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CLINICAL ARTICLE

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Clinical comparison of high-viscosity glass-hybrid systems with a sculptable bulk-fill composite resin in different cavity types

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Abstract

Objective: This randomized, double-blind clinical investigation assessed the performance of two high-viscosity glass-ionomer systems and a bulk-fill composite in different cavity types.

Materials and Methods: In 146 participants, 360 (class I, II, and V) cavities were restored using three different materials (Equia Forte HT, Chemfill Rock, and SonicFill 2) with equal allocation. Using modified World Dental Federation criteria, restorations were assessed after 1 week, 6 months, and 18 months by an experienced examiner. Statistical analysis was conducted using Fisher's exact and Wilcoxon signed rank tests ($\alpha = 0.05$).

Results: After 18 months, 267 restorations were assessed in 116 participants. After 18 months, 5 Equia Forte HT restorations failed due to debonding and fracture. Only one loss was observed in the Chemfill Rock restorations. Equia Forte HT exhibited significantly lower retention than SonicFill 2 after 18 months ($p = 0.019$), irrespective of cavity type. At 1 week, 3 Class I restorations with SF showed postoperative sensitivity. The type of cavity did not affect the performance of the restorative materials used ($p > 0.05$).

Conclusion: Equia Forte HT and Chemfill Rock presented similar clinical performance regardless of color match. Equia Forte HT showed a lower performance compared to SonicFill 2.

Clinical significance: Glass-hybrid materials presented a lower performance in terms of color match or retention when compared to a sculptable bulk-fill composite resin.

KEYWORDS
Chemfill rock, color match, equia forte HT, retention, SonicFill 2, world dental federation

1 | INTRODUCTION

Composite resins are promising materials used successfully in dental clinics for the long term. However, they are more expensive, need to be more technically sensitive, present polymerization shrinkage stress, and may lead to cytotoxic effects on pulp cells and oral soft tissues.[1,2] Glass-ionomer restorative materials have advantages such as faster and bulk placement, economical, biocompatible, fluoride release and uptake, similar thermal coefficients to tooth-hard structures, and chemical bonding to the tooth-hard structures. However,

these materials present low fracture strength, fracture toughness, and high wear under occlusal forces.[3–5] Therefore, high-viscosity glass-ionomer (HVGI) materials have been introduced by some manufacturers to improve their mechanical properties and their limited indications.[6] They are an alternative to composite resin and amalgam as permanent restorative materials with a higher powder/liquid ratio.[7,8] The hardening mechanisms of HVGI materials are the same as those of conventional glass-ionomer materials. However, the surface hardness, wear resistance, and compressive strength are improved, reducing their solubility. Additionally, fluoride release is the same as conventional glass-ionomer materials, and their biocompatibility is similar.[7,9,10]

A glass hybrid restorative material (Equia Forte HT) has been recently produced as an improved HVGI material. This system contains a poly-acrylic acid with a higher molecular weight, providing more strong construction, and a coating agent containing a newer monomer, which offers protection throughout the early maturation period. The particle size distribution of Equia Forte HT has improved compared to its predecessor, Equia Forte. Consequently, the flexural and compressive strength have been further enhanced because of better matrix loading, making it suitable for stress-bearing and non-stress-bearing restorations.[11,12] Also, this material presents improved translucency and handling properties.[12] However, the data on the clinical performance of Equia Forte HT are limited. In addition, conflicting results regarding Equia Forte have been reported in the literature.[13–19]

In another HVGI material (Chemfill Rock), zinc-reinforced fillers were incorporated into glass-ionomer powder to improve fracture strength, wear resistance, and setting reactivity.[20,21] This reactive zinc-glass filler has a specific ion release structure, resulting in excellent material strength owing to the quick release of zinc ions during the setting reaction. This material does not require a cavity preconditioner or coating agent, reducing restoration placement periods without affecting compressive strength or surface hardness. Several laboratory investigations have assessed the mechanical and physical properties of this material,[12,22] but there is limited data about its clinical efficacy.

Composite restorations are considered the gold standard for evaluating other restorative materials in permanent teeth, especially in the load-bearing posterior area.[13] Recent developments in composite resins have led to the production of bulk-fill composites with minimal polymerization shrinkage, which can be applied quickly.[23] More recently produced bulk-fill composites have been evaluated in some in vitro and in vivo studies.[23–26] However, randomized controlled studies evaluating the clinical performance of new materials are still insufficient.

The purpose of the present study is to compare the clinical performance of two different HVGI materials with a bulk-fill composite in different cavities. The hypotheses tested in the study were that (1) clinical success would not differ between restorative materials, and (2) the type of cavity would not affect the clinical performance of the materials.

2 | MATERIALS AND METHODS

2.1 | Study protocol approval and registration

This study was conducted at the Restorative Dentistry Department of the University from December 2021 to July 2023 after the Ethics Committee of Recep Tayyip Erdogan University (2021/201) approved the study protocol. The clinical study has also been registered at ClinicalTrials.gov with the identifying number NCT06109987.

2.2 | Estimation of the sample size

A previous study stated that the clinical success rate of an HVGI restorative system was 92.3% (in class II cavities) at a 4-year follow-up.[6] The average annual failure rate of this restorative material was calculated to be 1.9%, assuming that restoration losses are linear. Consequently, the clinical success rate for this restorative material after 18 months is expected to be about 97%. A superiority test was conducted with a significance level of 0.05 and a statistical power of 80% (www.sealedenvelope.com). To detect a 25% difference between the test groups, a minimum sample size of 29 restorations per group was needed. This number was raised to 40 restorations to account for the fact that some participants might drop out.

2.3 | Participant selection

The study recruited participants who received routine dental treatment at the university's dental clinic. In order to be eligible for the clinical trial, individuals were required to meet the following criteria: being in a state of good general health, being over the age of 18, having a minimum of 20 teeth that are correctly positioned, and having at least one primary carious lesion (class I, II, or V) that requires restorative treatment. The study excluded patients with removable prostheses, inadequate oral hygiene leading to multiple caries, periodontal and gingival disease, uncontrolled parafunctional behaviors, severe bruxism, and dentin hypersensitivity. Furthermore, those who were taking medication, undergoing orthodontic treatment, pregnant, or feeling spontaneous pain were not included in the study.

One dental expert evaluated 160 individuals to determine their eligibility. The clinical assessments were conducted by a mouth mirror, a periodontal probe, and an explorer while the area was well-lit. A total of 14 patients were excluded from the study: 10 due to failure to satisfy all the inclusion criteria and 4 due to their refusal to participate. A total of 146 patients were determined to be eligible. Patients who agreed to participate in the study were apprised in detail about its goals and potential problems. The participation of patients was entirely voluntary, and all participants gave their written informed consent forms.

TABLE 1 The materials used in this study.

Materials	Components	Application methods
Equia Forte HT GC, Tokyo, Japan (2206221)	95% fluoro-alumina-silicate glass, polybasic carboxylic acid, polyacrylic acid, water, camphorquinone	Mix capsules for 10 s, and apply to prepared cavity using a capsule applier
Equia Forte Coat GC, Tokyo, Japan (2104211)	Methyl methacrylate, photoinitiator, synergist, phosphoric acid ester monomer, butylated hydroxytoluene	Apply to restoration surfaces using a micro-applicator and light-cured for 20 s
GC Cavity conditioner GC, Tokyo, Japan (1805111)	Polyacrylic acid (20%), aluminum chloride hexahydrate (2.5%), distilled water	Applying to the prepared cavity for 10 s, removing by wet-cotton pellet, then drying with cotton-pellet without excessive drying.
Chemfill Rock Dentsply, USA (1903000819)	Zinc-modified fluoro-alumino-silicate glass, polyacrylic acid, itaconic acid	Mix capsules for 15 s, and apply to prepared cavity using a capsule applier
SonicFill 2 Kerr, USA (8318161)	Ba-glass, silicon dioxide, ethoxylated bisphenol A dimethacrylate, 3-trimethoxysilylpropyl methacrylate, triethyleneglycoldimethacrylate, bisphenol-A-bis-(2-hydroxy-3-mehacryloxypropyl) ether	Apply to cavity up to 5 mm using the sonic handpiece, and light-cured for 20 s
Ambar Universal FGM, Joinville, Brazil (280122)	10-methacryloyloxydecyldihydrogen phosphate, methacrylic monomers, photoinitiator, ethanol, stabilizers, silica nanoparticles, and coinitiators	Apply two layers with a microbrush for 20 s (10 s for each layer), gently air-drying for 10 s, light-cured for 10 s

2.4 | Randomization

The website www.sealedenvelope.com was used to determine the randomization procedure. This process was conducted by an independent researcher who was not engaged in any experimental steps. Randomization was performed separately for each cavity type. The designed restorative material groups were placed on sequentially numbered cards and then sealed in opaque envelopes. The operator opened each envelope on the day of the restorative procedures to detect the treatment procedure. If a patient had more than one restoration, the second restoration was selected in a different quadrant than the first restoration. Treatment was always started in the lowest numbered quadrant (1 → 4) and initially applied to a tooth with the highest number (FDI) in each quadrant. The study did not include any additional teeth that needed restorations in the same quadrant, and those teeth were treated based on the usual clinical practice. Patients and evaluators were blinded to treatment groups, but the operator knew who received which treatment.

2.5 | Cavity preparation and restorative procedures

Characteristics of the teeth were examined and recorded before the restorative procedure. Periapical radiographs were used to determine the status and extent of the carious and any potential periodontal or periapical pathology that may require endodontic treatment. The teeth that received treatment were vital, symptom-free, and in occlusal contact. All participants received their teeth cleaned using a rubber-cup with a pumice slurry, then washed to remove all remnants of debris or plaque. After that, a shade guide was employed to determine the color of the restorative materials. Local anesthetic (Ultraver D-S Forte, Beykoz, Istanbul) was applied to prevent sensitivity or pain during operations.

To prepare the cavities, diamond fissure or spherical burs (Wilofa Diamant, Willi Lohmann, Germany) were used in a high-speed handpiece (Kavo, Biberach, Germany) with copious water cooling. Soft dentin tissues were removed by a tungsten-carbide round bur (Ela, Engelskirchen, Germany) at a low-speed until hard dentin was detected using an excavator. Cavity preparation is limited only to removing tooth tissues affected by caries. Extra retention or bevels were not prepared on the cavity walls to prevent unnecessary loss of tooth structures. The bevels were created only when class V cavities were to be restored with the composite material (SonicFill 2) up to 1 mm at the enamel margins. Cavity preparation did not include cusps; the cavity depths ranged from 2 to 5 mm. After finishing the cavity preparation, the cavity was washed with an air-water spray and dried by the cotton pellet. The matrix system (Dispodent Sectional Matrix, Istanbul, Turkey) and appropriate wedges were placed in class II cavities.

A universal adhesive (Ambar Universal Bond, FGM, Brazil) was applied to cavities in the self-etch technique consistent with the manufacturer directives (Table 1) prior to the placement of a bulk-fill composite material (SonicFill 2; SF2; Kerr, Orange, USA). The first layer of the adhesive was applied vigorously by scrubbing for 10 s, followed by a second layer for 10 s. It was then lightly air-dried for 10 s to allow the solvent to evaporate. Next, the adhesive agent was light-cured for 10 s by an LED unit (VALO, Ultradent, Utah, USA) with a 1000 mW/cm^2 power output. Regardless of the type of cavity, the prepared cavities were filled with a single composite piece up to

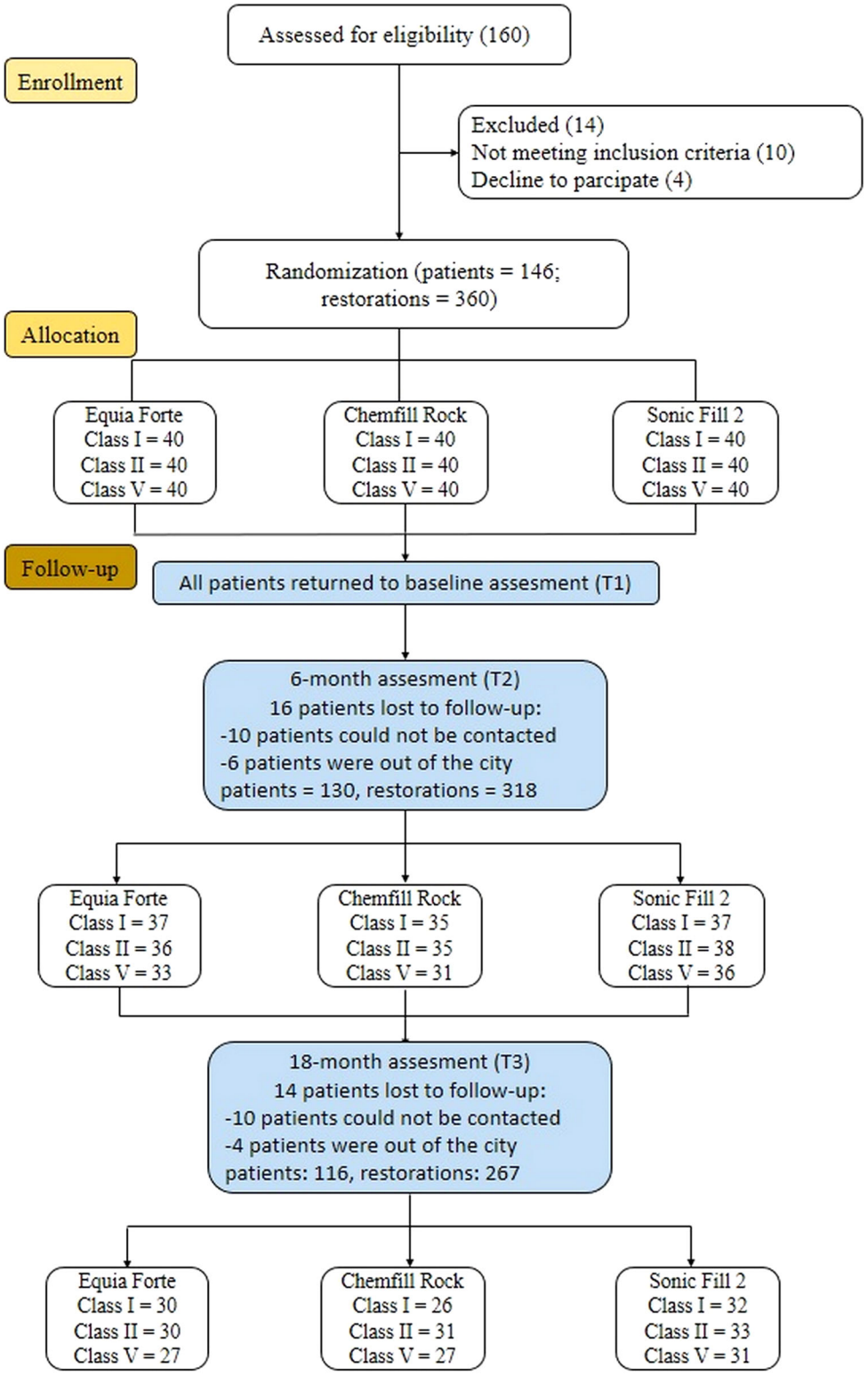

FIGURE 1 Clinical flow diagram presenting the recruitment of participants and their follow-up for 18 months.

5 mm, which was then polymerized twice for 20 s. Occlusion control was performed using articulation paper (Alfred Becht, Carl-Zeiss, Offenburg, Germany), followed by corrections using fine and ultra-fine diamond burs (Wilofa Diamant, Willi Lohmann, Germany). Finishing and polishing procedures were completed with polishing rubbers (Dien Fong Silicon Rubber Polisher, Shenzhen, China) at low speed under water cooling.

Before placing Equia Forte HT (EFHT; GC, Tokyo, Japan), 20% polyacrylic acid conditioner (Cavity Conditioner, GC, Tokyo, Japan) was applied for 10 s, followed by removal with a wet-cotton pellet. Then, the cavity was gently dried with cotton. EFHT and ChemFill Rock (CR; Dentsply Sirona, USA) capsules were placed in the automatic mixer by pressing with a finger, mixed for 10 s and 15 s, respectively, and injected into the cavity with a special capsule holder. The

TABLE 2 Distribution of restorations according to jaws.

Material		Maxilla		Mandible		Total
		Premolar	Molar	Premolar	Molar	
EF	Class I	4	9	3	14	87
	Class II	6	9	3	12	
	Class V	6	5	8	8	
CR	Class I	3	9	3	11	84
	Class II	8	6	5	12	
	Class V	7	7	8	5	
SF	Class I	3	14	4	11	96
	Class II	12	5	6	10	
	Class V	8	8	10	5	
Total		57	72	50	88	267

materials were condensed by a ball burnisher and waited to harden. Occlusion was checked with articulating paper. The corrections were performed with ultra-fine diamond finishing burs and then polished by polishing discs (OptiDisc, Kerr, Switzerland). With a micro brush, Equia Forte Coat (GC, Tokyo, Japan) was applied to EFHT restoration surfaces and then polymerized for 20 s. Surface coating was not used for ChemFill Rock restorations. The application methods and compositions of the materials are given in Table 1. All restorations were made by the same experienced operator.

2.6 | Clinical evaluation

The participants were called back after 1 week (T1), 6 (T2), and 18 (T3) months. Restorations were assessed in terms of retention and fracture, color or translucency match, marginal and surface staining, marginal adaptation, anatomic form, postoperative sensitivity, and secondary caries by modifying the World Dental Federation (FDI) criteria.[27] The estimated findings received the following scores: clinically excellent (1), clinically very good (2), clinically good (3), clinically sufficient or satisfactory (4), clinically unsatisfactory (4), and clinically poor (5).

One qualified clinician assessed the restorations using a mirror and probe under a reflector light. He examined 10 photos representing possible scores for each criterion before clinical evaluation. The postoperative sensitivity of the participants was evaluated by asking whether they had any pain throughout this period. Bite-wing and periapical radiographs were taken at 6- and 18-month evaluation periods. Periapical lesions, secondary caries, and compatibility with adjacent teeth were checked.

2.7 | Statistical analysis

Chi-square and Fisher Exact tests were performed to assess differences between restorative materials. Friedman and Wilcoxon Signed rank tests were performed to assess the effect of time on the restorations. Kaplan–Meier and Long-rank tests were also performed to determine the overall survival rates of the restorations. Survival rates were estimated by time to failure (4 or 5 scores) during clinical evaluation, regardless of color match and translucency criteria. The significance level was set at 0.05. The data was analyzed using statistical software (IBM SPSS 27.0; Chicago, IL, USA).

3 | RESULTS

A clinical flow diagram presenting the recruitment of participants is presented in Figure 1. Fourteen patients out of 160 did not meet the inclusion criteria and were excluded. One hundred forty-six patients (62 males and 84 females) were chosen, with a mean age of 28 (18–62). Initially, all patients participated (100%), but the participation rate fell to 89% in the 6-month evaluation. The participation rate further decreased to 79.4% in the 18-month evaluation. Finally, the last participation involved 116 patients, with 267 restorations being evaluated.

Table 2 displays the distribution of restorations based on jaws. Of the restorations, 59.9% (160) were placed in molars, and 40.1% (107) were placed in premolars. In terms of location, 48.3% (129) of the restorations were in the maxilla, and 51.6% (138) were in the mandible.

3.1 | Fracture and retention

No loss of retention or fracture was observed in any restoration at baseline and 6-month follow-up. After the 18-month follow-up, four of the EFHT restorations (1 in class I or V and 2 in class II) were lost, and 1 (class II) was fractured (Table 3). Only one of the CR restorations (class II) was lost (Table 4). No loss of retention or fracture was observed in the SF2 restorations (Table 5). The type of cavity did not affect the performance of the restorative materials used ($p > 0.05$). EFHT (94.2%) showed significantly lower retention than SF2 (100%) after 18 months ($p = 0.019$), regardless of cavity type (Table 6). More restoration failures (de-bonding and fracture) were observed in class II cavities (4.4%) regardless of restorative material (Table 6), with no significant differences ($p = 0.26$). The Kaplan–

TABLE 3 Clinical assessment scores of Equia Forte HT restorations during the 18 months according to different cavity types.

		Class I			Class II			Class V		
Criteria	**Score**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Fracture and retention	1	40 (100%)	37 (100%)	29 (96.6%)	40 (100%)	36 (100%)	27 (90.0%)	40 (100%)	33 (100%)	26 (96.2%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	1 (3.3%)	0	0	0
	5	0	0	1 (3.3%)	0	0	2 (6.6%)	0	0	1 (3.7%)
Color or translucency match	1	15 (37.5%)	15 (40.5%)	13 (44.8%)	20 (50%)	16 (44.4%)	10 (35.7%)	17 (42.5%)	15 (45.4%)	10 (38.4%)
	2	20 (50%)	17 (45.9%)	14 (48.2%)	15 (37.5%)	15 (41.6%)	13 (46.4%)	17 (42.5%)	13 (39.3%)	10 (38.4%)
	3	5 (12.5%)	5 (13.5%)	1 (3.4%)	5 (12.5%)	5 (13.8%)	4 (14.2%)	5 (12.5%)	5 (15.1%)	5 (19.2%)
	4	0	0	1 (3.4%)	0	0	1 (3.5%)	1 (2.5%)	0	1 (3.8%)
	5	0	0	0	0	0	0	0	0	0
Marginal and surface staining	1	40 (100%)	37 (100%)	29 (100%)	40 (100%)	36 (100%)	27 (96.4%)	40 (100%)	33 (100%)	26 (100%)
	2	0	0	0	0	0	1 (3.6%)	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Marginal adaptation	1	40 (100%)	37 (100%)	29 (100%)	40 (100%)	36 (100%)	27 (96.4%)	40 (100%)	33 (100%)	26 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	1 (3.6%)	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Anatomic form	1	34 (85%)	32 (86.4%)	24 (82.7%)	30 (75%)	25 (69.4%)	21 (75%)	40 (100%)	33 (100%)	26 (100%)
	2	5 (12.5%)	5 (13.5%)	4 (13.7%)	8 (20%)	8 (22.2%)	7 (25%)	0	0	0
	3	1 (2.5%)	0	1 (3.4%)	2 (5%)	3 (8.3%)	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Seconder caries	1	40 (100%)	37 (100%)	29 (100%)	40 (100%)	36 (100%)	28 (100%)	40 (100%)	33 (100%)	26 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0

TABLE 3 (Continued)

Criteria	Score	Class I			Class II			Class V		
		T1	T2	T3	T1	T2	T3	T1	T2	T3
Postoperative sensitivity	1	40 (100%)	37 (100%)	29 (100%)	40 (100%)	36 (100%)	28 (100%)	40 (100%)	33 (100%)	26 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0

Note: 1, clinically very good; 2, clinically good; 3, clinically sufficient; 4, clinically unsatisfactory; 5, clinically poor.

Meier test presented significant differences among the survival rates of restorative materials over 18 months (Figure 2). The overall survival rates were 94.2% for EFHT, 98.8% for CR, and 100% for SF2 after 18 months.

3.2 | Color match and translucency

The color match between teeth and the materials differed significantly for restorative materials ($p < 0.001$, Tables 3–5). The color and translucency of EFHT restorations matched the teeth better compared to CR restorations ($p < 0.001$) but were worse than SF2 restorations ($p < 0.001$, Table 6, and Figure 3).

3.3 | Marginal and surface staining

No surface staining was observed in any restorative material over time (Figure 3). No marginal discoloration was observed in any restorations at 1 week and 6-month follow-ups. During the 18-month follow-up, only 1 (3.2%) restoration showed minor marginal staining in the class II EFHT group (Table 3).

3.4 | Marginal adaptation

No deterioration in marginal adaptation was observed in any restorations during the 18-month follow-up (Figure 3). Only 1 (3.2%) restoration for EFHT in the class II cavity showed slight marginal discrepancies after an 18-month follow-up (Table 3).

3.5 | Anatomic form

There were no significant differences in anatomical form between the materials at baseline and during all evaluations ($p > 0.05$), regardless of cavity type. Furthermore, no significant difference was found between the initial measurements and later recalls for any of the materials ($p > 0.05$) (Tables 3–5). After 18 months, achieving proper anatomical form was significantly more difficult in class I and II cavities compared to class V (Table 6 and Figure 3) ($p = 0.002$), regardless of restorative material type.

3.6 | Postoperative sensitivity

No postoperative sensitivity was observed in the EFHT and CR restorations during the 18-month follow-up. Only three restorations for SF2 in the class I cavities showed slight postoperative sensitivity at 1 week (7.5%), with no significant differences when compared to other times ($p > 0.05$) or when compared to other cavities ($p = 0.269$) (Table 5). This postoperative sensitivity disappeared over time.

TABLE 4 Clinical assessment scores of Chemfill Rock restorations during the 18 months according to different cavity types.

		Class I			Class II			Class V		
Criteria	**Score**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Fracture and retention	1	40 (100%)	35 (100%)	26 (100%)	40 (100%)	35 (100%)	30 (96.7%)	40 (100%)	31 (100%)	27 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	1 (3.2%)	0	0	0
Color or translucency match	1	5 (12.5%)	5 (14.2%)	3 (11.5%)	8 (20%)	6 (17.1%)	5 (16.6%)	10 (25%)	10 (32.2%)	7 (25.9%)
	2	3 (7.5%)	3 (8.5%)	2 (7.6%)	3 (7.5%)	3 (8.5%)	3 (10%)	8 (20%)	6 (19.3%)	4 (14.8%)
	3	25 (62.5%)	21 (60%)	18 (69.2%)	21 (52.5%)	17 (48.5%)	17 (56.6%)	20 (50%)	14 (45.1%)	15 (55.5%)
	4	7 (17.5%)	4 (11.4%)	3 (11.5%)	5 (12.5%)	5 (14.2%)	2 (6.6%)	2 (5%)	0	0
	5	0	1 (2.8%)	0	3 (7.5%)	4 (11.4%)	3 (10%)	0	1 (3.2%)	1 (3.7%)
Marginal and surface staining	1	40 (100%)	35 (100%)	26 (100%)	40 (100%)	35 (100%)	30 (100%)	40 (100%)	31 (100%)	27 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Marginal adaptation	1	40 (100%)	35 (100%)	26 (100%)	40 (100%)	35 (100%)	30 (100%)	40 (100%)	31 (100%)	27 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Anatomic form	1	32 (80%)	28 (80%)	18 (69.2%)	31 (77.5%)	26 (74.2%)	21 (70%)	40 (100%)	31 (100%)	27 (100%)
	2	8 (20%)	6 (17.1%)	6 (23.1%)	7 (17.5%)	9 (25.7%)	6 (20%)	0	0	0
	3	0	1 (2.8%)	2 (7.6%)	2 (5%)	0	3 (10%)	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Seconder caries	1	40 (100%)	35 (100%)	26 (100%)	40 (100%)	35 (100%)	30 (100%)	40 (100%)	31 (100%)	27 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0

TABLE 4 (Continued)

Criteria	Score	Class I			Class II			Class V		
		T1	T2	T3	T1	T2	T3	T1	T2	T3
Postoperative sensitivity	1	40 (100%)	35 (100%)	26 (100%)	40 (100%)	35 (100%)	30 (100%)	40 (100%)	31 (100%)	27 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0

Note: 1, clinically very good; 2, clinically good; 3, clinically sufficient; 4, clinically unsatisfactory; 5, clinically poor.

3.7 | Secondary caries

No secondary caries were seen in any restorations during the 18-month follow-up.

4 | DISCUSSION

This study evaluated class I, II, and V restorations restored with two HVGI materials and a bulk-fill composite over 18 months. No significant difference was detected in the clinical performance of the restorative materials based on all the assessed criteria, regardless of color match and fracture/retention criteria. Thus, the first null hypothesis was mainly accepted.

The results obtained in the current clinical trial showed that cavity type did not affect the clinical performance of all materials used. Therefore, the second null hypothesis was accepted. The load-bearing capability of restorative materials in class V cavities may be less critical than in classes I and II. Materials used for class V preparations need to have specific characteristics, such as increased wear resistance, a lower elastic modulus, and a good appearance. At first, these materials were thought to have a modulus of elasticity similar to that of dentine.[28] In the study, although glass-ionomer materials have some advantages in the cervical region, SF2 composite resin was also found to be successful despite its high elasticity modulus (81.3 wt% filler content), which may not be enough to compensate for occlusal stresses, resulting in increased marginal leakage owing to diminished stress-relieving function.[29,30] SF2 material can be applied into the cavity as a flowable composite resin via sonic activation, providing quick placement and precise adaptation to the cavity walls, improving bonding strength and clinical performance. A recent study reported that sonic activation can improve the material adaptation to the cavity walls and margins.[24] In addition, the adhesive's elastic modulus and bond strength may be enough to resist the occlusal force and prevent micro-leakage.

Some randomized clinical trials have compared composite resin and glass-ionomer materials in non-carious cervical defects, but none have examined them in carious lesions in the cervical area. In this study, 1 EFHT restoration (3.7%) in class V cavities was lost after an 18-month follow-up, while restoration loss was not observed in the CR and SF2 groups. The number of restoration failures of a nano-composite material (12%) and a glass-ionomer (18%) reported in the previous study quite exceeded the findings of the present study when 18-month data were compared.[8] This variation may be explained by the fact that many non-carious cervical lesions exhibit little or no retention form, making it challenging to create a strong bond with the tooth. Another study reported that after 2-year, an HVGI material (Equia Fil) in cervical defects exhibited significantly lower retention (91%) than in a nano-hybrid composite (100%).[14] The failure of Equia Fil restorations has been attributed to the insufficient depth of the lesion, which makes it challenging to restore shallow lesions without adequate retentive areas.

TABLE 5 Clinical assessment scores of SonicFill 2 restorations during the 18 months according to different cavity types.

		Class I			Class II			Class V		
Criteria	**Score**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Fracture and retention	1	40 (100%)	37 (100%)	32 (100%)	40 (100%)	38 (100%)	33 (100%)	40 (100%)	36 (100%)	31 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Color or translucency match	1	40 (100%)	37 (100%)	32 (100%)	40 (100%)	38 (100%)	33 (100%)	40 (100%)	36 (100%)	31 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Marginal and surface staining	1	40 (100%)	37 (100%)	32 (100%)	40 (100%)	38 (100%)	33 (100%)	40 (100%)	36 (100%)	31 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Marginal adaptation	1	40 (100%)	37 (100%)	32 (100%)	40 (100%)	38 (100%)	33 (100%)	40 (100%)	36 (100%)	31 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Anatomic form	1	36 (90%)	33 (89.1%)	29 (90.6%)	34 (85%)	32 (84.2%)	28 (84.8%)	40 (100%)	36 (100%)	31 (100%)
	2	4 (10%)	4 (10.8)	3 (9.3%)	6 (15%)	5 (13.1%)	3 (9.1%)	0	0	0
	3	0	0	0	0	1 (2.6%)	2 (6.1.%)	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
Seconder caries	1	40 (100%)	37 (100%)	32 (100%)	40 (100%)	38 (100%)	33 (100%)	40 (100%)	36 (100%)	31 (100%)
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0

TABLE 5 (Continued)

Criteria	Score	Class I			Class II			Class V		
		T1	T2	T3	T1	T2	T3	T1	T2	T3
Postoperative sensitivity	1	37 (92.5%)	37 (100%)	32 (100%)	40 (100%)	38 (100%)	33 (100%)	40 (100%)	36 (100%)	31 (100%)
	2	3 (7.5%)	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0

Note: 1, clinically very good; 2, clinically good; 3, clinically sufficient; 4, clinically unsatisfactory; 5, clinically poor.

The retention rate is one of the most reliable factors indicating the clinical performance of the restorative material. The American Dental Association states that the retention rate must be at least 90% after an 18-month follow-up for a material to be clinically successful.[31] In this study, all materials showed retention rates above this rate. However, EFHT material showed a poor clinical success rate (90%) in class II cavities regarding retention and fracture compared to the findings of previous studies.[17,18] On the other hand, another study reported that Equia Forte material in class II cavities showed a high failure rate (25%) due to material loss and marginal fracture after 1 year.[19] Many factors influence the clinical performance of dental materials, such as cavity size, tooth type and location, technique used, operator skill, parafunctional habits, and oral hygiene. A previous study suggested that large cavities may significantly affect the clinical performance of restorative material.[17] Also, it has been stated that even after particular counseling sessions, there were no behavioral changes regarding teeth brushing, despite awareness of the importance of oral hygiene routines, which can fail the restoration in patients with poor oral hygiene due to dental plaque accumulation.[32,33]

Only one loss of EFHT restorations was observed in class I cavities, which is in line with the findings of a previous study that reported one retention failure for Equia Forte after a 12-month follow-up.[16] In all restorations, CR material was found to be more successful than EFHT material in terms of retention. A cavity conditioner was applied before the placement of EFHT material after removing decay. The use of polyacrylic acid-based agents in dental procedures facilitates the elimination of the smear layer before restoration, promotes ion exchange, and enhances bond strength by increasing surface energy. It also opens the mouths of dentinal tubules and creates microporosity, which makes it easier for the hybrid layer to form.[34] However, conflicting findings have been stated regarding the effect of conditioners on dentin bonding strength.[35,36] A previous study reported that CR material without conditioner showed higher bond strength to caries-affected dentin under intra-pulpal pressure when compared to HVGI materials (GC materials) with conditioner.[36] The lower bond strength of GC materials has been attributed to increased dentin permeability with the conditioner, leading to a wetter surface and possibly weaker bonding. In addition, in this study, only one fracture was seen for EFHT restorations in class II cavities, which showed no significant differences among materials. A previous in vitro study reported that EF and CR materials showed similar flexural strength and hardness values.[12]

Five of the EFHT restorations and one of the CR restorations failed in terms of fracture and retention. No failure was determined in the SF2 restorations, which corroborates the findings of previous studies that evaluated the initial version of SF2 in class I and II cavities up to 2-year follow-up.[25,26] However, it has also been reported that SF restorations showed marginal staining and discrepancy, which conflicts with the results of the present study.[25,26] This can be explained by the improved properties of SF. SF2 represents better adaptation, marginal integrity, and lower polymerization shrinkage stress than the

TABLE 6 Total clinical assessment scores after the 18 months according to restorative materials or different cavity types.

		Restorative materials			Cavity types		
Criteria	**Score**	**EFHT**	**CR**	**SF2**	**Class I**	**Class II**	**Class V**
Fracture and retention	1	82 (94.2%)	83 (98.8%)	96 (100%)	87 (98.9%)	90 (95.7%)	84 (98.8%)
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	1 (1.1%)	0	0	0	1 (1.1%)	0
	5	4 (4.6%)	1 (1.2%)	0	1 (1.1%)	3 (3.2%)	1 (1.2%)
Color or translucency match	1	33 (39.7%)	15 (18.1%)	96 (100%)	48 (55.1%)	48 (52.7%)	48 (57.1%)
	2	37 (44.5%)	10 (12%)	0	16 (18.4%)	16 (17.5%)	14 (16.6%)
	3	11 (13.2%)	49 (59%)	0	19 (21.8%)	21 (23%)	20 (23.8%)
	4	2 (2.4%)	5 (6%)	0	4 (4.6%)	3 (3.2%)	1 (1.2%)
	5	0	4 (4.8%)	0	0	3 (3.2%)	1 (1.2%)
Marginal and surface staining	1	82 (98.7%)	83 (100%)	96 (100%)	87 (100%)	90 (98.9%)	84 (100%)
	2	1 (1.3%)	0	0	0	1 (1.1%)	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
Marginal adaptation	1	82 (98.7%)	83 (100%)	96 (100%)	87 (100%)	90 (98.9%)	84 (100%)
	2	1 (1.3%)	0	0	0	1 (1.1%)	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
Anatomic form	1	71 (85.5%)	66 (79.5%)	88 (91.6%)	74 (85.1%)	70 (76.9%)	84 (100%)
	2	11 (13.2%)	12 (14.4%)	6 (6.2%)	10 (11.4%)	16 (17.5%)	0
	3	1 (1.2%)	5 (6%)	2 (2.4%)	3 (3.4%)	5 (5.4%)	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
Seconder caries	1	83 (100%)	83 (100%)	96 (100%)	87 (100%)	91 (100%)	84 (100%)
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
Postoperative sensitivity	1	83 (100%)	83 (100%)	93 (96.8%)	84 (96.5%)	91 (100%)	84 (100%)
	2	0	0	3 (3.2%)	3 (3.4%)	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0

Note: 1, clinically very good; 2, clinically good; 3, clinically sufficient; 4, clinically unsatisfactory; 5, clinically poor.

original version of SF2, thanks to special rheological modifiers and a new nano-scale zirconium oxide filler system.[37] On the other hand, in this study, a universal adhesive (Ambar Universal Bond) was used, which contains acidic functional monomers that promote chemical bonding with dental hard tissues. The use of functional monomers, particularly 10-methacryloyloxydecyl dihydrogen phosphate, improves the self-etching capability to dentin and enamel, providing long-term bonding stability. To our knowledge, there are no studies evaluating the clinical success of Ambar universal adhesive. Previous studies have reported that the Ambar universal bond showed similar or better micro-tensile bond strength and degree of conversion compared to other universal adhesives.[38,39]

No significant color changes were observed in the restorative materials over time, supporting the observations of previous studies that reported good color stability f or glass-ionomer restorations.[7,15] Modern HVGI materials demonstrate improved color compatibility with adjacent tooth structures and have more color options than traditional glass-ionomer materials, mostly thanks to the presence of

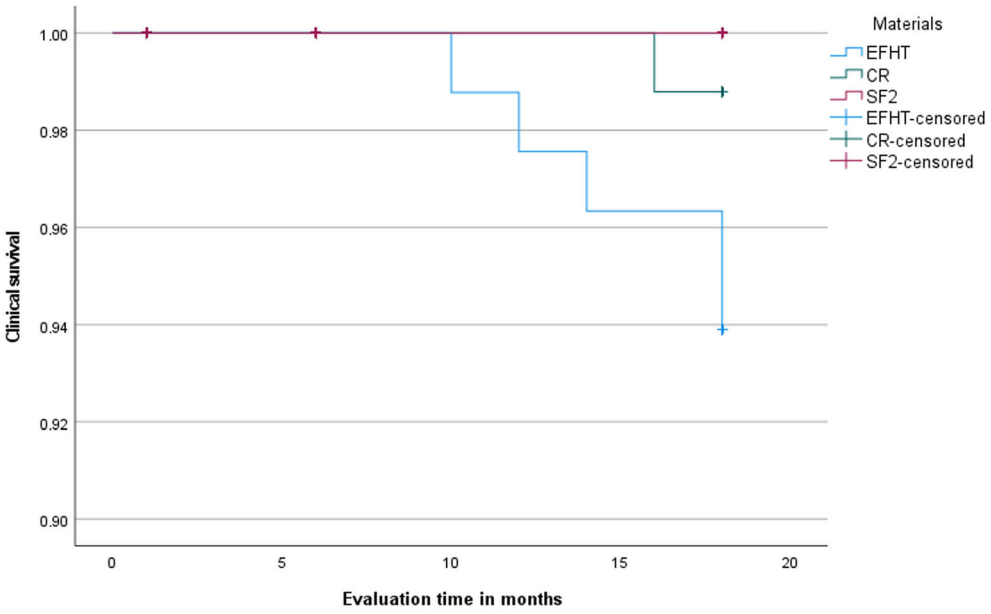

FIGURE 2 Kaplan–Meier survival curves for the restorative materials used (Log-rank, $p = 0.030$).

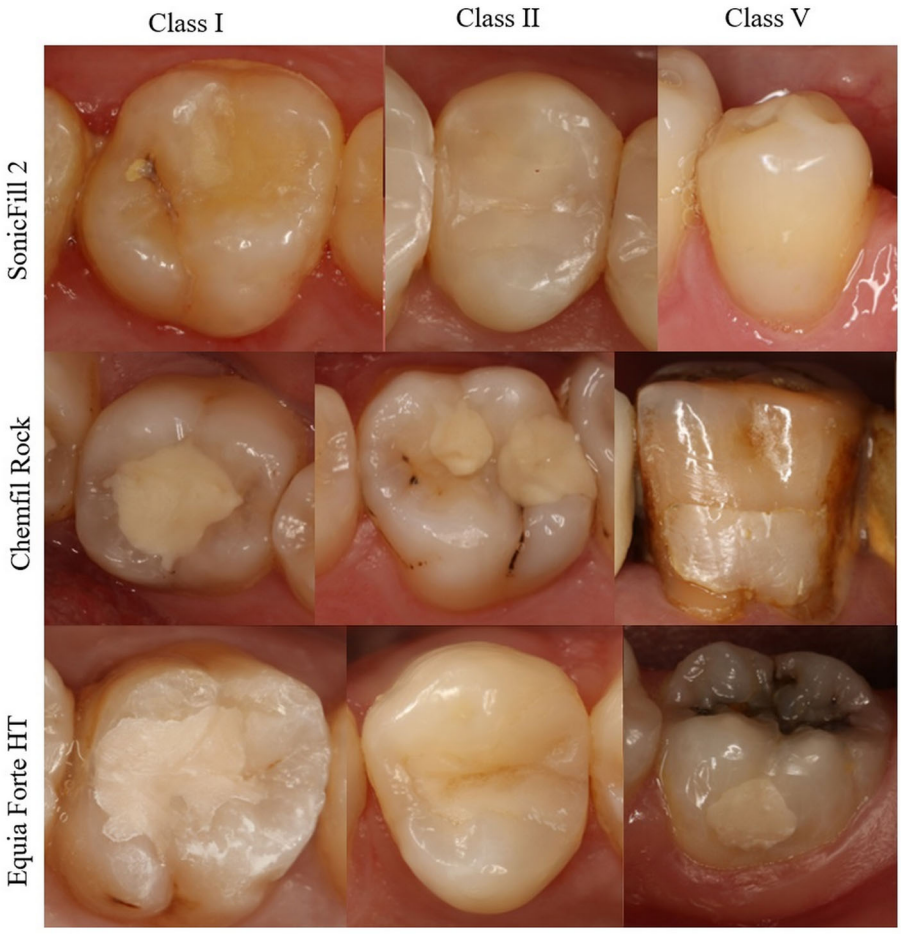

FIGURE 3 Representative images of tested restorative materials in different cavities after 18 months.

small-glass particles and resin-based coating agents.[15] However, in this study, both glass-ionomer materials showed a significantly discernible color difference with adjacent teeth compared to the SF2 composite. CR was less successful in color matching than EFHT, which can be explained by their different compositions. These results align with the findings of a previous study, which examined reinforced glass-ionomer materials with or without resin-coating varnish.[15] The restorations did not need to be replaced because they were placed in

the posterior part of the mouth and did not cause discomfort in the patients.

In this study, no failure was observed for all restorations in terms of marginal discoloration and discrepancy. However, only one marginal discoloration (3.2%) and one marginal discrepancy (3.2%) for EFHT restorations in class II cavities were determined. These results corroborate the findings of a previous study that reported no marginal staining or marginal discrepancy for Equia Forte in class I cavities.[16] However, a recent study reported that Equia Forte showed 5.4% marginal staining and 8.1% marginal discrepancy in class II cavities after 5-year follow-up,[17] which exceeds the findings in our study. Comparing the longer follow-up period to the current trial,[6,18] a higher number of failures may be anticipated. However, additional factors that may contribute to explaining these differences need to be investigated. A previous study reported higher deterioration in marginal adaptation with increasing restoration sizes.[5]

In this study, no postoperative sensitivity was detected for any restorations regardless of cavity-type, except for SF2. In class I restorations, postoperative sensitivity was detected in three restorations of SF2 at the initial evaluation (7.5%), but no sensitivity was observed in the 6-month and 18-month controls. Generally, postoperative sensitivity in composite restorations has been associated with stress caused by polymerization shrinkage.[40] Previous studies have reported postoperative sensitivity ranging from 0 to 26.5% in restorations filled with bulk-fill composite materials.[19,41] Polymerization stress is affected by some factors, such as cavity geometry, the viscosity of the material, and the degree of monomer conversion.[42] There is more shrinking stress in class I cavities with a high C factor, which leads to sensitivity. It has been found that SF2 showed lower polymerization shrinkage stress, which is attributed to its higher filler content (81.3 wt%), resulting in reduced post-operative sensitivity.[23]

The current study assessed the clinical performance of restorative materials within a short 18-month follow-up period. Studies with less than 3 years of follow-up time have been reported to provide little information because most materials do not fail in the initial period. However, studies conducted with shorter observation times are valuable in eliminating materials that lead to premature catastrophic failures.[1] Clinical randomized studies with extended follow-up periods may reveal problems including secondary caries, marginal and surface discoloration, and other undetected detrimental consequences.[43] Thus, studies with longer follow-up periods are needed for the results of this study to be validated.

5 | CONCLUSIONS

Within the limitations of the present clinical study, it was determined that:

1. No significant difference was found between the high-viscosity glass-ionomer materials in all cavity types, but Equia Forte HT showed a better color match.
2. Equia Forte HT showed lower clinical performance than SonicFill 2 in terms of retention/fracture and color match/translucency criteria.
3. The type of cavity did not influence the clinical performance of restorative materials.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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