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ORIGINAL ARTICLE

Clinical performance of high-viscosity glass ionomer and resin composite on minimally invasive occlusal restorations performed without rubber-dam isolation: a two-year randomised split-mouth study

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Abstract

Objective The aim of this clinical trial was to evaluate the 2-year clinical performances of high-viscosity glass ionomer and nanohybrid resin composite restorations performed without rubber dam isolation.

Materials and methods Occlusal carious lesions on the right and left mandibular second molars of 56 patients (26 female, 30 male patients) were restored in a split-mouth design. High-viscosity glass ionomer (Hv-GIC) (Equia, GC) and nanohybrid resin composite (GrandioSO, Voco) were used as restorative materials. Clinical evaluations of the restorations were performed according to the Fédération Dentaire Internationale criteria. Data were analysed using the Friedman's analysis of variance and Mann-Whitney U tests (α=0.05).

Results After 2 years, the success rate of Hv-GIC restorations was 96% and that of resin composite restorations was 100%. Hv-GIC showed lower marginal discoloration and greater surface wear and loss of anatomic form (p<0.05). Resin composite showed significantly better surface lustre.

Conclusion The 2-year performance of resin composite was similar to that of Hv-GIC for the occlusal restorations of mandibular second molars, in spite of being performed without rubber-dam isolation.

Clinical relevance Saliva contamination can be a clinically significant problem for dental restorations. High-viscosity glass ionomers are a satisfactory alternative to resin composites with the advantage of fast application in such situations.

Trial registration Clinical Trials Registration number-date: NCT04488380-22/07/2020, retrospectively registered.

Keywords High-viscosity glass ionomer · Restorative glass ionomer · Nanohybrid composite · Split-mouth · Occlusal restoration · Rubber dam

Introduction

Resin composites are the most commonly used restorative materials with the advantages of requiring minimal cavity preparations, 'tooth-like' optical properties, and good mechanical properties. However, isolation is of considerable importance for long-lasting adhesion between the tooth and resin composite. Contamination of the tooth surfaces can hamper effective contact between the adhesive and adherent. Salivary proteins fill the micro-gaps on tooth surfaces, and water interferes with the polymerisation of the resin composite and negatively affects adhesion [1, 2]. Blood contamination can occur before and after the polymerisation of the adhesive. Cleansing and drying the blood-contaminated tooth surfaces and reapplication of the adhesive may recover the adhesion potential when the contamination occurs before light polymerisation [3]. However, if it occurs after light polymerisation, blood proteins adsorb onto the polymerised adhesive surface and the oxygen-inhibited layer might be lost [4].

Use of rubber dam is considered as the ideal method for effective tooth isolation [5]. However, patient refusal and inconvenient and time-consuming characteristics of the rubber dam application procedure are common reasons of not using

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rubber dam [6]. In some cases, tooth eruption may be not complete to support a rubber-dam clamp [7]. Tooth isolation can be performed with cotton rolls and a saliva ejector in such instances.

During dental treatments, difficulties in isolation are often encountered. Pooling of saliva in the mandibular molar region due to the patient's position and effect of gravity is one of the common problems. Unintentional tongue movements can also render the stable positioning of cotton rolls difficult. In addition, salivary flow rates are higher in younger individuals than those in older adults [8]. Hence, cases wherein rubber dam is not used, especially mandibular molar restorations of younger patients with high salivary flow rates, are challenging in terms of saliva isolation. When the teeth to-be-restored are at risk for saliva contamination, restorative materials that can be applied in a short time and are less affected by moisture should be preferred.

Amalgam and restorative glass ionomers are alternative materials for restorations that are at risk for saliva contamination. Amalgam is less preferred because of the unaesthetic appearance and requirement for standard and larger cavity designs [9]. Recently, minimally invasive cavity preparation is preferred to macroretentive amalgam cavities. Considering the concept of minimally invasive dentistry, cavities limited to removal of demineralised and unsupported enamel, and removal of carious dentin [10]. In addition, partial caries removal and the stepwise excavation technique are alternative operative caries management interventions to the traditional one step complete caries removal which increases the incidence of pulp exposure in vital, symptomless, and carious primary and permanent teeth [11]. Therefore, excessive removal of sound tooth structures for retention which is required for amalgam cavities is not needed. Moreover, the phase down of amalgam use was discussed because of the ecotoxic features of mercury [12].

Restorative materials that contain glass particles include resin-modified glass ionomer cements, compomers, high-viscosity glass ionomer cements (Hv-GIC), and giomers. Hv-GICs are the most advantageous among glass-ionomer-based restorative materials, owing to no requirement for the use of adhesive agents, ease of application, and acceptable resistance to masticatory forces [13]. Hv-GICs are manufactured by reducing the particle size and altering the composition ratios of conventional glass ionomer cements [14]. Consequently, their physical and mechanical properties are enhanced and setting reactions are accelerated. Moreover, the physical properties of Hv-GIC are not affected by early exposure to water. Hence, it is known as a 'moisture-tolerant' material [15]. These advancements in the mechanical and physical properties of Hv-GICs have improved their clinical performance in Class I and Class II cavities [16, 17].

Resin composites and adhesive systems are technique-sensitive materials. Therefore, isolation of the operative field is critical for the long-term success of restorations [1]. For more than a century, rubber-dam application has been believed to be the optimal method of isolation for dental procedures. However, in clinical practice, most resin composite restorations are not performed under rubberdam isolation [5]. In a previous clinical study, the use of cotton rolls or retraction cords was found to be similar to rubber-dam isolation in terms of retention of Class V restorations [18]. In addition, on evaluation of the main factors affecting the longevity of direct anterior and posterior composite resin restorations, use of rubber dam isolation was reported to have no correlation with the clinical performance of composite resin restorations [19].

Therefore, the aim of this randomised, split-mouth, and single-centre clinical study was to compare the 2-year clinical performances of Hv-GIC and nanohybrid resin composite restorations performed on occlusal surfaces without rubber-dam isolation. The null hypothesis was 'there are no differences in the 2-year clinical success rates of Hv-GIC and resin composite restorations performed without rubber-dam isolation'.

Materials and methods

This study followed the Consolidated Standarts of Reporting Trials (CONSORT) statement [20].

Ethics approval

This study was approved by the Ethics Committee at Izmir Katip Celebi University Faculty of Medicine (#13-93). Prior to the initiation of the study, the aim of the study, treatment procedures, and study-related risks were explained to the patients, and informed consents were obtained.

Protocol registration

This clinical trial was registered at ClinicalTrials.gov (NCT04488380).

Trial design, settings, and location of data collection

This study was a parallel design, randomised, split-mouth, double blinded, and single-centre, clinical trial. The allocation ratio was 1:1 for the participants into the study groups. The restorations were performed on patients between October 2015 and April 2016 in the clinic of the Department of Restorative Dentistry, Izmir Katip Celebi University.

Sample size calculation

The primary outcome was the overall clinical success. All other FDI criteria were considered secondary outcomes. The sample size for the study was calculated using the G*Power programme (G*Power Ver. 3.0.10, Franz Faul, Universität Kiel, Germany, http://www.psycho.uniduesseldorf. de/aap/projects/gpower) considering the primary outcome. At least 47 restorations per group were required to obtain the f=0.25 effect size difference between the study groups with a power of 80% and an alpha error of 5%. Considering the long-term follow-up period, 20% (9 restorations) were added, and finally, the study was initiated with the participation of 56 patients.

Patient selection

Seventy-seven patients younger than 19 years of age were considered for inclusion in this study; however, nine patients did not meet the inclusion criteria, and 12 patients declined to participate in the study. After exclusion, 112 occlusal carious lesions in 56 patients (30 male and 26 female patients; mean age, 16.8 years, range 15-18) were enrolled in this clinical trial. The flow chart of patients and the progress of all restorations through each stage of the study are shown in Fig. 1.

The inclusion criteria for the study were as follows: (1) good health and oral hygiene, (2) occlusal primary carious lesions on both mandibular second molars, (3) permanent mandibular second molars with mesial and occlusal contacts, (4) contraindication to the use of rubber dam due to tooth position, patient rejection or patient inadaptability, and (5) the ability to return for periodic follow-up visits. The exclusion criteria was as follows: (1) hypomineralisations, carious lesions and restorations on mandibular second molar except for enamel pit carious lesions or initial carious lesions on buccal, lingual and approximal surfaces.

In this study, the reasons for not using rubber dam isolation were as follows: patients or their parents refused to use rubber dam before the restorative procedure (n=40), patients could not tolerate the rubber dam application during the restorative procedures (n=8), and tooth eruption was not sufficient for clamp retention (n=8).

Lesion selection and randomisation

The teeth were initially cleaned by using a rotary polishing brush and paste for clear visual examination. The severity of the lesion was determined according to the international caries detection and assessment system (ICDAS). Patients with occlusal caries that scored 3 or 4 on the ICDAS scale (a white or brown spot lesion with localised enamel breakdown, without visible dentine exposure-ICDAS Score 3 or an underlying dentine shadow-ICDAS Score 4) were included in the study. A simple randomisation was prepared using a computer generated sequence (basic random number generator function of Microsoft Excel). First, the patients included in the study were numbered according to their examination order. These numbers were recorded in a column in an Excel document by the staff. Second, the allocated groups were combined into two pairs; resin composite/Hv-GIC and Hv-GIC/resin composite since it was a split mouth study. The first alternative (resin composite/ Hv-GIC) was written for half of the patients in the adjacent column, and the second alternative (Hv-GIC/resin composite) for the other half of the patients. The random number generator was used for each patient in the third column. The allocation assignment was performed by ordering the allocation groups according to the ascending values of random numbers. The first restorative material of each pair was applied to the tooth with smallest ISO notation in each patient. This randomisation table was prepared by a staff in the Department of Restorative Dentistry who did not take place in the research. However, the operator had given all details about the patients and treatments to the staff before generating this randomisation sequence.

Blinding

Clinical evaluations were performed by the two examiners who were not involved with the restorative procedures and were blinded to the group assignment. Participants were also blinded to the group assignment.

Restorative procedure

All restorative procedures were performed by a single experienced dentist. Oral hygiene instructions were provided, and oral prophylaxis was performed before the treatment. Minimally invasive cavity preparations were performed, and preservation of sound tooth structure was attempted in all cases. Cavities were not extended to non-carious fissures and bevel preparation was not performed. Enamel was prepared using diamond round burs (Diatech, Heerbrugg, Switzerland) at high speed with water cooling. Slow speed tungsten carbide burs and hand instruments were used to remove soft caries. The cavity preparation was restricted to the removal of soft and firm carious tissues and ended when the affected dentin was reached. Isolation was performed with cotton rolls and a normal saliva ejector. The absence of saliva or blood contamination was verified macroscopically using a dental mirror, before and during the restoration process.

Occlusal lesions on mandibular second molar teeth were restored using either an Hv-GIC (Equia Fil, GC, Alsip, IL, USA) with a resin-based coat (Equia Coat) or a nanohybrid resin composite (GrandioSo, Voco GmbH, Cuxhaven, Germany) with a self-etch adhesive system (Clearfil SE Bond, Kuraray, Tokyo, Japan). The manufacturers and compositions of the materials used in the study are shown in Table 1.

All materials were manipulated according to the manufacturers' instructions. For restorations in the Hv-GIC group, a cavity conditioner (Cavity Conditioner, GC, Tokyo, Japan)

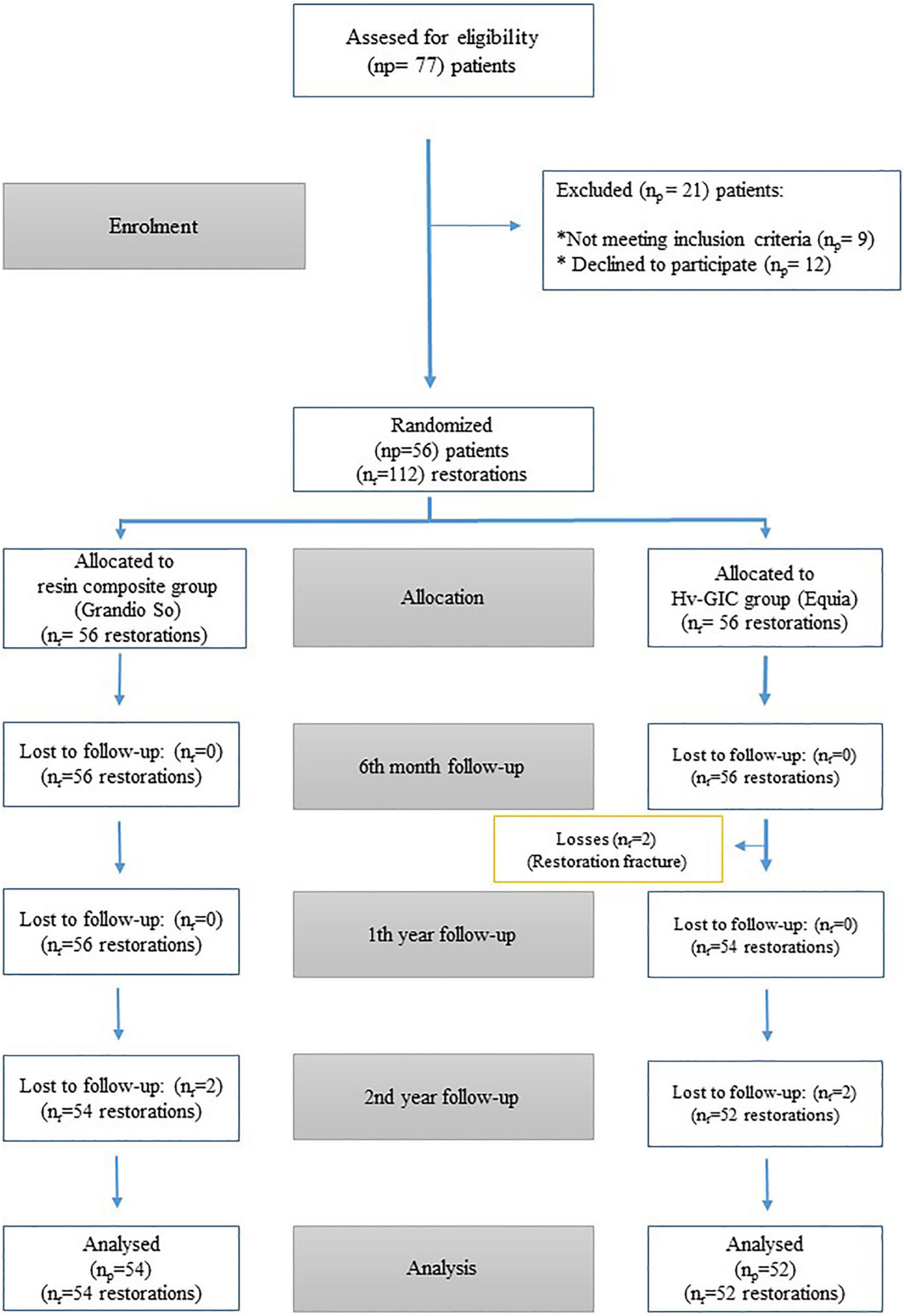

Fig. 1 Flow chart. np; number of patients, nr; number of restorations

Table 1 Restorative materials and application procedures

Material		Composition	Manufacturer
Clearfil SE Bond	Adhesive	Primer: MDP, HEMA hydrophilic aliphatic dimethacrylate dl-camphorquinone, water, accelerators Adhesive: MDP, HEMA, Bis-GMA, Hydrophobic dimethacrylate dl-Camphorquinone N,N-diethanol-p-toluidine, Silanated colloidal silica	Kuraray, Tokyo, Japan
GrandioSO	Nano-hiybrid resin composite	Functionalized SiO_2 nano-particle (20–40 nm) and glass ceramics (1 μm) (73% by vol. and 89% by weight)	VOCO, Cuxhaven, Germany
Cavity Conditioner		77% distilled water, 20% polyacrylic acid, 3% aluminium chloride hydrate	GC, Tokyo, Japan
EquiaFil	Conventional glass ionomer cement	Powder: 95% strontium fluoro alumino-silicate glass, 5% polyacrylic acid Liquid: 40% aqueous polyacrylic acid	GC, Tokyo, Japan
EQUIA Coat	Resin based coat	40%-50% methyl methacrylate, 10%-15% colloidal silica, 0.09% camphorquinone, 30%-40% urethane methacrylate, 1%-5% phosphoric ester monomer	GC, Tokyo, Japan

Bis-GMA: bisphenol-A glycidyl dimethacrylate; HEMA: 2-hydroxyethyl methacrylate; MDP: 10-metacryloxydecyle dihydrogen phosphate

was applied for 10 s on the enamel and dentine, and the cavity was rinsed and gently air-dried. Equia capsules were mixed for 10 s and were injected immediately in the cavity in bulk and contoured with hand instruments. After setting of the Hv-GIC (2.5 min), the occlusion was verified, and the restoration was finished with superfine diamond burs (Diatech, Swiss Dental, Heerbrugg, Switzerland) under water cooling. The coating (Equia Coat, GC) was applied and light polymerised for 20 s at a standard power of 1000 mW/cm^2 (Valo; Ultradent Products Inc., South Jordan, UT, USA).

For restorations in the resin composite group, enamel surfaces were selectively etched for 15 s with phosphoric acid (Scotchbond Universal Etchant, 3M ESPE, ST Paul, USA). A primer (SE Primer) was actively applied for 20 s and was gently air-dried. A bonding agent (SE Bond) was applied, gently air-thinned, and light polymerised for 10 s (Valo; Ultradent Products Inc). The nanohybrid resin composite was placed in 2-mm increments, and each increment was light polymerised for 20 s. The composite restorations were finished using extrafine-grit diamond burs at high speed and polished with rubber polishing cups (Astropol, Ivoclar, Schaan, Liechtenstein) at low speed.

Evaluation procedure

The restorations were examined at baseline (1 week after the restoration) and subsequently at 6-month, 1-year, and 2-year follow-ups using the Fédération Dentaire Internationale (FDI) criteria [21]. The clinical evaluation was performed by two examiners other than the clinician who performed the restorative procedures. The three primary criteria used for evaluation were (a) functional (fractures, retention, marginal adaptation, and wear), (b) aesthetic (surface roughness, surface staining, marginal staining, and anatomic form), and (c) biological (postoperative sensitivity and recurrence of caries). Functional examination was performed by visual evaluation and tactile assessment with a probe, aesthetic properties were evaluated by visual examination, and biological properties were evaluated by air pressure application for hypersensitivity test, and visual and tactile examination for postoperative sensitivity.

In case of disagreement, consensus was achieved after discussion. Prior to the study, 20 Class I composite restorations were used to calibrate both intra- and inter-examiner reliability. The examiners were unaware of the material used to restore the lesion.

According to the FDI criteria [21], Scores 1 and 2 represent the highest degree of clinical acceptability, while Score 3 means a clinically satisfactory restoration with minor shortcomings. Score 4 stands for a clinically unsatisfactory but reparable restoration, and Score 5 indicates an unacceptable restoration that needs to be replaced.

Statistical analysis

Data were analysed using the SPSS software, version 20.0 (IBM Corporation, NY, USA). Differences in criteria during the two-year evaluation period were analysed with the Friedman's analysis of variance test. Differences between the two restorative materials for each criterion during each evaluation year were analysed with the Mann-Whitney U test. The statistical significance was defined as α=0.05.

Results

All patients returned for the 6-month and 1-year follow-up recall evaluations. Two patients (two restorations from each group) did not return for the 2-year follow-up, leading to a recall rate of 93%. Table 2 presents the scores allotted during the recall periods, and statistical comparisons between the groups and Fig. 2 represents the restoration images at baseline, 1 year, and 2 year. The test of inter-examiner agreement resulted in Cohen's Kappa value of 0.84.

During this study, no patients complained of pain or postoperative sensitivity in the restored teeth. At baseline, no significant differences existed in all the evaluated criteria between the two study groups.

After 6 months, a significant difference was observed in terms of surface lustre in favour of the resin composite group (p=0.02). There were no significant differences between the study groups in other evaluated criteria. When compared to baseline, the difference in surface lustre of restorations in the Hv-GIC group was significant (p<0.05) (Table 3).

After 1-year, the success rate (percentage of clinically acceptable restorations) of resin composite was 100% and Hv-GIC was 96%, and there was no statistical difference between the study groups (p>0.05). Two Hv-GIC restorations were scored unacceptable (Score 4) due to fracture and retention problems (Fig. 3). However, recurrent caries formation was not evident. Resin composite was significantly better than Hv-GIC in terms of surface lustre (p<0.05). There were no significant differences between the tested materials in other evaluated criteria. When compared to baseline, the differences in surface lustre, surface staining, and marginal adaptation scores were significant for both groups (p<0.05). Moreover, significant reductions in surface anatomy, fracture, and retention were observed in the Hv-GIC restorations (p<0.05).

After 2 years, no evaluated restorations were scored as unacceptable, and the success rate was the same as the previous year. There were significant differences in all evaluated criteria except for postoperative sensitivity and recurrence of caries for restorations in both resin composite and Hv-GIC groups as compared to baseline (Table 3). Regarding surface lustre, anatomic form, and wear, resin composite was significantly better than Hv-GIC (p<0.05), though Hv-GIC showed significantly less marginal staining (p=0.026). There were no differences in other criteria between resin composite and Hv-GIC restorations.

Discussion

The 2-year clinical performances of Hv-GIC and nanohybrid resin composite in occlusal restorations of mandibular second molar teeth were evaluated in this study. The null hypothesis, 'there are no differences in the 2-year clinical success rates of Hv-GIC and resin composite restorations performed without rubber-dam isolation' was not rejected. Two Hv-GIC restorations were designated clinically unacceptable because of restoration fracture at 1-year follow-up; however, no significant differences were found between the study groups.

Clinical studies are essential to evaluate the long-term biological, functional, and aesthetic performances of restorative materials. Restorations on mandibular molars are challenging in terms of saliva isolation, especially when rubber-dam placement is not possible. Resin composites are hydrophobic and require a well-isolated environment during placement. Unlike resin composites, glass ionomers are moisture-tolerant because of the requirement of moisture in the setting reaction and in the maintenance of mechanical properties. They do not involve time-consuming steps such as etching, primer and bond application, and light polymerisation. This study was designed as an age-restricted, randomised, and split-mouth trial to eliminate the effects of variables such as the salivary flow rate, stage of tooth eruption, location of the lesions, occlusion, and method of tooth brushing.

During the maturation stage, water is important for glass ionomer cements; however, both dehydration and water contamination during the initial setting reaction may impair the physical properties of the cement [22]. A nanofill coating material is used with the Equia system to prevent water contamination during the maturation stage. Application of a coating material seals the surface of Hv-GIC restorations, protects the margins, decreases the roughness, and gives a glossy surface [17]. There was no difference between the material groups in surface lustre at baseline in this study. However, after 6 months, the Hv-GIC restorations started losing surface lustre gradually over 2 years. At the 2-year follow-up, there was a significant difference between surface lustre scores of Hv-GIC and resin composite. This finding corresponds with that of previous clinical studies that evaluated the performances of Class I, II, and V Hv-GIC restorations [17, 23–25]. The loss of surface lustre could be attributed to the degradation of coating material by occlusal or brushing forces.

Resin composite surfaces also roughen over time, and surface lustre scores were significantly different from the baseline at 6 months, 1 year, and 2 years, similar to the surfaces of Hv-GIC. GrandioSo is a nanohybrid resin composite with 20–40 nm silicon dioxide nanoparticles and 0.5–3 μm glass-ceramic particles. The effects of filler size on the surface roughness of resin composite are well known [26]. We believe that the increase in surface roughness of resin composite with time was the result of abrasion of the organic matrix and exposure of the glass-ceramic fillers in this study. Similar to the results of this study, a previous study showed that after polishing, GrandioSo was rougher than other tested composites [27].

Marginal discoloration is a sign of deterioration of marginal adaptation and develops on marginal irregularities such as

Table 2 Comparison of the tested restorative materials according to the FDI criteria throughout the evaluation periods

		Resin composite (GrandioSo)					High-viscosity glass ionomer (Equia Fil)					p value*		
		At baseline	6-month follow up	1-year follow up	2-year follow up	Clinically acceptable restorations (%)	At baseline	6-month follow-up	1-year follow-up	2-year follow-up	Clinically acceptable restorations (%)	6 months	1 year	2 years
		Score 1/2/3/4/5	Score 1/2/3/4/5	Score 1/2/3/4/5	Score 1/2/3/4/5		Score 1/2/3/4/5	Score 1/2/3/4/5	Score 1/2/3/4/5	Score 1/2/3/4/5				
Aesthetic properties	Surface lustre	53/3/0/0/0	46/10/0/0/0	40/16/0/0/0	28/22/4/0/0	100%	54/2/0/0/0	31/25/0/0/0	15/39/0/0/0	5/38/9/0/0	100%	**0,02**	**0,000**	**0,000**
	Surface staining	56/0/0/0/0	53/3/0/0/0	50/6/0/0/0	43/10/1/0/0	100%	56/0/0/0/0	53/3/0/0/0	50/4/0/0/0	43/9/0/0/0	100%	1,000	0,509	0,591
	Marginal staining	56/0/0/0/0	54/2/0/0/0	54/2/0/0/0	34/18/2/0/0	100%	56/0/0/0/0	55/1/0/0/0	52/2/0/0/0	42/10/0/0/0	100%	0,560	1,000	**0,026**
	Anatomic form	43/13/0/0/0	43/13/0/0/0	41/15/0/0/0	37/17/0/0/0	100%	40/16/0/0/0	39/17/0/0/0	34/20/0/0/0	22/30/0/0/0	100%	0,396	0,227	**0,011**
Functional properties	Fracture and retention	56/0/0/0/0	56/0/0/0/0	54/2/0/0/0	49/5/0/0/0	100%	56/0/0/0/0	56/0/0/0/0	50/3/1/2/0	48/3/1/2/0	96%	1,000	0,134	0,530
	Marginal adaptation	55/1/0/0/0	54/2/0/0/0	49/7/0/0/0	40/14/0/0/0	100%	55/1/0/0/0	51/5/0/0/0	43/10/1/0/0	40/11/1/0/0	100%	0,244	0,291	0,697
	Wear	56/0/0/0/0	56/0/0/0/0	56/0/0/0/0	49/5/0/0/0	100%	56/0/0/0/0	55/1/0/0/0	52/2/0/0/0	28/23/1/0/0	100%	0,317	0,080	**0,000**
Biological Properties	Postoperative sensitivity	56/0/0/0/0	56/0/0/0/0	56/0/0/0/0	54/0/0/0/0	100%	56/0/0/0/0	56/0/0/0/0	54/0/0/0/0	52/0/0/0/0	100%	1,000	1,000	1,000
	Recurrence of caries	56/0/0/0/0	56/0/0/0/0	56/0/0/0/0	51/3/0/0/0	100%	56/0/0/0/0	56/0/0/0/0	54/0/0/0	50/1/1/0/0	100%	1,000	1,000	0,687

*Mann Whitney U Test (p<0.05)

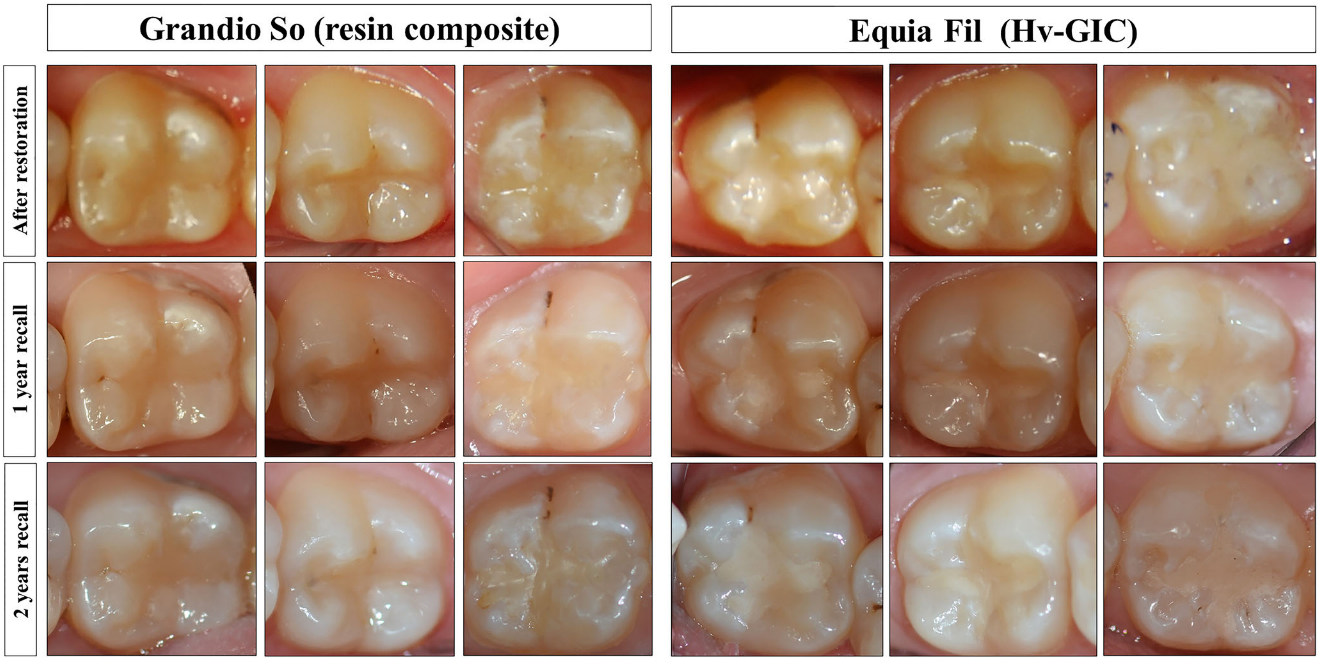

Fig. 2 Resin composite and Hv-GIC restorations at baseline, 1 year and 2 years follow-ups

gaps and fractures [28]. Hv-GIC restorations demonstrated significantly lower marginal staining than resin composite ones after 2 years, but not in the 6-month and 1-year evaluations. Polymerisation shrinkage, leading to failure of adhesion, postoperative sensitivity, marginal staining, and recurrent caries formation, is the principal disadvantage of resin composite occlusal restorations that have a high C-factor [29]. In addition, composites have a higher coefficient of thermal

Table 3 Change of restorations comparison to baseline at different time intervals

Evaluation criteria		Material	Evaluation periods *p* values*		
			6 months	1 year	2 years
Aesthetic properties	Surface lustre	GrandioSo	0.080	**0.001**	**0.000**
		Equia Fil	**0.000**	**0.000**	**0.000**
	Surface staining	GrandioSo	0.083	**0.014**	**0.007**
		Equia Fil	0.083	0.046	**0.003**
	Marginal staining	GrandioSo	0.157	0.157	**0.000**
		Equia Fil	0.317	0.157	**0.002**
	Anatomic form	GrandioSo	1.000	0.157	**0.046**
		Equia Fil	0.317	**0.025**	**0.000**
Functional properties	Fracture and retention	GrandioSo	1.000	0.157	**0.025**
		Equia Fil	1.000	**0.042**	**0.010**
	Marginal adaptation	GrandioSo	0.317	**0.014**	**0.000**
		Equia Fil	**0.046**	**0.002**	**0.001**
	Wear	GrandioSo	1.000	1.000	**0.025**
		Equia Fil	0.317	0.083	**0.000**
Biological Properties	Postoperative sensitivity	GrandioSo	1.000	1.000	1.000
		Equia Fil	1.000	1.000	1.000
	Recurrence of caries	GrandioSo	1.000	1.000	0.830
		Equia Fil	1.000	1.000	0.180

*Wilcoxon Signed Rank Test (p<0.05)

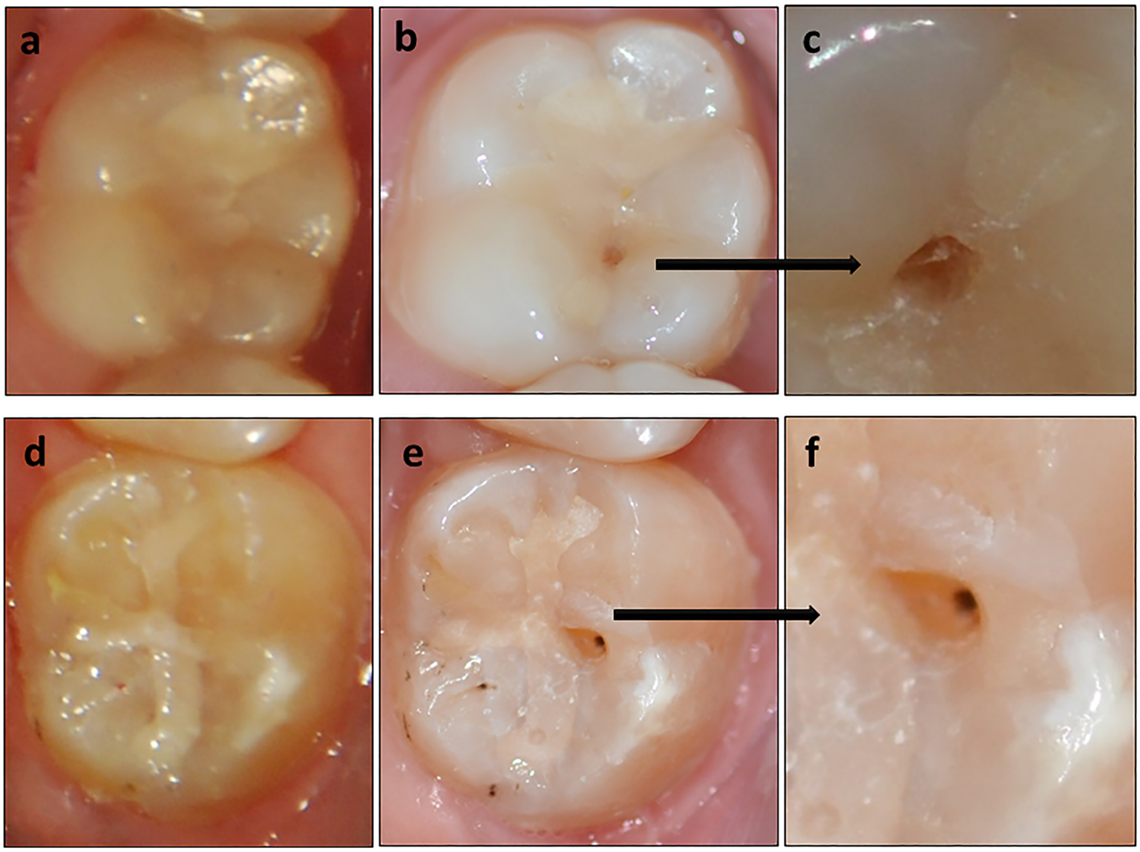

Fig. 3 Images of clinically unacceptable Hv-GIC restorations at 1-year follow-up. **a**, **e** At baseline. **b**, **e** At 1 year. **c**, **f** Extended images of chipping/fracture parts

expansion than glass ionomer cements and hard dental tissues [22]. Possible isolation inadequacies and aforementioned factors could be responsible for the marginal staining of composite restorations observed in this study after 2 years. Similar to our results, Turkun and Kanık reported moderate staining in only few restorations, with marginal discoloration in Class I and II Hv-GIC restorations at the 6-year follow-up.

Conventional glass ionomer cements have a relatively low wear resistance, and wear of the contact-free area is three times greater than that in resin composites [30]. Although Hv-GIC is more resistant to wear than conventional glass ionomer cements, and surface coating increases the strength and wear resistance for a limited period [17, 22], significantly higher wear rates were observed in the Hv-GIC restorations after 2 years. Less surface discoloration of Hv-GIC restorations could be considered a positive effect of wear. In contrast, continuous wear could lead to significant loss of anatomic form of the restorations.

Saliva contamination can be a clinically important problem when restoring mandibular second molars, especially in young patients with high salivary flow rates. Rubber-dam may produce better isolation compared to other techniques because it isolates the tooth from the oral cavity. It provides isolation from saliva, gingival fluid and blood contamination. In addition, this isolation is stable and is not affected by the environmental factors. Rubber dam also eliminates saliva contamination caused by the any movement of patient's head or tongue. However, incomplete tooth eruption will not permit clamp placement, and issues with patient cooperation may restrict application. Hence, isolation should be performed with cotton rolls and a saliva ejector in this situation. Although there is very low-quality evidence regarding the fact that the use of rubber dam lead to a lower failure rate in direct composite restorations, compared with the failure rate for the use of cotton roll [19, 31], the moisture-tolerant and fast-track restorative materials may be a good alternative to resin composites when there is a difficulty in providing good isolation. In this study, Hv-GIC restorations were completed in a fast and single step to restrict the possible negative effects of isolation inadequacies. In contrast, in the resin composite group, the adhesive was applied and immediately light polymerised before the incremental application of the resin composite. Each layer of the restoration was light polymerised, and hence, the restorative procedure required more time. Therefore, during the restorative procedure, risk of invisible saliva contamination was higher in the resin composite group. The effect of different time requirements for the two types of restorations was not obvious in short-term evaluations, but a significant increase in marginal staining in composite restorations may be one of the indicators of long-term results. However, possible differences in inherent material properties must also be considered.

Low fracture toughness is an important limitation of glass ionomer cements, though fracture toughness improves with the maturation of the material [32]. In this study, two Hv-GIC restorations were designated as clinically unacceptable due to restoration fracture after 1 year. At 2-year recall, the success rates of resin composite and Hv-GIC were 100% and 96%, respectively. Gurgan and others [16] compared Hv-GIC and micro-hybrid resin composite in Class I and II restorations and reported similar and successful clinical performances after 10 years. As in this study, restorations were performed without rubber dam isolation, and similar to our results, they reported the fracture of two restorations in the Hv-GIC group at 3 and 4 years.

One of the limitations of this study was the use of moderate carious lesions. For the standardisation of cavity dimensions, only moderate carious lesions that scored 3 or 4 on the ICDAS scale were included in this study. Because increasing cavity depth could negatively affect the adhesion of resin composite and increasing cavity width could negatively affect the fracture resistance of Hv-GIC. Another limitation of this study was the qualitative wear assessment by the evaluators. However, baseline images were used as reference for the detection of alterations at follow-up visits, as described [21]. To conclude, at the 2-year evaluation, high-viscosity glass ionomer exhibited comparable clinical performance to nanohybrid resin composite. Although wear and loss of anatomic form and surface lustre are the most common problems associated with glass ionomer restorations, they exhibited less marginal staining after 2 years. High-viscosity glass ionomers are clinically and aesthetically a satisfactory alternative to resin composites, and they have the advantage of fast application.

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Declarations

Conflict of interest Author Hüseyin Hatirli declares that he has no conflict of interest. Author Bilal Yasa declares that he has no conflict of interest. Author Esra Uzer Çelik declares that she has no conflict of interest.

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.

Informed consent Informed consent was obtained from all individual participants included in the study.

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