



The influence of different placement techniques on the clinical success of bulk-fill resin composites placed in Class II cavities: a 4-year randomized controlled clinical study

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Abstract

Objective The purpose of this double-blind and split-mouth randomized controlled clinical trial was to evaluate the clinical success of the placement technique (bulk-filling and incremental techniques) of a bulk-fill resin composite in Class II carious lesions.

Materials and methods Two different bulk-fill resin composites, X-tra fil (Voco) and Filtek Bulk Fill (3M ESPE), were used in the bulk-filling and incremental techniques for 20 patients. The study was carried out in 4 groups, with 20 restorations in each group. Restorations were appraised at baseline, 6-month, 2-year, and 4-year recall. World Dental Federation (FDI) and the US Public Health Service (USPHS) criteria were used in the evaluations. The Friedman, Kruskal–Wallis, and Mann–Whitney *U* tests were used for the statistical analysis.

Results At the end of year 4, there was no loss of restoration in any group. According to the USPHS and FDI criteria, there was a difference in the baseline and 4-year in marginal adaptation and marginal discoloration of the restorations ($P < 0.05$). When Filtek-Bulk was placed as an incremental technique, there was a minor fracture in four restorations ($P > 0.05$). In addition, Filtek-Bulk showed a color change according to the results based on both the USPHS and FDI criteria ($P < 0.05$). The difference between the two placement techniques of each resin composite was not significant at the year 4 recall when all criteria were evaluated ($P > 0.05$).

Conclusions The 4-year clinical success of the evaluated bulk-fill composites is not dependent on the placement technique used.

Clinical relevance This study can help clinicians choose which technique (bulk fill and incremental techniques) bulk-fill composites can be used.

Trial registration US National Library of Medicine, www.clinicaltrials.gov, ID: NCT04565860 Registered on 10/09/2020. Clinical Evaluation of Bulk-fill resin Composites in Class II Restorations.

Keywords Bulk-fill resin composite · Incremental technique · Bulk technique · Resin composite · FDI · USPHS

Introduction

Nowadays, clinicians often use light-curable direct resin-based composites (conventional resin composites) to restore teeth due to their many advantages. Some of these advantages are conservative cavity preparation and preserving healthy dental tissue [1]. Additionally, it does not compromise tooth strength compared to other fillings since it requires minimal tooth structure removal. Furthermore, clinical studies have reported that composite resins provide long-term success [2]. Therefore, optical and mechanical properties of composite resins were being developed day by day [1].

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In many clinical cases, polymerization shrinkage and the limited polymerization depth of most conventional composites are prevented with the use of thinner composite layers [3–5]. Traditionally, the resin composites are placed in increments of 2 mm (maximum) that are cured separately (incremental technique) [1, 3]. This incremental technique provides sufficient light penetration and monomer conversion [6]. However, it has disadvantages such as the risk of blood or saliva contamination between layers, bonding failures, and time-consuming protocols, and it is difficult to apply in large cavities. [7]. On the other hand, there are various benefits to bulk-filling of the cavities: it is more time-efficient and can avoid technical errors such as voids and contamination between layers [4, 6].

Polymerization shrinkage is one of the major disadvantages of conventional resin composite restorations [5]. It has been associated with marginal insufficiencies, cracked cusps, cuspal movement, and enamel fractures, which may result in microleakage, postoperative sensitivity, and secondary caries [7]. Shrinkage stress is influenced by tooth-related variables such as cavity size and configuration factors (C-factor). Cavities with a high C-factor will cause greater stresses owing to a greater number of bonded surfaces [8]. The most important factors that affect it are volumetric shrinkage of the restorative material and elastic modulus. In resin composites with a lower modulus of elasticity or a slower curing rate, lower polymerization stress may occur [9]. However, these properties are often inversely proportional to each other and largely depend on the amount, size and shape, monomer structure, or chemistry of filler particles [10].

Another important parameter for resin composite restoration is the depth of cure. Resin composite contains a photoinitiator that is triggered by blue visible light to activate the polymerization. Many resin composites contain camphorquinone as a primary photo-initiator and a tertiary amine as a co-initiator [4, 7, 11]. In addition, photoinitiators such as trimethyl benzoyl diphenylphosphine oxide (TPO) and dibenzoylgermanium (Ivocerin) derivatives have also been used [11, 12]. Various strategies have been developed by manufacturers to increase the depth of cure. In particular, extensive efforts have been made with new monomers, initiator systems, and filler technology; translucency was also increased for better light penetration and polymerization [11, 12]. Based on these, manufacturers have presented to the market “bulk-fill composites” that can be polymerized in a single layer up to 4–5 mm thick. Bulk-fill resin composites were obtained as a result of changes made in the amount, ratio, and chemistry of the composition of conventional composites [12]. Manufacturers modified the chemistry of a monomer is known as the Bowen Monomer (Bis-GMA: 2,2-bis [4-(2-hydroxy-3-methacryloxypropoxy) phenyl] propane) to obtain a new low-viscosity monomer [12]. By increasing the translucency and placing photoactive groups

in the methacrylate resin, the polymerization depths of the bulk-fill composites were increased, and the composite could be polymerized up to 4 mm thickness with the “bulk” technique [12]. Thus, bulk-fill resin composites can be described as resin composites that are sufficiently polymerizable in a single layer up to 4 mm thick [11]. In other words, bulk-fill resin composites aim to decrease polymerization shrinkage, increase the depth of cure, and avoid the disadvantages of the incremental technique [11].

A material that is presented to the dental market is primarily evaluated in vitro conditions that simulate the oral environment. Nonetheless, clinical trials are needed to clearly determine the clinical properties of the materials.

In the literature, there are many in vitro studies [13–17] examining parameters such as color stabilization, depth of polymerization, degree of transformation, surface properties, and monomer release related to bulk-fill composites. Meta-analyses about some of its clinical features were made [18, 19]. According to the meta-analysis, the current clinical studies have been performed on a variety of bulk fill resin composites such as Tetric EvoCeram Bulk-fill (Ivoclar Vivadent, Schaan, Liechtenstein), SureFil SDR (Dentsply, Milford, DE, USA), Filtek bulk-fill (3 M ESPE, St Paul, MN, USA), and QuiXfil (Dentsply De Trey, Konstanz, Germany). In addition, they have been realized in class I and Class II cavities [18, 19]. Based on these, the purpose of this study is that there are insufficient clinical studies in the literature to confirm the claims of the manufacturers and the evaluation of the difference between the traditionally accepted incremental techniques with the bulk technique for composite resins. In addition is that there are not enough studies [18, 19] in the literature related to the materials we evaluated. Thus, the current study aims to evaluate the clinical success of bulk-fill resin composite positioned through different placement techniques (bulk-filling and incremental techniques) in Class II carious lesions using the criteria of the World Dental Federation (FDI) and the United States Public Health Service (USPHS). The tested null hypothesis was that “Placement techniques do not have a significant effect on the clinical success of bulk-fill resin composites.”

Materials and methods

The current study was realized according to the consolidated reporting trials standards (CONSORT). The study protocol was approved by the Erciyes University Clinical Research Ethics Committee. All restorations were performed in the Clinic of the Erciyes University School of Dentistry Department of Restorative Dentistry. This was a randomized, double-blind, and split-mouth clinical study. The treatment procedure was explained to all

volunteers and information was given about complications. Informed consent forms were subsequently read and signed by all patients.

Selection of participants and randomization

Study design

A total of 158 volunteers aged 18–22 years (the mean age of the participants was 19.2 years) with similar oral hygiene (none of the patients had gingivitis and periodontitis in the gingival health assessment), and similar oral hygiene habits (they had all brushed their teeth at least twice a day), and were inspected by two pre-calibrated dentists. Evaluations were made under reflector light using a mouth mirror, explorer, and periodontal probe. Using the inclusion–exclusion criteria and radiographic findings, 20 participants (12 females, 8 males) were included in the study (Fig. 1).

Sample size calculation

The sample calculation in the study was made based on the difference between the success rates of the groups. The large effect size suggested by Cohen [20] was used as the

effect size. Using an alpha of 0.05, a power of 80%, and a two-sided test, the minimal sample size was 20 restorations in each group in order to detect a difference of 30% among the tested groups.

Inclusion criteria

Patients who had:

- (1) At least, 4 Class-II caries lesions in first and second molar teeth (MO or DO).
- (2) Good health systemically
- (3) An acceptable level of oral hygiene
- (4) Teeth with occlusal and proximal contact
- (5) And were 18–20 years old

Exclusion Criteria

- (1) Patients who had deep caries lesions reaching the pulp
- (2) Patients with bruxism
- (3) Patients with periodontal disease
- (4) Patients who refused to participate
- (5) Teeth that have secondary caries

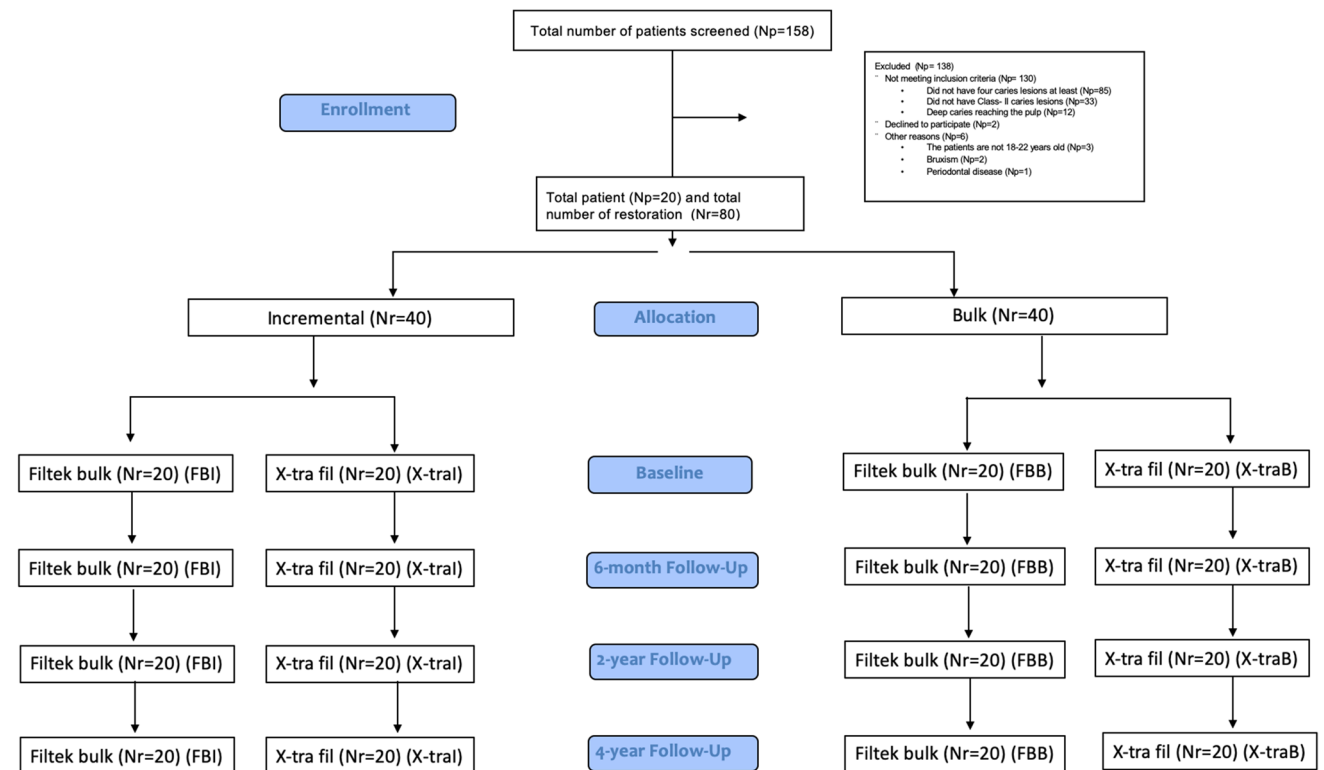


Fig. 1 Schematic representation of inclusion and exclusion criteria. Np, number of patients; Nr, number of restoration; FBB, filtek bulk (bulk-filling); X-traB, X-tra fill (bulk-filling); FBI, filtek bulk (incremental); X-tral, X-tra fill (incremental)

Randomization

A researcher, who was not involved in any of the experimental phases, used a random list to distribute teeth to all groups. The number corresponding to each treatment was recorded on cards. The cards were placed within numbered, opaque, and sealed envelopes. The randomization was done on an intra-individual basis. Thus, four restorations (two bulk-fill resin composites that had different placement techniques (bulk-filling and incremental technique)) were placed randomly. These envelopes were opened immediately before the restorative procedure to prevent disclosure of the randomization list. All restorations were performed by one experienced and trained operator.

Groups and restorative procedure

Study groups

Table 1 shows the materials, ingredients, and application procedures used in this study. In the present study, two different bulk-fill resin restorative composites (X-tra fil (Voco, GmbH, Cuxhaven, Germany), Filtek Bulk (3M ESPE, St. Paul, MN, USA)) (Table 1) were used in the bulk-filling and incremental technique. The bulk-fill resin composites were used in both the bulk-filing and incremental techniques for the same participant. The study consists of 4 groups and 20 restorations in each group (80 restorations in total).

Cavity preparation

The treatment procedure is as follows. A rubber dam was applied to each patient after local anesthesia. To remove caries and create the cavity, high-speed round diamond burs (Diamir, srl Resia UD, ITALY), low-speed tungsten carbide burs (Meisinger, Düsseldorf, GERMANY), and hand instruments were used. Cavity assessments were made by probing with a sharp explorer and visually examining the color of the dentin.

The cavities were prepared as follows:

- (1) None of the cavity preparations included one or more tubercle.
- (2) Margins of the prepared cavity were not beveled.
- (3) The buccolingual width of the cavity preparations did not pass one-third of the intercuspal distance.
- (4) No cavity exceeded a depth of 4 mm.

A periodontal probe was used to determine whether the cavity depth was 4 mm or not. An automatrice system (Hawe Supermat, Kerr, Orange, CA, USA) was placed. Subsequently, cavities were cleaned by rinsing with water and air-dried for 5 s.

Adhesive procedure

A one-step universal adhesive system (Clearfil Universal, Kuraray, Okayama, Japan) was used for the self-etch mode following the manufacturer's instructions (Table 1).

Restoration procedure

After bonding procedures, the groups were created as follows.

- (1) X-tra fil (bulk-filling) (X-traB)
- (2) X-tra fil (incremental) (X-traI)
- (3) Filtek Bulk (bulk-filling) (FBB)
- (4) Filtek Bulk (incremental) (FBI)

For the incremental technique, the cavities were filled horizontally in 2 pieces with a 2 mm thickness of each layer. For the bulk technique, one layer (approximately 4 mm) was applied in bulk (Fig. 2). An LED light device (Valo, 1000 mW/cm², Ultradent Products Inc, South Jordan, USA) was used for the cure of the restorations according to the manufacturer's recommendations (10 s for X-tra fil, 20 s for Filtek Bulk Fill). Diamond burs (Finishing diamond 858–018, Diatech Dental Ac, Heerbrugg, SWISS) were used to finish and polish the restorations. Spiral discs (3 M ESPE, St. Paul, MN, USA) and sanding paper (3 M ESPE, St. Paul, MN, USA) were used to polish the proximal surfaces. Then, proximal contacts were checked with dental floss (Oral-B Indicator, soft compact 35 toothbrush, Procter & Gamble, Cincinnati, OH, USA).

Clinical evaluation

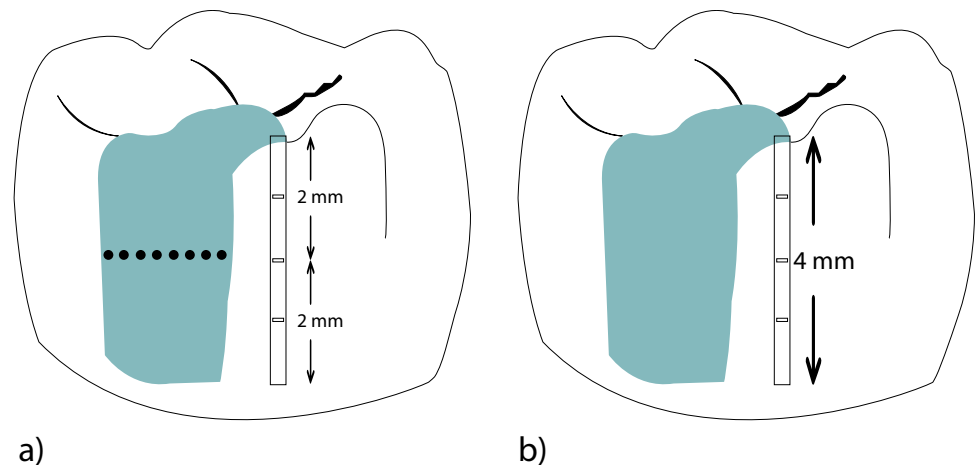
The evaluations were made at baseline, 6th-month, 2nd-year, and 4th-year using FDI [21] (Table 2) and USPHS [22] criteria, by two calibrated scorers (Table 3). The evaluations were performed by two pre-calibrated observers. The scorers were blind to the group assignment because they were not involved in the restoration procedures. In a double-blind randomized clinical trial design, subjects were likewise kept in the dark regarding their group assignment. In case of inconsistencies between scorers, the restorations were re-evaluated by two examiners and a final consensus was reached. The resulting data were recorded in the standardized case report form.

Evaluations of postoperative sensitivity were made 7 days after restorative procedures by asking the patient about the effect of occlusal force (chewing) and cold/hot stimuli. To detect secondary caries after 4-year, bite-wing radiographs were taken. These evaluations were arranged with the FDI and USPHS criteria (Tables 2 and 3). On the scales employed in the study, each criterion was assessed

Table 1 Materials, composition, and placement technique used in the present study

Materials	Composition	Application
X-tra fill, VOCO, Cuxhaven, Germany Batch #1,445,118	Bis-GMA, UDMA, TEGDMA, Barium aluminum, silicate vitreous particles	Incremental 1. The composite resin is applied incrementally to the entire cavity 2. Each layer is polymerized with a curing light for 20 s
Filetek Bulk Fill, 3M ESPE, St Paul, MN, USA Batch #N878473	Bis-GMA UDMA, TEGDMA, PEGDMA and bis-EMA, Non-agglomerated silica nanoparticles (20 nm), non-agglomerated zirconia (4 to 11 nm). 78.5 wt% and 63.3 vol%	Incremental 1. The composite resin is applied incrementally to the entire cavity 2. Each layer is polymerized with a curing light for 20 s
Clearfil Universal Bond, Kuraray, Okayama, Japan Batch #2B0005 pH = 2.3	MDP, Bis-GMA, HEMA, hydrophilic aliphatic dimethacrylate, colloidal silica, silane coupling agent, CQ, ethanol, water	1. Apply the adhesive with the applicator to the entire surface and rub for 10 s. 2. Dry gently for about 5 s until it no longer moves and the solvent has evaporated completely. 3.Harden the adhesive with a curing light for 10 s
<i>Bis-GMA</i> , bis-phenol A diglycidylmethacrylate; <i>HEMA</i> , 2-hydroxyethyl methacrylate; <i>TEGDMA</i> , triethyleneglycoldimethacrylate; <i>MDP</i> , 10-methacryloyloxydecyl dihydrogen phosphate; <i>UDMA</i> , urethane dimethacrylate; <i>PEGDMA</i> , polyethylene glycol dimethacrylate; <i>CQ</i> , camphorquinone; <i>Bis-EMA</i> , bisphenol-A polyethylene glycol diether dimethacrylate		Bulk 1. The composite resin is applied as bulk filing to the entire cavity 2. Layer is polymerized with a curing light for 20 s

Fig. 2 Schematic presentation of the application of restoration techniques. **a** The application of the incremental technique. **b** The application of the bulk technique



independently. It describes the characteristics of a clinically acceptable restoration on both scales. For each criterion, there are three scores (“alpha” for an ideal clinical condition, “bravo” for clinically acceptable condition, and “charlie” for clinically unacceptable condition.) in the USPHS and five (“clinically very good”, “clinically good,” “clinically sufficient/satisfactory,” “clinically unsatisfactory,” “clinically poor”) in the FDI. In the USPHS criteria, regardless of the severity of postoperative sensitivity, when postoperative sensitivity was determined, it was evaluated as “charlie,” and in the absence of postoperative sensitivity, it was evaluated as “alpha.” Secondary caries were scored in the same way.

Statistical analysis

Data were evaluated in the statistical package program of IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were given as median (M), minimum (min), and maximum (max) values. Comparisons between groups at each measurement time according to FDI and USPHS scoring were made using Kruskal–Wallis analysis. Dunn–Bonferroni test was used as a post hoc test in the Kruskal–Wallis analysis. Friedman’s two-way analysis of variance by ranks was used to compare within-group score values according to measurement times in each group. Bonferroni correction was applied in multiple comparison tests in Friedman’s analysis. A value of $p < 0.05$ was considered statistically significant.

Results

All restoration was evaluated at baseline, 6-month, 2-year, and 4-year recall. According to both criteria used in the current study, all 80 restorations of the 20 participants were evaluated without any loss. The findings are shown in

Tables 4 and 5 and statistical analysis results are shown in Tables 6 and 7.

Fractures and retention

Eight restorations (three restorations in the FBB group, four restorations in the FBI group, and one restoration in the X-traI group) were broken at the end of year 4. There was no loss of any retention after 4 years (Tables 4 and 5).

At the end of 4 years, according to the FDI and USPHS criteria, the between of the groups showed no statistical difference between the baseline and the 4-year findings ($P > 0.05$). When the groups were evaluated among themselves, there were no statistically significant differences in the 4-year recall ($P > 0.05$) (Tables 6 and 7).

Postoperative sensitivity

Post-operative sensitivity was determined in 6 restorations at the baseline (Tables 4 and 5). Nevertheless, postoperative sensitivity was not detected in any restoration after year 4. The difference between the groups was not statistically significant at the baseline evaluation ($P > 0.05$). There was no statistical difference between the baseline and the 4-year findings for all groups ($P > 0.05$). Additionally, at the end of 4 years, there was no statistical difference between groups (Tables 6 and 7).

Marginal adaptation

Initially, 80 restorations were scored as “clinically very good” according to FDI criteria and “alpha” according to USPHS (Tables 4 and 5). According to the FDI and USPHS criteria, 63 restorations showed marginal incompatibility at the end of 4 years (Tables 4 and 5). According to the FDI and USPHS criteria, when each group was evaluated in terms of marginal adaptation, there was a statistical

Table 2 World Dental Federation (FDI) criteria used for clinical evaluation [14]

	Esthetic property			Functional properties		Biological properties		
	Staining marginal	Staining surface	Esthetic anatomical form	Marginal adaptation	Fractures and retention	Approximal anatomical form	Postoperative (hyper) sensitivity	Recurrence of caries
1. Clinically very good	No marginal staining	No surface staining	Form is ideal	Harmonious outline, no gaps, no discoloration	Restoration retained, no fractures/cracks	Normal contact point (floss or 25-µm metal blade can pass)	No hypersensitivity	No secondary or primary caries
2. Clinically good (after correction very good)	Minor marginal staining, easily removable by polishing	Minor surface staining, easily removable by polishing	Form is only slightly deviated from the normal	Marginal gap (50 mm) Small marginal fracture removable by polishing	Small hairline crack	Contact slightly too strong but no disadvantage (floss or 25 µm metal blade can only pass with pressure) Slightly deficient contour	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)	Moderate marginal staining, not esthetically unacceptable	Moderate surface staining that may also present on other teeth, not esthetically unacceptable	Form deviates from the normal but is esthetically acceptable	Gap < 150 mm not removable Several small enamel or dentin fractures	Two or more or larger hairline cracks and/or chipping (not affecting the marginal integrity)	Somewhat weak contact, no indication of damage to tooth, gingiva or periodontal structures; 50 µm metal blade can pass Visible deficient contour	Premature/slightly more intense 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)	Pronounced marginal staining; major intervention necessary for improvement	Unacceptable surface staining on the restoration and major intervention necessary for improvement	Form is affected and unacceptable esthetically. Intervention/correction is necessary	Gap > 250 mm exposed Chip fracture damaging margins Notable enamel or dentin wall fracture	Chipping fractures that damage marginal quality; bulk fractures with or without partial loss (less than half of the restoration)	Too weak and possible damage due to food impaction; 100 µm metal blade can pass Inadequate contour Repair possible	Premature/very intense Extremely delayed/weak with subjective complaints Negative sensitivity intervention necessary but not replacement	Caries with cavitation (localized and accessible and can be repaired)
5. Clinically poor (replacement necessary)	Deep marginal staining not accessible for intervention	Severe surface staining and/or subsurface staining, generalized or localized, not accessible for intervention	Form is unsatisfactory and/or lost. Repair not feasible/reasonable. Replacement needed	Filling is loose but in situ	Partial or complete loss of restoration	Too weak and/or clear damage due to food impaction and/or pain/gingivitis. Insufficient contour requires replacement	Very intense, acute pulpitis or nonvital. Endodontic treatment is necessary and restoration has to be replaced	Deep secondary caries or exposed dentin that is not accessible for repair of restoration

Table 3 Modified United States Public Health Service (USPHS) criteria used for clinical evaluation [15]

	Marginal staining	Color match	Surface staining	Anatomic form	Fractures and retention	Marginal adaptation	Postoperative sensitivity	Recurrence of caries
Alfa	No discoloration along the margin	The restoration matches the adjacent tooth structure in color and translucency	No discoloration along the margin	Continuous with adjacent anatomy	Retained none	Restoration is continuous with existing anatomic form	No postoperative sensitivity directly after the restorative process and during the study period	No evidence of caries contiguous with the margin
Bravo	Slight and superficial staining (removable, usually localized)	The mismatch in color and translucency is within the acceptable range	Slight and superficial staining (removable, usually localized)	Missing restorative material without exposing the dentin or base	Small chip, but clinically acceptable	Detectable V-shaped defect in enamel only catches explorer going both ways	–	–
Charlie	Deep staining cannot be polished away	The mismatch in color and translucency is outside the acceptable range	Deep staining cannot be polished away	Missing restorative material sufficient to expose the dentin or base	Missing failure due to bulk restorative fracture	Detectable V-shaped defect to dentin-enamel junction	Sensitivity present at any time during the study period	Evidence of presence of caries

difference between the baseline and the year-4 findings for all groups ($P < 0.05$). In addition, according to the USPHS and the FDI criteria, FBI, X-traB, and X-traI showed statistically significant marginal incompatibility after 4 years compared to baseline and 6 months ($P < 0.05$). In the FBB group, the 24 and 48-month score values are statistically higher than the baseline and 6-month values ($P < 0.05$). According to the statistical analysis, the difference between the groups was also not significant in terms of marginal adaptation at a 4-year evaluation ($P > 0.05$). These findings are shown in Tables 4, 5, 6, and 7.

Marginal discoloration

At the baseline, all restorations were evaluated as “clinically very good,” according to the FDI criteria, and as “alpha” according to the USPHS criteria. After 4 years, according to the FDI criteria, minor discoloration of 35 restorations was observed. There was also marginal staining for 32 restorations according to the USPHS criteria.

According to the FDI and the USPHS criteria, FBB showed statistically significant marginal discoloration after 4 years compared to baseline, 6 months, and 2 years ($P < 0.05$). On the other hand, FBI, X-traB, and X-traI, there was no statistical difference between baseline, 6 months, 2 years, and 4 years ($P > 0.05$). Additionally, according to the statistical analysis, the difference between the groups was not significant in marginal adaptation at the end of the 4-year evaluation ($P > 0.05$). Similarly, according to the statistical analysis, the difference between the bulk-filling and incremental techniques of each resin composite was not significant at the 4-year recall ($P > 0.05$). These findings are shown in Tables 4, 5, 6, and 7.

Secondary caries

Secondary caries were not determined in any restoration at the 4-year recall. According to the statistical analysis, the difference between the bulk-filling and incremental techniques of each resin composite was not significant at the 4-year recall ($P > 0.05$). Additionally, according to the statistical analysis, the difference between the groups was not significant in terms of secondary caries at the end of the 4-year evaluation ($P > 0.05$). Similarly, there was no statistical difference between the baseline and the 4-year findings for any of the groups ($P > 0.05$) (Tables 6 and 7).

Anatomical form

At baseline, 80 restorations were scored as “alpha” according to the USPHS criteria but a minor distortion of 3 restorations was observed at the end of the 4 years. According to the statistical analysis, differences between baseline and

Table 4 The findings at baseline, 6-month, 24-month, and 48-month recall according to FDI criteria

FDI Criteria	Baseline				6 Month				24 Month				48 Month			
	Bulk		Incremental		Bulk		Incremental		Bulk		Incremental		Bulk		Incremental	
	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)
Marginal staining	20	20	20	20	20	20	20	20	13	18	17	19	7	13	11	14
	<i>Very good</i>															
									5		1		10	6	3	3
	<i>Good</i>								2	2	2	1	3	3	3	3
	<i>Satisfactory</i>															
	<i>Unsatisfactory</i>															
	<i>factory</i>															
	<i>Poor</i>															
Surface staining	20	20	20	20	20	20	20	20	11	19	13	18	11	17	13	15
	<i>Very good</i>															
	<i>Good</i>								7	1	7	2	4	4	3	3
	<i>Satisfactory</i>								1				4	3	2	2
	<i>Unsatisfactory</i>								1				1			
	<i>factory</i>															
	<i>Poor</i>															
Esthetic anatomical form	20	20	20	20	20	20	20	20	19	20	19	20	19	19	19	20
	<i>Very good</i>															
	<i>Good</i>								1		1		1	1	1	
	<i>Satisfactory</i>															
	<i>Unsatisfactory</i>															
	<i>factory</i>															
	<i>Poor</i>															
Marginal adaptation	20	20	20	20	20	20	20	20	8	11	10	13	3	4	4	3
	<i>Very good</i>															
	<i>Good</i>								9	9	9	6	13	12	12	14
	<i>Satisfactory</i>								3		1	1	4	4	3	3
	<i>Unsatisfactory</i>															
	<i>factory</i>															
	<i>Poor</i>															

Table 4 (continued)

FDI Criteria	Baseline				6 Month				24 Month				48 Month			
	Bulk		Incremental		Bulk		Incremental		Bulk		Incremental		Bulk		Incremental	
	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)	Filtek bulk-fill (FBB)	X-tra fill (X-traB)	Filtek bulk-fill (FBI)	X-tra fill (X-traI)
Fractures and retention	20	20	20	20	20	20	20	20	18	20	19	20	17	20	16	19
Very good	—	—	—	—	—	—	—	—	2	—	—	—	3	—	2	1
Good	—	—	—	—	—	—	—	—	—	—	1	—	—	—	2	—
Satisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unsatisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poor	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Approximal	20	20	20	20	20	20	20	20	19	20	19	20	19	19	19	20
Very good	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Good	—	—	—	—	—	—	—	—	1	—	1	—	1	1	1	—
Satisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unsatisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poor	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Postoperative	19	17	19	19	20	20	20	20	20	20	20	20	20	20	20	20
Very good	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Good	1	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Sensitivity	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Satisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unsatisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poor	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Recurrence of caries	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Very good	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Good	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Satisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unsatisfactory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poor	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

FBB, filtek bulk (bulk-filling); X-traB, X-tra fill (bulk-filling); FBI, filtek bulk (incremental); X-traI, X-tra fill (incremental)

Table 5 The findings at baseline, 6-month, 24-month, and 48 month recall according to USPHS criteria

USPHS Criteria	Baseline						6 Month			24 Month			48 Month				
	Bulk		Incremental		Bulk		Incremental		Bulk		Incremental		Bulk		Incremental		
	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	Filtek bulk-fill	X-tra Fill	
Marginal staining	Alfa	20	20	20	20	20	20	20	20	13	18	17	19	9	13	11	14
	Bravo	—	—	—	—	—	—	—	—	7	2	3	1	11	7	9	6
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Surface staining	Alfa	20	20	20	20	20	20	20	20	11	19	13	18	11	17	13	15
	Bravo	—	—	—	—	—	—	—	—	9	1	7	2	9	3	7	5
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Color match	Alfa	20	20	20	20	20	20	20	20	11	19	13	18	11	17	13	15
	Bravo	—	—	—	—	—	—	—	—	9	1	7	2	9	3	7	5
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anatomic form	Alfa	20	20	20	20	20	20	20	20	19	20	19	20	19	19	19	20
	Bravo	—	—	—	—	—	—	—	—	1	—	1	—	1	1	1	—
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Marginal adaptation	Alfa	20	20	20	20	20	20	20	20	8	11	10	13	3	7	4	3
	Bravo	—	—	—	—	—	—	—	—	12	9	10	7	17	13	16	17
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fractures and retention	Alfa	20	20	20	20	20	20	20	20	18	20	19	20	17	20	16	19
	Bravo	—	—	—	—	—	—	—	—	2	—	1	—	3	—	4	1
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Postoperative sensitivity	Alfa	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20	20
	Bravo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Charlie	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Recurrence of caries	Alfa	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	Bravo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Charlie	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

FBB, filtek bulk (bulk-filling); X-traB, X-tra fill (bulk-filling); FBI, Filtek Bulk (incremental); X-traI, X-tra fill (incremental)

Table 6 Comparison of groups according to FDI criteria

		Groups				p^{\ddagger}
		Filtek bulk-fill bulk (FBB) M (min–max)	Filtek bulk-fill incremental (FBI) M (min–max)	X-tra Fill bulk (X-traB) M (min–max)	X-tra Fill incremental (X-traI) M (min–max)	
Marginal staining	Baseline	1 (1–1) ^A	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1) ^A	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–3) ^{AB}	1 (1–3)	1 (1–3)	1 (1–3)	0.091
	48 months	2 (1–3) ^B	1 (1–3)	1 (1–3)	1 (1–3)	0.234
	p^{\ddagger}	< 0.001	0.165	0.086	0.142	
Marginal adaptation	Baseline	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1.000
	6 months	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1.000
	24 months	2 (1–3) ^B	1.5 (1–3) ^{AB}	1 (1–2) ^{AB}	1 (1–3) ^{AB}	0.350
	48 months	2 (1–3) ^B	2 (1–3) ^B	2 (1–3) ^B	2 (1–3) ^B	0.585
	p^{\ddagger}	< 0.001	< 0.001	< 0.001	< 0.001	
Fractures and retention	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–2)	1 (1–3)	1 (1–1)	1 (1–1)	0.296
	48 months	1 (1–2)	1 (1–3)	1 (1–1)	1 (1–2)	0.130
	p^{\ddagger}	0.101	0.327	1.000	0.392	
Surface staining	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–3)	1 (1–3)	1 (1–3)	1 (1–3)	0.188
	48 months	2 (1–4) ^a	1.5 (1–2) ^{ab}	1 (1–2) ^b	1 (1–2) ^b	0.006
	p^{\ddagger}	0.165	0.518	0.112	0.998	
Approximal anatomical form	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–2)	1 (1–2)	1 (1–1)	1 (1–1)	0.567
	48 months	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–1)	0.795
	p^{\ddagger}	0.572	0.572	0.392	1.000	
Postoperative sensitivity	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	48 months	1 (1–3)	1 (1–1)	1 (1–1)	1 (1–1)	0.392
	p^{\ddagger}	0.392	1.000	1.000	1.000	
Recurrence of caries	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	48 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	p^{\ddagger}	1.000	1.000	1.000	1.000	

Scoring: 1: very good, 2: good, 3: satisfactory, 4: unsatisfactory, 5: poor

[‡]Friedman’s two-way analysis of variance by ranks, [†]Kruskal–Wallis H test, *a* and *b* superscripts indicate differences between groups. There is no statistical difference between groups with the same superscripts. *A* and *B* superscripts indicate differences between measurements. There is no statistical difference between measurements with the same superscripts

Statistically significant values are presented in bold

4 years were not significant in terms of anatomical form ($P > 0.05$). Additionally, according to the statistical analysis, the difference between the groups was not significant in terms of anatomical form at the end of the 4-year evaluation ($P > 0.05$). Similarly, according to the statistical analysis, the difference between the bulk-filling and incremental

techniques of each resin composite was not significant at the 4-year recall ($P > 0.05$). These findings are shown in Tables 4, 5, 6, and 7.

When evaluated in terms of esthetic anatomical form and approximal anatomical form, at baseline, 80 restorations were scored as “clinically very good” according to the FDI

Table 7 Comparison of groups according to USPHS criteria

		Groups				<i>p</i> [‡]
		Filtek bulk-fill Bulk (FBB) <i>M</i> (min–max)	Filtek bulk-fill Incremental (FBI) <i>M</i> (min–max)	X-tra fill bulk (X-traB) <i>M</i> (min–max)	X-tra fill incremental (X-traI) <i>M</i> (min–max)	
Marginal staining	Baseline	1 (1–1) ^A	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1) ^A	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–2) ^{AB}	1 (1–2)	1 (1–2)	1 (1–2)	0.057
	48 months	2 (1–2) ^B	1 (1–2)	1 (1–2)	1 (1–2)	0.391
	<i>p</i> [‡]	< 0.001	0.850	0.518	0.850	
Marginal adaptation	Baseline	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1.000
	6 months	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1 (1–1) ^A	1.000
	24 months	2 (1–3) ^B	1,5 (1–2) ^{AB}	1 (1–2) ^{AB}	1 (1–2) ^{AB}	0.395
	48 months	2 (1–2) ^B	2 (1–2) ^B	2 (1–2) ^B	2 (1–2) ^B	0.366
	<i>p</i> [‡]	< 0.001	0.001	0.006	< 0.001	
Fractures and retention	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–3)	1 (1–2)	1 (1–1)	1 (1–1)	0.284
	48 months	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	0.139
	<i>p</i> [‡]	0.101	0.999	1.000	0.392	
Surface staining	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	0.195
	48 months	1 (1–3) ^a	1 (1–2) ^{ab}	1 (1–2) ^b	1 (1–2) ^b	0.006*
	<i>p</i> [‡]	0.165	0.518	0.938	0.999	
Color match	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	0.195
	48 months	1 (1–3) ^a	1 (1–2) ^{ab}	1 (1–2) ^b	1 (1–2) ^b	0.006*
	<i>p</i> [‡]	0.165	0.518	0.938	0.999	
Approximal anatomical form	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–2)	1 (1–2)	1 (1–1)	1 (1–1)	0,567
	48 months	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–1)	0.795
	<i>p</i> [‡]	0.572	0.572	0.392	1.000	
Postoperative sensitivity	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	48 months	1 (1–2)	1 (1–1)	1 (1–1)	1 (1–1)	0.392
	<i>p</i> [‡]	0.392	1.000	1.000	1.000	
Recurrence of caries	Baseline	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	6 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	24 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	48 months	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1.000
	<i>p</i> [‡]	1.000	1.000	1.000	1.000	

Scoring: 1: Alfa, 2: Bravo, 3: Charle

[‡]Friedman's two-way analysis of variance by ranks, [†]Kruskal–Wallis H test, *a* and *b* superscripts indicate differences between groups. There is no statistical difference between groups with the same superscripts. *A* and *B* superscripts indicate differences between measurements. There is no statistical difference between measurements with the same superscripts

*Mean rank values FBB: 49.2, FBI: 44.83, X-traB: 32.98, X-traI: 34.95

Statistically significant values are presented in bold

criteria. However, a minor distortion of 3 restorations after the 4-year recall was observed. According to the statistical analysis, differences between baseline and 4 years were not significant in terms of anatomical form ($P > 0.05$). Similarly, according to the statistical analysis, the difference between the bulk-filling and incremental techniques of each resin composite was not significant at the 4-year recall ($P > 0.05$). These findings are shown in Tables 4 and 5.

Color match/ staining surface

At baseline, 24 of the 80 restorations that were scored as “clinically very good” according to FDI criteria, and as “alpha” according to USPHS criteria, showed a color change at the end of the 4 years. According to the FDI criteria and USPHS criteria, FBB and FBI groups showed statistically significant surface discoloration after year 4 compared to baseline ($P < 0.05$). The color change of the X-traB and X-traI groups was not statistically significant ($P > 0.05$).

Additionally, according to the FDI and USPHS criteria, the difference between the groups was statistically significant in terms of color change at a 4-year evaluation ($P < 0.05$). According to the FDI criteria, when the resin composites were placed using the incremental technique, the difference between the FBI and X-traI groups was not statistically significant ($P > 0.05$). However, when the resin composites were also placed using the bulk-filling technique, the FBB group showed significantly greater color changes than X-traB according to the FDI and USPHS criteria ($P < 0.05$). Additionally, according to the statistical analysis, the difference between the bulk-filling and incremental techniques of each resin composite was not significant at the 4-year recall ($P > 0.05$) (Tables 6 and 7).

Discussion

The results of this study showed that no difference was observed, between the bulk-filling and incremental techniques of each resin composite at the 4-year recall when evaluated in terms of all criteria. However, FBB showed greater color change than X-traB at the end of the 4 years. Additionally, when each group was evaluated at the baseline and 4-year recall, there was a marginal incompatibility in all groups according to the FDI and USPHS criteria. All groups showed marginal discoloration according to the FDI and USPHS criteria. Also, FBB showed color change according to both criteria. The results of the present study showed that no difference was observed between the bulk-filling and incremental techniques regarding the placement technique of the bulk-fill composite when evaluated according to all criteria. Therefore the null hypothesis of the present study was accepted.

Researchers often use the USPHS and FDI criteria in clinical trials that evaluate restoration success. It is easy to define the characteristics of a clinically acceptable restoration using both techniques, and while the USPHS criteria are sufficient for long-term studies, the FDI criteria can give more sensitive results in short-term studies because it has more scoring options [23–25]. In the present study, the 4-year restoration success of the bulk-fill composite was examined using both FDI and USPHS criteria.

The main focus of this study was to evaluate the clinical efficacy of the placement technique of the bulk-fill composite; therefore, the type of adhesive was standardized. Clear fill universal adhesive was used for all restorations and has been tested in several in vitro and in vivo studies [12–29]. The adhesive was used in self-etch mode.

Although many in vitro and in vivo studies exist in the literature on bulk-fill resin composites [13–19], there are insufficient clinical studies about the materials tested in the current study [30–32]. Although in vitro tests contribute to the development of restorative materials, they cannot exactly reflect the variable conditions found in the mouth. Only one study [32] solely evaluates post-operative sensitivity to the placement technique (bulk-filling and incremental techniques) of the bulk-fill composite, while the clinical studies available in the literature compare bulk-fill composites with traditional composites. For this reason, it is not possible to make a direct comparison with previous studies. In terms of all criteria evaluated, except for color match, there were no significant effects of the placement technique of the bulk-fill composite evaluated in this study, at the 4-year recall.

Retention rate is one of the most important criteria that evaluate the clinical success of restorative materials. The American Dental Association requires a retention rate of at least 90% of the restorations after 18 months to obtain full acceptance [33]. In this study, after 4 years of survival, the rate of all restorations was 100%.

Bulk-fill composites have high transparency and more reactive photoinitiators that allow a higher depth of cure [19]. The higher reactivity enables the insertion of more thicker increments (4–5 mm) with uniform polymerization and degree of conversion [21–34]. Thanks to these factors, satisfactory mechanical properties and increased longevity of restorations are obtained [5]. In addition, bulk-fill composites contain polymerization modulators that achieve low contraction and less stress [35]. The thicker increments can also help to reduce air voids in restorations, forming a more homogeneous restoration [34, 35]. There was a minor fracture, which was clinically adequate and acceptable, in only two restorations in the FBI group at the end of 4 years. Except for this, the restorations were quite successful. The longevity of restorations is also related to parafunctional habits such as bruxism [36]. Van Dijk and Pallesen [36, 37] reported a remarkable number of failures caused by fractures

of the material and tooth, most of which occurred in patients with bruxism. Therefore, good clinical behavior of resin composites may have been related to the high depth of cure and reactive photoinitiators, while the reason for minor fracture in two restorations of the FBI group may have been related to bruxism.

The marginal staining of composites is usually related to insufficient bonding, failure in the polishing procedure, and the formation of a gap due to polymerization shrinkage between the cavity wall and the restoration [38]. Akman et al. [39] did not find any difference in marginal staining using X-tra fil resin composite. Similarly, Balkaya et al. [40] did not find any difference in marginal staining using Filtek bulk-fill. Conversely, although no significant effect of the placement technique was evaluated in the present study, at the 4-year recall, in FBB group, differences at the end of 4-year were significant when groups are evaluated within themselves. These differences may have resulted from the adhesive material used in the present study. In addition, unlike other studies, the present study offers 4 years of data.

The marginal adaptation of the composite restorations was found to be affected by polymerization shrinkage of the composites and the type of bonding agent [41]. Polymerization shrinkage is dependent on the volumetric shrinkage and elastic modulus of the composite material, as well as variables of interest such as cavity size and configuration. However, these properties largely depend on the amount of filler [9–11]. According to Campos et al. [42], the marginal adaptation of bulk-fill composites is adequate. Additionally, bulk-fill composites showed similar behavior to conventional composites in Class II cavities. According to studies that include X-tra fil and Filtek bulk-fill resin composite, no difference was found in terms of marginal adaptation at the end of 12 months [39, 40]. On the contrary, there was no significant effect of the placement technique of the bulk-fill composites evaluated in the present study on marginal adaptation. Furthermore, differences at the end of 4 years were significant when groups are evaluated within themselves. A reason for this difference may have been the adhesive material used in the present study. Also, 4-year recall data are presented in this study.

Staining of the restoration is one of the most common reasons for composite restorations to be replaced [43]. The color change of resin composites may be caused by extrinsic or intrinsic factors. Extrinsic factors may be associated with diet, plaque deposition, or surface deterioration. Intrinsic factors such as resin matrix components, filler amount and size, and initiator systems can cause a color change in resin composites [43]. According to Balkaya et al. [40] and Akman et al. [39], there was no statistical difference in terms of color change between bulk-fill resin composites. In the present study, the color change was significant in all groups after 4 years. These differences may be explained by the fact

that this study presents 4 years of data. On the other hand, in this study, there was no significant effect of the placement technique of the evaluated bulk-fill composites on restoration success at a 4-year recall. There was no difference between the two resin composites when applied incrementally, but when applied in bulk, FBB showed more color change than X-traB and X-traI. This may be related to factors such as resin matrix components, filler amount and size, and initiator systems.

Clinical studies are needed to clearly define the clinical behavior of a material. In the future, clinical studies can be carried out in different fields. One of them is biomimetic nano-hydroxyapatite, which is among the remineralization materials. There are current studies [44, 45] in this area, but clinical studies are needed. In addition, the use of such remineralization agents may increase clinical survival by preventing secondary caries that may occur in resin restoration. This will be economical for the patient.

Limitations

In this *in vivo* study, Class II cavities with low C-factor without cusp loss were included to provide standardization. Additional studies are needed including cavities with larger tissue loss to verify our results. In addition, in the present study to work with the split-mouth method, a total of four groups (two resin composite, and two methods) were applied to the same patient's mouth. If an additional material or method is added, the number of groups will increase, and it will be difficult to include suitable participants for the study. However, as in our previous study [26], additional *in vivo* and *in vitro* studies containing more materials can be performed if the split-mouth working principle is compromised. Another limitation of the present study is the evaluation of patients admitted to a single clinic. Studies with more participants in more than one center are needed. Additionally, a period of 4 years is not a sufficiently adequate time to evaluate the long-term clinical success of bulk-fill resin composites and to determine the difference between the placement techniques. Therefore, further long-term clinical follow-up studies are needed.

Conclusions

Within the limitations of the present study, no difference was observed between the bulk-filling and incremental techniques at the end of 4 years. FBB showed a greater color change than X-traB and X-traI at the end of 4 years. Filtek Bulk and X-tra fil bulk-fill resin composites showed marginal incompatibility and marginal staining at the end of

4 years. The FDI and USPHS evaluation criteria showed similar results after 4 years.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00784-022-04749-7>.

Declarations

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

Consent to participate Informed consent was obtained from all study participants.

Conflict of interest The authors declare no competing interests.

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