A single increment was inserted in the cavity without submerging the tip of the syringe into the material already dispensed and photoactivated for 40 s. Material was kept 2 mm below the occlusal margin.
	Filtek Z350XT		Organic matrix: Bis-GMA, Bis-EMA, UDMA, and TEGDMA. Filler: agglomerated silica nanofillers and nanoagglomerated zirconia/silica (78.5% wt)	Oblique increments of up to 2 mm were inserted, finishing the restorations. Each increment was photoactivated for 20 s and the last increment for 40 s.
Test XST	XP Bond2	Dentsply Caulk (Milford, DE, USA)	PENTA, UDMA, dimethacrylate modified by carboxilic acid (TCB resin), triethileneglycol dimethacrylate, hydroxyethylmethacrylate, canphoroquinone, ethyldimethylaminebenzoato, tert-butylhydroquinon, silica, tert-butanol (T-butanol)	Dentin was left slightly moist. One drop of XP Bond was applied with a microbrush, allowed to sit for 20 s, air-dried for 5 s, and photoactivated for 20 s .
	SureFil SDR		Organic matrix: SDR-UDMA, EBPADMA, TEGDMA, CQ, butyl hydroxy toluene; stabilizers UV, titanium dioxide, iron oxide pigments. Filler: barium glass fluoride aluminum silicate, strontium glass (68% wt)	A single increment was inserted using a constant and slow pressure in the deepest part of the cavity, keeping the tip inside the material until an increment of not more than 4 mm was obtained. The material was kept 2 mm below the cavosurface angle for posterior insertion of the universal resin and photoactivated for 40 s.
	TPH3		Organic matrix: Bis-GMA, silica dimethacrylate, EDAB, and others. Filler: silanized barium glass aluminum borosilicate, silanized barium glass, fluoride, aluminum borosilicate (75% wt)	Resin was placed using the incremental technique, and each increment was photoactivated for 20 s. The last increment was photoactivated for 40 s.

*Abbreviations: Bis-GMA, bisphenol A glycydil methacrylate; TEGDMA, triethylene-glycol dimethacrylate; HEMA, hydroxyethyl methacrylate; UDMA, urethane dimethacrylate; Bis-EMA, bisphenol A ethoxylate methacrylate; PENTA, dipentaerythritol*penta *acrylate monophosphate; EBPADMA, bisphenol A ethoxylated dimethacrylate; CQ, camphorquinone; EDAB, ethyl-4-dimethylamino benzoate.*

rinsed with an air/water spray for 10 seconds. Subsequently, adhesive systems and restorative materials were applied, following the recommendations of the respective manufacturers. Table 1 presents the specifications for each group.

To restore the shape of the proximal walls, wooden wedges, preformed metal matrices, and rings (Unimatrix sectional matrix system, TDV Dental Ltda, Pomerode, Brazil) were used. Subsequently, the preparations were restored. In cases where the depth in the proximal box was greater than 6 mm, the low-shrinkage flowable resin composites were inserted in two increments, with the first increment being 4 mm thick. Otherwise, low-shrinkage flowable resin composites were inserted, reserving 2 mm of the restorative depth for the final occlusal resin composite. In order to compare the interproximal contacts of the restorations over time, care was taken to perform restorations so that the point of contact with the adjacent tooth was reconstructed with the bulk-fill resin. Adhesive and resin composites were light cured with a Valo curing light (Ultradent) in the standard application mode and an output of 1000 mW/cm^2.

Table 2: *Modified US Public Health Service Criteria Rating System for Clinical Evaluation of the Restorations*

Retention
Alpha (A): presence of the restoration
Bravo (B): partial retention
Charlie (C): total absence of the restoration
Marginal integrity
Alpha (A): There is no visual evidence of marginal fracture, and the tip of the dental probe is not trapped in the tooth/restoration interface.
Bravo (B): There is visible and tactile evidence of a cleft, but the dentin and/or base is not exposed, nor does the restoration present mobility.
Charlie (C): The dental probe penetrates the tooth/restoration interface, presenting exposed dentin and/or base, but the restoration is not mobile, fractured, or lost.
Marginal discoloration
Alpha (A): There is no visual evidence of marginal discoloration at the tooth/restoration interface.
Bravo (B): There is visual evidence of marginal discoloration at the tooth/restoration interface that can be removed with polishing.
Charlie (C): There is visual evidence of deep marginal discoloration at the tooth/restoration interface that cannot be removed with polishing.
Surface texture
Alpha (A): smooth and shiny, similar to enamel
Bravo (B): slightly rough
Charlie (C): high roughness, not reflective
Wear
Alpha (A): no wear, continuous interface
Bravo (B): discontinuous interface, no exposed dentin
Charlie (C): discontinuous interface, exposed dentin
Secondary caries
Alpha (A): There is no visual evidence of tooth decay at the tooth/restoration interface.
Charlie (C): There is visual evidence of tooth decay at the tooth/restoration interface.
Anatomical form
Alpha (A): The restoration presents continuity with the anatomical form of the existing tooth.
Bravo (B): The restoration has a slight overcontour or undercontour.
Charlie (C): There is loss of restorative material leading to exposure of dentin and/or base.
Surface staining
Alpha (A): absent
Bravo (B): present
Color
Alpha (A): nonapparent interface with the tooth
Bravo (B): subtle visualization between tooth and restoration
Charlie (C): clear visualization between tooth and restoration
Gingival tissue
Alpha (A): no inflammation
Bravo (B): mild inflammation
Charlie (C): severe inflammation

After finishing the restorative procedures, the rubber dam was removed, and occlusal adjustments were made using fine and ultrafine diamond burs (#1190F, 3118F, 1190FF, and 3118FF, KG Sorensen). All restorations were finished using polishing points (Jiffy, Ultradent).

Evaluation

Two independent and calibrated examiners, neither of whom placed the restorations, were responsible for the clinical evaluations. The examiners were kept blind at all assessments.

At 24 hours, seven and 90 days, and six months after finishing the restorative procedures, the subjects were evaluated for postoperative sensitivity. The analysis included spontaneous pain as well as that caused by hot and cold thermal stimuli.

Isolation of the operative field during the evaluations was performed using cotton rolls. The cold test was performed with an anesthetic tube filled with frozen water and by placing the ice in direct contact with the restoration for 15 seconds. The hot thermal test was performed using gutta-percha (Dentsply Maillefer) directly heated by a lamp and placed in direct contact with the restoration for 15 seconds (temperature $<60°C$). Patients received a scale that was used to identify the pain intensity reported according to the modified visual analog scale[20] using scores ranging from 1 to 6: 1, no pain; 2, slight pain; 3, moderate pain; 4, a little worse pain; 5, very bad pain; and 6, the worst pain.

The clinical performance of the restorations was performed through visual and tactile inspection, using a flat dental mirror (SS White, Rio de Janeiro, Brazil) and a periodontal probe (#6 Satin Steel Handle, Hu-Friedy).

After 24 hours, six months, and one year, the restorations were evaluated using the modified US Public Health Service (USPHS) criteria,[21] as described in Table 2. The tightness of the proximal contact was determined based on the resistance to dental floss (Sanifill, São Paulo, Brazil) between the restored surface and the adjacent tooth. The following scores were used: 0, no contact; 1, minimum contact; 2, ideal contact; 3, tight contact; and 4, very tight contact.[22] In cases where more than one proximal surface was involved, the worst score of the two contacts was recorded.

Statistical Methods

The kappa index was used to measure the degree of agreement between the two evaluators. The Fried-

Table 3: *Characteristics of the Cavities and Restorative Procedures*

Variables	Characteristics	n	Groups		
			PA	ABF	XST
Operator	1 (experience of 19 y)	81	27	27	27
	2 (experience of 1 y)	78	26	26	26
Teeth	Maxillary premolar	67	22	23	22
	Maxillary molar	34	11	13	10
	Mandibular premolar	27	7	9	11
	Mandibular molar	31	13	8	10
Restored faces	2	87	30	30	27
	3	67	20	23	24
	4	5	3	0	2
Previous condition	Unsatisfactory amalgam	106	39	35	32
	Unsatisfactory resin composite	52	14	18	20
	Primary caries lesions	1	0	0	1
Deep	3 mm	29	12	9	8
	≥4 mm	61	17	19	25
	≥5 mm	69	24	25	20
Previous dentin	Normal	34	10	15	9
	Sclerotic	125	43	38	44
Anesthesia	Yes	156	52	52	52
	No	3	1	1	1
Restorative time	≤10 min	133	43	45	45
	≤20 min	26	10	8	8
Operator perception	Easy	113	39	38	36
	Medium	38	13	12	13
	Dificult	8	1	3	4

Abbreviations: PA, Peak Universal + Amelogen Plus; ABF, Adper Single Bond 2 + Filtek Bulk Fill Flow + Filtek Z350XT; XST, XP Bond + SDR + TPH3.

man and Wilcoxon tests were used to evaluate postoperative sensitivity and interproximal contacts within each group, and the Kruskal-Wallis and Mann-Whitney tests were used within the same evaluation period. The equality test of two proportions was used to evaluate clinical performance.

Logistic regression analysis was performed to predict the probability of success of the clinical performance results at one year, using the characteristics cited in Table 3. Afterward, the Hosmer-Lemeshow test was performed to evaluate the efficacy of the logistic regression model. "A" and "B" scores were considered because there were only two observations for the "C" score (color and gingival tissue). All tests were performed at a significance level of 0.05%.

RESULTS

The mean age of the 53 subjects was 48.3 years (±10.0), and all participants attended all of the evaluations. The oral health characteristics were (in percentage) VPI, 22.92 ± 20.3; GBI, 14.52 ± 18.8; and DMFT, 22.71 ± 3.91. A total of 65 molars and 94 premolars were restored. The characteristics of the preparations and the restorative procedures are described in Table 3.

There was a statistically significant agreement among the evaluators at the periods analyzed ($p<0.001$), showing that there was an excellent concordance of kappa (baseline=0.79, six months =0.91, one year=0.89).

Data regarding postoperative sensitivity are shown in Table 4. No statistically significant difference was observed at any of the evaluated periods among all groups ($p>0.05$). There was a statistically significant reduction in comparison to spontaneous sensitivity between the periods for all study groups when comparing the initial evaluation to the subsequent periods ($p<0.05$). Regarding cold stimulus, ABF was the only group that did not present a reduction in cold sensitivity over time ($p>0.05$). No statistically significant differences between periods were found for the hot stimulus ($p>0.05$).

Table 4: *Means (Standard Deviation) of the Postoperative Sensitivities Experienced by Patients for All Groups and Evaluation Periods Using a Modified Visual Analog Scale*[a]

	Spontaneous			Cold			Hot		
	PA	ABF	XST	PA	ABF	XST	PA	ABF	XST
24 h	1.62(1.10) Aa	1.49(0.87) Aa	1.51(1.03) Aa	2.57(1.55) Aa	2.51(1.37) Aa	2.39(1.59) Aa	1.55(0.91) Aa	1.62(1.08) Aa	1.51(0.87) Aa
7 d	1.23(0.61) Ab	1.13(0.44) Abc	1.21(0.57) Abc	2.38(1.19) Aab	2.23(1.15) Aa	1.98(1.20) Aab	1.55(0.82) Aa	1.47(0.80) Aa	1.47(0.84) Aa
90 d	1.15(0.4) Ab	1.13(0.44) Abc	1.13(0.44) Abc	2.06(1.35) Abc	2.17(1.39) Aa	1.81(1.11) Ab	1.30(0.54) Aa	1.24(0.51) Aa	1.31(0.61) Aa
6 mo	1.17(0.60) Ab	1.11(0.37) Ac	1.06(0.23) Ac	1.94(1.18) Ac	2.09(1.21) Aa	1.96(1.17) Ab	1.45(0.75) Aa	1.28(0.53) Aa	1.32(0.64) Aa

Abbreviations: PA, Peak Universal + Amelogen Plus; ABF, Adper Single Bond 2 + Filtek Bulk Fill Flow + Filtek Z350XT; XST, XP Bond + SDR + TPH3.
[a] *Uppercase letters compare groups within a same evaluation period (columns), and lowercase letters compare the periods of each group individually (lines), both for each type of postoperative sensitivity separately.*

The data from the USPHS criteria are presented in Table 5. When the analysis among groups was carried out, a statistically significant difference was observed for the following criteria: color, marginal discoloration, and superficial staining. A statistically significant color alteration was observed for PA when compared to ABF and XST at six months and one year. After one year, a low percentage of color alteration was observed for XST, which was statistically different from the other groups. Regarding marginal discoloration, the only difference observed was for ABF at six months, which presented a greater number of restorations with the bravo score when compared to the other groups.

When comparing the evaluation periods for each of the groups, a statistically significant difference was observed for marginal discoloration, marginal integrity, and superficial staining. With regard to marginal discoloration, a statistical difference occurred in both PA and XST after one year when compared to the other periods. ABF presented statistically significant differences in marginal discoloration between the baseline and the subsequent evaluations. Initial degradation of marginal integrity was observed for all groups; PA presented continuous and increased degradation over time, while ABF and XST presented differences only at the one-year follow-up. With regard to superficial staining, PA and ABF presented alterations over time; ABF staining was observed starting at the six-month evaluation period, while PA presented alterations only after one year.

All XST restorations presented an A score for superficial staining at six months, which was statistically different from the other groups. For the one-year evaluation, the highest number of bravo scores for superficial staining was observed for ABF, which was statistically different from the other groups.

The interproximal contacts data are shown in Table 6. When the performance of each group was compared over time, a significant reduction in the intensity of contacts for XST was observed after one year. There was no significant difference among the groups.

The probability of success after one year was observed in the following variables: number of surfaces for the retention, operator for the marginal integrity, sclerotic dentin for marginal discoloration, and mandibular molar for surface texture ($p<0.05$).

DISCUSSION

The present study represents a prospective, randomized, double-blind, split-mouth model, which provides the best evidence for a clinical trial.[23] With the split-mouth design, it is possible to analyze the test and control groups under the same conditions, where the three analyzed groups are present in the same subject, increasing the statistical efficiency and decreasing the amount of patients required for the study.[24] The method used for the analysis of postoperative sensitivity was the visual analog scale, which has been the most frequently used scale for this type of clinical trial.[25] According to the results found in our study, no differences were found among groups for postoperative sensitivity. These results are in accordance with another clinical study in which the sensitivity risk was not affected by the type of adhesive or the restorative strategy used.[16,26]

The highest mean of sensitivity was found during the first 24 hours after the restorative procedure, which leads us to reject the first null hypothesis. The higher intensity of spontaneous sensitivity found in this period may be associated not only with the restorative materials used but also with the trauma generated during the cavity preparation and restorative procedures.[11,16,27]

Table 5: *Clinical Evaluation of Resin Composite Restorations (US Public Health Service). Percentage Values of "A" Score and Numbers of "A," "B," and "C" Scores in Parentheses, Respectively*[a]

Category	Groups	Baseline	6 Mo	1 Y
Retention	PA	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	94.3% (50-A/2-B/1-C) Aa
	ABF	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa
	XST	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	96.2% (51-A/2-B/0-C) Aa
Marginal integrity	PA	100% (53-A/0-B/0-C) Aa	92.5% (49-A/4-B/0-C) Ab	71.7% (38-A/15-B/0-C) Ac
	ABF	100% (53-A/0-B/0-C) Aa	94.3% (50-A/3-B/0-C) Aa	73.6% (39-A/14-B/0-C) Ab
	XST	100% (53-A/0-B/0-C) Aa	94.3% (50-A/3-B/0-C) Aab	83.0% (44-A/9-B/0-C) Ab
Marginal discoloration	PA	98.1% (52-A/1-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	73.6% (39-A/14-B/0-C) Ab
	ABF	98.1% (52-A/1-B/0-C) Aa	83.0% (44-A/9-B/0-C) Bb	73.6% (39-A/14-B/0-C) Ab
	XST	100% (53-A/0-B/0-C)Aa	96.2% (51-A/2-B/0-C) Aa	77.4% (41-A/12-B/0-C) Ab
Surface texture	PA	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	96.2% (51-A/2-B/0-C) Aa
	ABF	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	94.3% (50-A/3-B/0-C) Aa
	XST	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	92.5% (49-A/4-B/0-C) Aa
Wear	PA	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa
	ABF	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa
	XST	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa
Secondary caries	PA	100% (53-A/0-C) Aa	100% (53-A/0-C) Aa	100% (53-A/0-C) Aa
	ABF	100% (53-A/0-C) Aa	100% (53-A/0-C) Aa	98.1% (52-A/1-C) Aa
	XST	100% (53-A/0-C) Aa	100% (53-A/0-C) Aa	98.1% (52-A/1-C) Aa
Anatomical form	PA	98.1% (52-A/1-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa
	ABF	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa
	XST	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa	100% (53-A/0-B/0-C) Aa
Surface staining	PA	100% (53-A/0-B) Aa	96.2% (51-A/2-B) Bab	84.9% (45-A/8-B) Ab
	ABF	100% (53-A/0-B) Aa	86.8% (46-A/7-B) Bb	66.0% (35-A/18-B) Bc
	XST	100% (53-A/0-B) Aa	100% (53-A/0-B) Aa	94.3% (50-A/3-B) Aa
Color	PA	71.7% (38-A/13-B/2-C) Ba	75.5% (40-A/12-B/1-C) Ba	84.9% (45-A/8-B/0-C) Ba
	ABF	92.5% (49-A/3-B/1-C) Aa	90.6% (48-A/4-B/1-C) Aa	92.5% (49-A/4-B/0-C) Bba
	XST	92.5% (49-A/4-B/0-C) Aa	94.3% (50-A/3-B/0-C) Aa	96.2% (51-A/2-B/0-C) Aa
Gingival tissue	PA	98.1% (52-A/0-B/1-C) Aa	98.1% (52-A/0-B/1-C) Aa	96.2% (51-A/1-B/1-C) Aa
	ABF	96.2% (51-A/2-B/0-C) Aa	98.1% (52-A/1-B/0-C) Aa	96.2% (51-A/2-B/0-C) Aa
	XST	100% (53-A/0-B/0-C) Aa	98.1% (52-A/0-B/1-C) Aa	98.1% (52-A/1-B/0-C) Aa

Abbreviations: PA, Peak Universal + Amelogen Plus; ABF, Adper Single Bond 2 + Filtek Bulk Fill Flow + Filtek Z350XT; XST, XP Bond + SDR + TPH3.
[a] *Uppercase letters compare groups within the same evaluation period (columns),and lowercase letters compare the periods of each group individually (lines). Numbers in parentheses: number of scores present in Table 2.*

Table 6: *Means (Standard Deviation) of the Interproximal Contacts for Groups and Evaluation Periods*[a]

Groups	Evaluation Periods		
	24 H	6 Mo	1 Y
PA	1.92(0.51) Aa	1.87(0.48) Aa	1.79(0.49) Aa
ABF	1.85(0.45) Aa	1.79(0.41) Aa	1.79(0.41) Aa
XST	1.94(0.41) Aa	1.83(0.38) Aa	1.73(0.44) Ab

Abbreviations: PA, Peak Universal + Amelogen Plus; ABF, Adper Single Bond 2 + Filtek Bulk Fill Flow + Filtek Z350XT; XST, XP Bond + SDR + TPH3.
[a] *Uppercase letters compare groups within a same evaluation period (columns), and lowercase letters compare the periods of each group individually (lines).*

When the data obtained for cold sensitivity testing were analyzed, only one restorative system with a low-shrinkage flowable resin composite (ABF) maintained the same intensity of discomfort at all evaluation times. On the other hand, the other restorative system that used a low-shrinkage flowable resin composite (XST) resulted in a reduction of this type of sensitivity after 90 days. These data corroborate the findings of another clinical study that observed low postoperative sensitivity after 30 days in restorations performed with the same low-shrinkage resin used in the present study.[17]

The distinct performance of the two restorative systems containing low-shrinkage flowable resin composites is possibly a result of the different

monomers present in the composition of these resin composites. Although the materials had similar percentages of filler loading (Filtek Bulk Fill Flow 64.5%, SDR 68% by weight), the monomers of Filtek Bulk Fill Flow present a similar structure to conventional resins,[28] while Surefil SDR presents a patented monomer (SDR-UDMA), according to the manufacturer. Furthermore, Surefil SDR showed a significantly higher degree of conversion when compared to Filtek Bulk Fill Flow.[29]

No differences in sensitivity were observed when the hot stimulus was applied since reversible or irreversible pulpal inflammation is required for a response to this test.[30] Other studies in the literature that assessed postoperative sensitivity did not evaluate restorations with the hot stimulus test;[16,17] therefore, it is not possible to compare the results found in this study with other studies.

With regard to the clinical analysis of the restorations, the modified USPHS criteria have been used to evaluate the survival of restorations in several clinical studies,[18,19,31] although there are other criteria for the clinical evaluation of restorations, such as those used by the World Dental Federation.[16] It is worth mentioning that the kappa test revealed excellent agreement among the evaluators. This was possible due to the calibration carried out prior to the evaluations using projected images of the different criteria that would be analyzed.

After the one-year follow-up, the restorations in all groups showed similar clinical performance. In three- and five-year follow-ups, 27.6% and 35.9%, respectively, of class II restorations with minimal marginal discoloration were found when the low-shrinkage Surefil SDR resin composite was used.[18,19] Similar results were obtained in the present study, in which 22.6% of the restorations presented bravo scores for this criterion after one year. These data also show that, up to the one-year evaluation period, the restorative system is not responsible for the degree of marginal discoloration of the restorations.

When considering superficial staining, only the XST restorations remained without a statistical difference after the one-year follow-up, rejecting the second null hypothesis. On the other hand, the beginning of superficial staining of the ABF restorations began at the six-month evaluation, with a greater number of B scores at the last evaluation. The good performance of XST over time may be related to the absence of triethylene-glycol dimethacrylate in the coating resin, leaving this restorative option less susceptible to liquid absorption when compared to the other options evaluated.[32] Additionally, the decreased behavior of ABF when compared to PA may be related to the greater sorption capacity of the nanoparticulated resin in ABF when compared to the microhybrid resin in PA.[33]

When the criterion of marginal integrity was analyzed over time, the teeth that received restorations with the incremental technique presented alterations starting at the six-month evaluation and became worse at the one-year evaluation. On the other hand, the groups that received the low-shrinkage flowable resin composites presented marginal degradation only after one year. In a recent study comparing the same low-shrinkage resin composites used in this study, Surefil SDR and Filtek Bulk Fill Flow showed similar polymerization shrinkage when evaluated using microtomography in class II cavities.[34] These materials differ from conventional resin composites because they have increased polymerization depth, which can be attributed to an increase in translucency and specific monomers. However, the literature is inconsistent in determining the depth of polymerization, although it is reported that these materials are more suitable for narrow preparations with depths greater than 4 mm since they have a greater potential for adaptation.[35] This fact can probably be explained by the low modulus of elasticity of these materials, reducing the stresses generated by the polymerization contraction and, thereby, maintaining the marginal integrity.[36] This information may justify the similarity found among the groups evaluated after one year of clinical evaluation.

In order to evaluate the interproximal contact of the restorations over time using the new low-shrinkage materials, the restorations restored the area of contact with the adjacent tooth. The literature is scarce in clinical work evaluating the intensity of the interproximal contacts of resin composite restorations. Teich and others[22] attempted to standardize the evaluation of the thickness of the contact areas using different brands of dental floss. They carried out a study assigning scores to measure the intensity of the interproximal contacts in natural and restored teeth. The same scores were used in this study to evaluate the interproximal contacts re-established by the restorations using the low-shrinkage resin composites in comparison to the incremental technique.

The current study found no difference among the groups tested, which can be justified by the stan-

dardization of the matrix used since the use of different types of matrices can influence the intensity of the interproximal contact as opposed to the technique or material used.[3] A decrease in the intensity of contact was observed only for XST. However, it should be noted that not all patients had a harmonious and standardized occlusion, and dental movement may have occurred in some cases. Furthermore, a one-year period is not sufficient time to develop variations in most categories. These are potential limitations of this study.

According to the logistic regression analysis, some factors influenced the results of the present study after one year of evaluation. A lower number of surfaces restored increased the retention of restorations, with a smaller interface area being subject to failure. The operator factor influenced the marginal integrity results, where the most experienced operator obtained a higher number of A scores. There are reports in the literature that the most experienced operators influence the success of noncarious class V restorations and restorations using the active release technique.[37,38] Other studies have reported that the clinical success of restorations depends on several factors, including tooth type and location, operator, socioeconomic status, demographics, and behavioral elements.[39] The properties of the material showed a smaller effect on the longevity of the restorations.[39] The presence of sclerotic dentin influenced the present results; it was observed that most of the teeth restored in this study had sclerotic dentin (78.6%), which may have caused a bias in the interpretation of the results.

It is important to emphasize that a new generation of low-shrinkage resin composite has been released in the market, the "full-body" bulk-fill resin composites, which contain a high filler load and are preferable in more extensive restorations.[35] It is believed that clinical trials evaluating this new generation of resin composite are necessary. In addition, a longer evaluation of this study can also elucidate the differences between the restorative systems used.

CONCLUSIONS

The different restorative systems did not influence spontaneous postoperative sensitivity, and after 90 days, there was a reduction of this sensitivity for all study groups. ABF maintained the same degree of cold sensitivity over time. Marginal discoloration was identified earlier for ABF, although marginal discoloration was observed for all study groups after one year. A reduction in interproximal contact was observed for XST after one year of evaluation. Furthermore, other factors should be considered during a clinical evaluation, such as current composite chemistry enhancements and the C-factor.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the ethics committee. The approval code for this study is 1,235,100.

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.

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