©*Operative Dentistry, 2022*, **47-4,** 382-391

Clinical Research

Twelve-month Clinical Performance Evaluation of a Glass Carbomer Restorative System

ZB Kaynar • N Dönmez

Clinical Relevance

The glass carbomer material claiming to be usable as a permanent restorative material did not exhibit sufficient clinical properties for long-term use as expected when compared with the resin composite material. It is recommended that this material should only be used as a short-term interim restorative material.

SUMMARY

Objective: The aim of this *in vivo* study was to evaluate the clinical one-year follow-up of a silica- and flouroapatite-reinforced glass carbomer filling material as compared to a resin composite restorative material.

Methods and Materials: In this study, a total of 100 restorations were performed. Caries were removed conventionally with diamond burs. Half of the restorations were restored with nanocomposite resin (TEP) (Tokuyama Estelite, Tokuyama Dental, Japan) and the other half were restored with glass carbomer (GC) material (GCP Dental, The Netherlands). Each restorative material was applied according to the manufacturer's instructions. Restorations were evaluated with modified USPHS criteria at the end of the first week, 6 months, and 12 months. Data were analyzed using Fisher's Exact Chi-Square test, Fisher Freeman Halton Test, and Continuity (Yates) Correction. The Wilcoxon sign test was used for intra-group comparisons of the parameters.

Results: When the filling materials were compared with one another, a statistically significant difference was observed in the 12th month on the marginal discoloration. A statistically significant difference was observed between the two materials in the 6th month on the marginal adaptation (p<0.05).

Conclusions: In view of these results, there is a need to improve the physical properties of the GC filling material in further *in vivo* studies.

*Zeynep Buket Kaynar, Faculty of Dentistry, Department of Restorative Dentistry, Istanbul Okan University, Istanbul, Turkey

Nazmiye Dönmez, Faculty of Dentistry, Department of Restorative Dentistry, Bezmialem Vakif University, Istanbul, Turkey

*Corresponding author: Necmettin Erbakan Street, Aydıntepe, Number: 2, Tuzla/Istanbul Okan University; e-mail: buket_karakus@hotmail.com

http://doi.org/10.2341/21-016-C

INTRODUCTION

Glass ionomer cements (GIC) have become one of the most widely used materials in dentistry since the

1970s.[1] Properties of being able to chemically bond to dental hard tissues, showing anticariogenic properties, releasing fluoride, and having an expansion coefficient close to dentin have made the use of GICs widespread. Despite all these advantages, their disadvantages—such as poor compressive, tensile strengths, and aesthetic properties; low fracture and wear resistance; the inability to eliminate microleakage; short working time; and a long-lasting hardening process—have led to studies to improve the material.[2] Glass carbomer cement (GC) (GCP Dental, Netherlands) is one of the materials that developed as a result of studies on the improvement of GICs.

Although GC is considered a glass ionomer-based material, the presence of nano-sized powder particles and fluorapatite distinguish GCs from GICs. In the development of this material, the aim is to create an enamel-like structure using nanoparticle technology.[3,4] There are nano-sized fluorapatite/hydroxyapatite particles in the content of GCs. The addition of nano-hydroxyapatite and nano-fluorapatite is known to increase the mechanical properties of glass ionomers and their bond strength to dentin.[5] The reactive glasses inside them are modified with dialkyl siloxanes and the liquid of GC consists of weak polyacrylic acid and does not contain resin, solvent, and monomer.[6,7] With the addition of fluorapatite, the GIC is converted to a material similar to fluorapatite.[8] Furthermore, thanks to the fine structure of cement, a smooth and polished surface similar to resin composites has been obtained.

GC is used together with an organic, biocompatible surface coating gloss (GCP Gloss, GCP Dental) that is carbon-silicone based. The gloss aids in producing an excellent restorative material by improving the transparency which is necessary for optimum heat-based setting. It also maintains the restorative material from moisture and saliva contamination during the initial setting phase, and from dehydration later on.[8] The monomer-free condition and the addition of nano-sized hydroxyapatite and fluorapatite particles in GC ensures it as a more biocompatible option than RMGIC.[9]

Similar to GICs, GCs are also chemically hardened. Manufacturers have recommended that the wear resistance and compressive strength of the material is increased through the use of a light device with a high light power during the hardening process of GC.

Although the mechanical and physical properties of the GC restorative system have been studied by laboratory studies in the literature, there is a limited number of studies investigating the clinical performance of this material. Therefore, the aim of this randomized controlled clinical trial was to compare the clinical performance of GC with a nanohybrid posterior resin composite (TEP) (Tokuyama Estelite Posterior, Tokyo, Japan) in the restoration of Class II and Class I cavities and to evaluate the clinical performance for 12 months. The hypothesis of the study was that both restorative materials would have similar clinical performance.

METHODS AND MATERIALS

Study Design

This study was a randomized controlled clinical trial where teeth were randomly assigned to one of the two restorative material groups with an allocation ratio 1:1.

This clinical study was approved by the Clinical Research Ethics Committee. Patients were informed about the purpose of the study, treatment strategies, dental materials to be used, risks of treatment, and written consents were taken before beginning the study. The study was registered at Clinical Trials.gov Protocol Registration and Results System with the ID: NCT04127929 (16.10.2019). PASS Sample Size Software (NCSS, LLC, Kaysville, Utah) was used to calculate the sample size. In order to get the f = 0.25 effect difference between the groups with 80% power and an alpha error of 5%, at least 50 restorations per group were needed.

The samples in this study were allocated similar to the clinical study by Baba MG and others.[10] The study sample consisted of 100 premolar/molar teeth in healthy, cooperative patients with the following eligibility criteria: patient (26 female, 10 male) between the ages of 20 and 25 years (mean age: 23 years) with a proximal and occlusal lesion on at least one premolar or molar who were available for follow-up after 1 week, 6 months, and 12 months of restoration placement. All patients were recruited from the Restorative Dentistry Clinic in the Faculty of Dentistry, from October 2017 until April 2019.

Inclusion and Exclusion Criteria

The inclusion criteria were: (a) no systemic disorders; (b) older than 18 years of age (20-25 years of age); (c) presence of vital molar/premolar teeth with occlusal or proximal caries; (d) no parafunctional habits such as grinding or clenching of the teeth; (e) no sensitivity to percussion; (f) no spontaneous pain; (g) no luxation; (h) having good cooperation; and (i) having agreed to attend regular follow-up evaluations. The exclusion criteria were: (a) presence of any indication for endodontic treatment or extraction (abscess, swelling, fistula, pain on palpation or percussion, spontaneous pain or night pain); (b) teeth with a congenital developmental defect; (c) teeth with pathological mobility; (d) patients under the age of 18; (e) teeth which do not have normal

Table 1: *Description of Experimental Materials*					
Restorative Material	**Type**	**Manufacturer**	**Composition**	**Lot No**	**Used Color**
Estelite posterior composite resin	Nano-hybrid composite	Tokuyama Dental, Tokyo, Japan	Organic matrix; Bis-GMA TEGDMA Bis-MPEPP Inorganic; Silica-zirconia Particle size:2 um Particle size/ratio: 0.1-10 um Weight;%84 filler Volume;%70 filler	243E67	A 2
Glass carbomer	Glass-ionomer based	GCP Dental, Netherlands	Nano-fluoroapatite Nano-hydroxyapatite Polyacids Fluoroaluminosilicate glass	7609020	A 2
Glass carbomer bloss	Silicon based	GCP Dental, Netherlands	Modified polysiloxanes	1607101	

Abbreviations: Bis-GMA, bisphenol A-glycidyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; Bis-MPEPP: 2,2-bis[(4-methacryloxy polyethoxy)phenyl]propane.

occlusion due to skeletal or pathological reasons; and (f) loss of contact or opposing tooth.

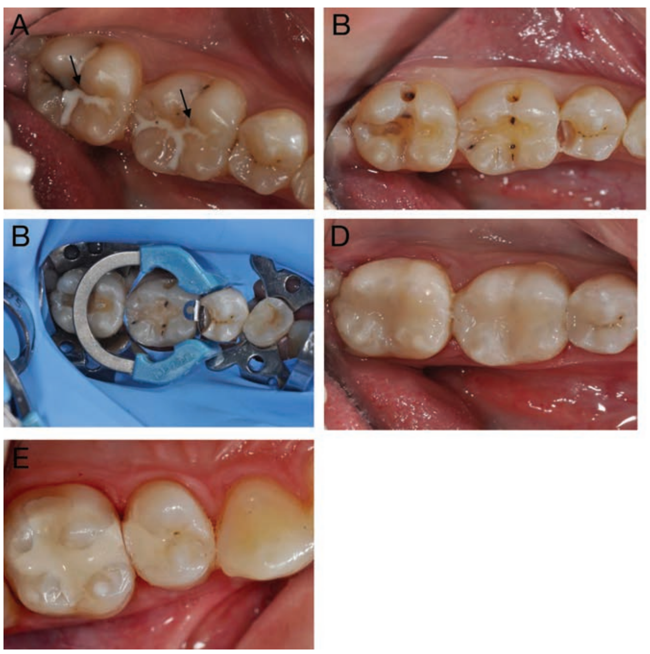

Figure 1. *Each stage of restoration procedures. (A): The view of carious lesions. (B): The view of teeth after removal of caries. (C): The cavity isolation with rubber-dam. (D): The finishing of composite restorations and control with articulation paper. (E): The finishing of GC restorations. Abbreviations: GC, glass carbomer.*

Lesion Selection

A total of 100 Class I (54) and Class II (46) (MO or OD) carious lesions at levels of D1 or D2 (according to clinical and radiographic evaluations) with a minimum of two and a maximum of four permanent premolars or molars according to International Caries Detection and Assessment System (ICDAS)[11] were included in the study.

Randomization and Allocation

The included teeth were assigned randomly by the second author blindly, using the "bowl technique," to one of the two restorative material groups.

According to type of restorative material to be applied, patients included in the study were randomly divided into two groups. Group 1: Nano-hybrid composite restoration group (Class I: 28; Class II: 22); Group 2: Glass carbomer restoration group (Class I: 26; Class II: 24). Two different restorative materials were used in this study (Table 1).

Restorative Procedure

The same experienced dentist performed all restorative procedures. Routine professional oral care, including dental surface cleaning and oral hygiene motivation, were performed. The initial photos of the teeth were taken using a digital camera (Nikon D7200, Tokyo, Japan) with the help of an intraoral photo mirror.

Criterias	Scores	Explanations
Retention	Alfa	No loss of restorative material
	Charlie	Any loss of restorative material
Color match	Alfa	Matches tooth
	Bravo	Acceptable mismatch
	Charlie	Unacceptable mismatch
Marginal discoloration	Alfa	No discoloration
	Bravo	Discoloration without axial penetration
	Charlie	Discoloration with penetration indirection pulpal
Anatomic form	Alfa	Continuous
	Bravo	Slight discontinuity, clinically acceptable
	Charlie	Discontinuous, failure
Marginal adaptation	Alfa	Closely adapted, no crevice is visible
	Bravo	Crevice is visible, explorer will penetrate
	Charlie	Crevice in which dentin is exposed
Secondary caries	Alfa	No caries present
	Charlie	Caries present
Postoperative sensitivity	Alfa	Not present
	Bravo	Sensitivity with diminishing intensity
	Charlie	Constant sensitivity without diminishing intensity
Surface texture	Alfa	Enamel-like surface
	Bravo	Surface rougher than enamel, clinically acceptable
	Charlie	Surface unacceptably rough

Table 2: Modified USPHS Criteria

Abbreviations: USPHS, United States Public Health Service.

Local anesthesia (Ultracain DS Fort, Sanofi Health Products, Istanbul, Turkey) was performed depending on the patient's needs. The removal of caries on the occlusal and proximal surfaces of the teeth was started using rotary instruments (W&H, Austria) and diamond burs (G&Z Instruments, Austria). A steel bur was used to remove caries in dentin tissue. Cavities were prepared in accordance with the minimally invasive approach.

Before restoration of the teeth, cavity isolation was provided with rubber-dam, cotton rolls, and saliva suction for both materials. The sectional matrix system (Palodent V3, Dentsply, USA) was used to create a contact in Class II cavities. For the resin composite restoration group, in both cavity types (Class I and Class II), enamel edges were roughened by 35% orthophosphoric acid for 30 seconds using a selective etch method. After rinsing and drying procedures, two-step self-etch adhesive system (Clearfil SE Bond, Kuraray, Japan) was applied in both cavity types (Class I and Class II) where composite material would be applied. The cavities were restored using both restorative materials according to the manufacturer's instructions. In Group 1, composite material was incrementally applied in the cavities and light cured with a Light Emitting Diode light curing unit (VALO Cordless, Ultradent, USA) set at a standard power of 1000 mW/cm^2. For Group 2, etching and bonding procedures were not applied and the glass carbomer material was placed in the cavity in a single stage. After the cavity was completely filled, the surface cover with silicone content was applied to the restoration and condensed with finger pressure. After that, the restoration was cured for 60 seconds using the GCP CarboLED (GCP Dental), which is a thermo-cure, high-energy lamp that operates on wavelengths higher than those produced by regular light-cure devices (1400 mW/cm^2).

After removing the rubber dam, occlusion control, finishing, and polishing were done with fine grain, yellow band, end flame-shaped diamond burs (G&Z Instruments, Austria). The restorations were polished under water cooling using polishing pastes containing diamond particles (Kuraray Twist Dia, Japan). Surface cover was applied again, following the finishing and polishing procedures. All restorative procedure steps are shown in Figure 1.

Clinical Evaluation

The restorations were evaluated clinically with 1 week, and subsequently at 6-month and 12-month follow-ups. The clinical evaluation was performed by two calibrated observers other than the clinician who placed the restorations using modified United States Public Health Service (USPHS) criteria (Table 2).[12] Restorations were scored using the terms Alpha, Bravo, and Charlie. Alpha was used for restorations that were considered clinically successful; Bravo was used for the restorations with several deficiencies but requiring no replacement; and Charlie was used for the clinically unacceptable restorations where the restoration had to be replaced.[13] In case of a disagreement, a consensus between examiners was achieved after discussion. Prior to the study, calibration was performed on e-calib between the two observers.

Statistical Analysis

Statistical analysis was performed with SPSS Statistics software, Version 22. Fisher's Exact Chi-Square test, Fisher Freeman Halton Test, and Continuity (Yates) Correction were used to compare qualitative data. The Wilcoxon sign test was used for intragroup comparisons of parameters. The level of significance was set at $\alpha = 0.05$.

RESULTS

A flow diagram is presented in Figure 2. After 12 months, 100 restorations in 36 patients were evaluated and scored according to the USPHS criteria. The overall clinical recall rate of restorations at the 12-month recall was 100%. The clinical properties of the restorations were evaluated according to the CONSORT flow diagram. The modified USHPS scores of the restorations are given in Table 3.

When the Charlie score was observed for a clinical evaluation criteria, the restorations were replaced. In terms of anatomical form, marginal adaptation, and retention, Charlie was scored in some restorations of the GC group. Restorations were replaced with the GC.

Retention

No statistically significant difference was found between the 1-week, 6-month, and 12-month performance results for either restorative material group in terms of retention. When materials were compared with different periods in terms of retention, there was no statistically significant change in terms of the Alpha score after 6 and 12 months in the TEP group compared to the 1

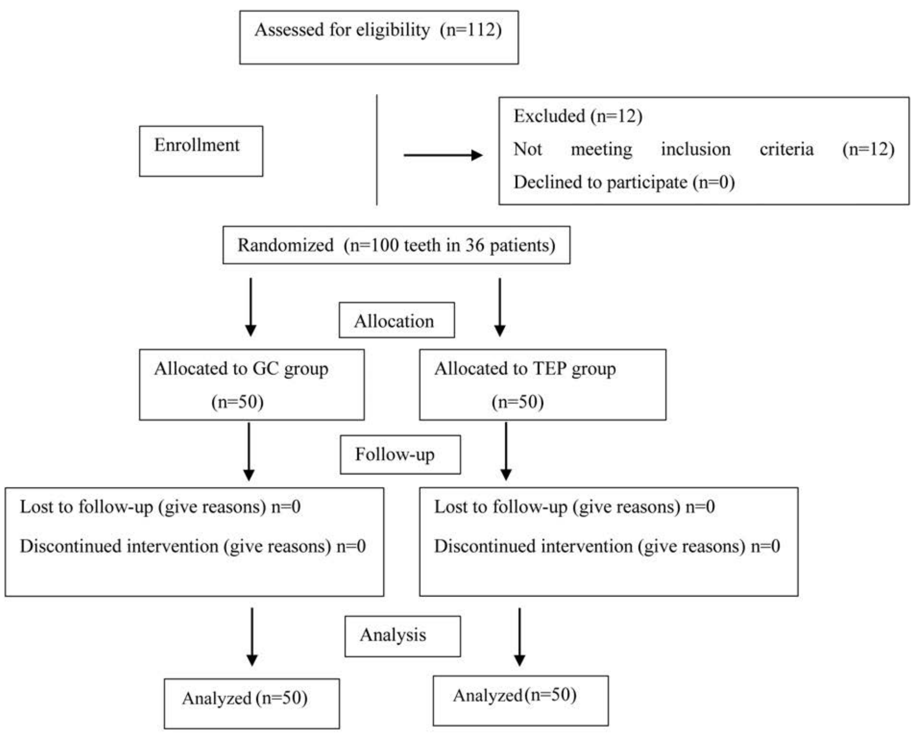

Figure 2. *Flow-chart of 12-month follow-up with GC and TEP restorations. Adapted from CONSORT flow diagram. Abbreviations: GC, glass carbomer; TEP, Tokuyama Estelite Posterior restorations.*

Table 3: *Baseline, 1-week, 6-month, and 12-month Clinical Evaluation of Restorations According to USPHS Criteria*

		GC n (%)	TEP n (%)	p	GC n (%)	TEP n (%)	p	GC n (%)	TEP n (%)	p
Retention	Alfa	50 (100)	50 (100)		48 (96)	50 (100)	0.45	46 (92)	50 (100)	0.12
	Charlie				2 (4)	0 (0)		4 (8)	0 (0)	
Color match	Alfa	50 (100)	50 (100)		45 (90)	50 (100)	0.06[a]	43 (86)	48 (96)	0.19[b]
	Bravo				5 (10)	0 (0)		5 (10)	2 (4)	
	Charlie							2 (4)	0 (0)	
Marginal	Alfa	45 (90)	50 (100)	0.06[a]	42 (84)	50 (100)	0.01*	35 (70)	45 (90)	0.014[b,*]
Adaptation	Bravo	5 (0)	0 (0)		8 (16)	0 (0)		10 (20)	5 (10)	
	Charlie							5 (10)	0 (0)	
Anatomic form	Alfa	50 (100)	50 (100)		40 (80)	45 (90)		37 (74)	43 (86)	
	Bravo				8 (16)	5 (10)		9 (74)	4 (8)	
	Charlie				2 (4)	0 (0)		4 (8)	3 (6)	
Marginal	Alfa	50 (100)	50 (100)		48 (96)	48 (96)	1.000[a]	37 (74)	50 (100)	0.000[b,*]
Discoloration	Bravo				2 (4)	2 (4)		6 (12)	0 (0)	
	Charlie							7 (14)	0 (0)	
Secondary	Alfa	50 (100)	50 (100)		50 (100)	50 (100)		50 (100)	50 (100)	
Caries										
Post-operative	Alfa	46 (92)	48 (96)		48 (96)	50 (0)		48 (96)	50 (0)	
Sensitivity	Bravo	4 (8)	2 (4)		2 (4)	0 (0)		2 (4)	0 (0)	
Surface	Alfa	50 (100)	50 (100)		43 (86)	45 (90)	0.76[a]	40 (80)	42 (84)	0.311[b]
Texture	Bravo				7 (14)	5 (10)		7 (14)	8 (16)	
	Charlie							3 (6)		

Abbreviations: USPHS, United States Public Health Service.
[a]*Fisher exact test.*
[b]*Wilcoxon sign test.*
*p<0.05.

Figure 3. *Restoration scored as Charlie because of loss of retention on palatal surface of GC restoration. Abbreviations: GC, glass carbomer.*

week score (p>0.05). In GC, there was a statistically significant increase in the Charlie score at 12-months (8%) compared to 1 week (0%) (Figure 3).

Surface Texture Change

There was no statistically significant difference between the two restorative materials in terms of surface texture changes after 1 week, 6 months, and 12 months. When materials were compared with different periods in terms of surface texture change, the Bravo scores for surface texture change at 6 months (10%) and 12 months (16%) in the TEP group were found to be statistically significantly higher compared to after 1 week (0%) (p=0.05). In GC, Bravo scores for surface texture change at 6 months (14%) and 12 months (14%) were found to be statistically significantly higher compared to 1 week (0%) (p<0.05).

Color Match

There was no statistically significant difference between the two restorative materials in terms of color match at one-week, six-months and 12-months.

When materials were compared with different periods in terms of color match in the TEP group, there was no statistically significant change in terms of color match at 6 months and 12 months compared to 1 week. Also in the TEP group, there was no statistically significant change in terms of color match after 12 months compared to 6 months ($p>0.05$). In GC, Bravo scores for color match at 6 months (10%) and 12 months (10%) were found to be statistically significantly higher compared to the 1 week (0%) ($p<0.05$). There was no statistically significant change in terms of color match results at 12 months compared to 6 months ($p>0.05$).

Marginal Discoloration

There was no statistically significant difference between the two restorative materials in terms of marginal discoloration at 1 week and 12 months. A statistically significant difference was observed between the two restorative material groups in terms of discoloration at 12 months ($p<0.05$). In the GC group, Bravo and Charlie scores for marginal discoloration at 12 months (12% and 14%, respectively) were found to be statistically significantly higher compared to the 1 week (0% and 0%, respectively) ($p<0.05$). Bravo and Charlie scores for marginal discoloration at 12 months (12% and 14%, respectively) were found to be statistically significantly higher compared to 6 months (4% and 0%, respectively) ($p<0.05$) (Figure 4).

Anatomic Form

There was no statistically significant difference between the two restorative materials in terms of anatomic form at 1 week, 6 months, and 12 months. In the TEP group, Bravo scores for anatomic form at 6 months (10%) and 12 months (8%) were found to be statistically significantly higher compared to 1 week (0%) ($p<0.05$).

In the GC group, Bravo and Charlie scores for anatomic form at 6 months (16% and 4%, respectively) and 12 months (18% and 8%, respectively) were found to be statistically significantly higher compared to 1 week (0% and 0%, respectively) ($p<0.05$).

Marginal Adaptation

When both restorative material groups were evaluated in terms of marginal adaptation, the percentages of Alpha scores for marginal adaptation were 100% in the TEP group and 90% in the glass carbomer group at 1 week. Although the difference between them was close to the significance level, no statistically significant difference was observed between them ($p>0.05$). Percentages of Bravo scores for marginal adaptation was 16% and 0% in the GC and TEP groups at 6 months, respectively. There was a statistically significant difference between the groups in terms of Bravo scores for marginal adaptation ($p=0.006$; $p<0.05$). In the TEP group, the Bravo scores at 12 months (10%) were found to be statistically significantly higher compared to 1 week (0%) ($p=0.025$; $p<0.05$). A statistically significant increase was observed between the 6-month and 12-month Bravo scores (0% and 10%, respectively) ($p<0.05$). In the GC group, there was a statistically significant increase in the Bravo score at the 12-months (16%) compared to the first week (10%) ($p<0.05$). Bravo and Charlie scores

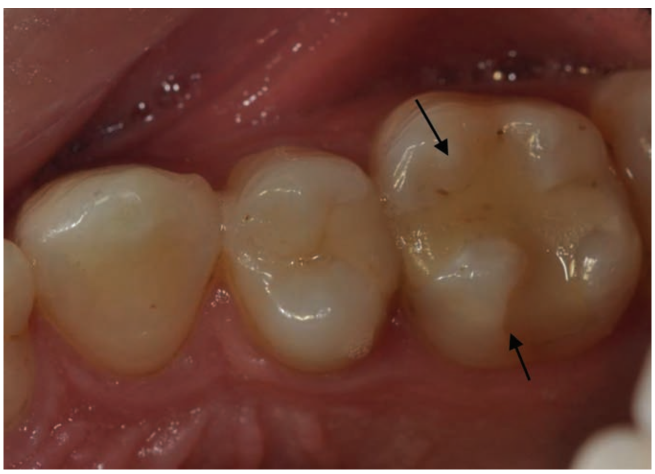

Figure 4. *Restoration scored as Charlie because of marginal discoloration of GC restorations. Abbreviations: GC, glass carbomer.*

Figure 5. *Restoration scored as Charlie because of marginal fracture in the GC group at the end of 12 months. Abbreviations: GC, glass carbomer.*

at 12 months (20% and 10%, respectively) were found to be statistically significantly higher compared to six months (16% and 0%, respectively) ($p<0.05$) (Figure 5).

Secondary Caries

No secondary caries were observed in either group at 1 week, 6 months, and 12 months.

Postoperative Sensitivity

No statistically significant difference was observed between the materials in terms of postoperative sensitivity at 1 week, 6 months, and 12 months.

DISCUSSION

Although a large number of laboratory studies have been conducted on this new GC material in recent years, the results of studies evaluating the clinical success of this material have not been clear when used as a permanent restorative material in adult individuals. The present clinical study evaluated the clinical performance of the GC filling material used in adults as a permanent restorative material. At the end of the study, statistically significant differences were observed between the materials in terms of marginal discoloration, marginal adaptation, anatomic form, and retention. Therefore, our hypothesis was partially rejected.

Today, resin composite materials are the most preferred restorative materials in the restoration of the posterior and anterior teeth. Resin composites show shrinkage during polymerization, leading to several disadvantages including microleakage, deterioration of marginal adaptation, marginal fractures, postoperative sensitivity, and development of secondary caries. Glass carbomer filling material, one of the glass ionomer-based restorative materials developed in recent years, has been introduced as an alternative restorative material to resin composites.

The literature review showed that there were no clinical studies in which GC was used as a restorative material in adults, however, there were studies where it was used as a fissure sealant. In a study by Gorseta and others,[9] glass carbomer and resin-based fissure sealant material were used as fissure sealants and 100% clinical success was achieved in both materials in terms of retention at 6 months, however, this rate decreased to 75% at 12 months, but it was not statistically significant. In a four-year clinical follow-up study by Zhang and others where high viscosity GIC, GC, and resin-based fissure sealant were used as fissure sealants, the GC group was found to be less successful in clinical practice compared to other materials.[14]

El-Housseiny and others[15] concluded in their study that glass carbomer restorations showed significantly worse clinical performance than resin-modified glass ionomer and composite restoration in first primary molars in terms of anatomical form and marginal adaptation. These results are similar to our study.

In a three-year clinical follow-up study by Hu and others when glass carbomer fissure sealant, resin-based fissure sealant, and glass ionomer fissure sealant were used, no significant differences were observed between the materials in terms of pit and fissure retention rate.[16]

Chen and others conducted a study in which they followed the anti-caries effects of glass ionomer, GC and resin-based fissure sealants for six months, one year and two years and found that the lowest retention rate was in the GC group at the end of two years.[17]

In a study by Olegario and others, GC, high viscosity glass ionomer, and compomer material were clinically monitored for three years using an atraumatic restorative technique and the clinical success of the GC material was found to be significantly lower than that of compomer and high viscosity GIC material.[18]

In the present study, there was no statistical difference between 1 week and 6 months in the glass carbomer group, however, there was a statistically significant increase in the 12 month Charlie score compared to the 1 week score ($p=0.046$; $p<0.05$). This finding was similar to the findings reported by Olegario and others.[18]

As with GIC materials, it is recommended to use a silicone-based sealant to protect the surface from moisture and saliva for GC restorations.[8] In a laboratory study by Zoergiebl and others,[19] sealant application was reported to have no effect on the mechanical properties of GCs. On the other hand, Menne-Happ and others[8] reported in their laboratory study that the sealant applied to the glass carbomer protected the surface of the material from dehydration and made finishing and polishing processes easier. Menne-Happ and others[8] compared the groups that applied sealant to those that did not and reported that surface cracks were formed in the group in which no sealant was used when glass carbomer samples were examined visually. This was attributed to the dehydration due to not using any sealant. In the present clinical study, a silicone-based sealant was applied both to facilitate condensation of the material and to protect it from dehydration. Following the sealant application, light was applied for 60 seconds. There was no statistically significant difference between the materials at 1 week, 6 months, and 12 months when the cavities were restored with both materials in terms of surface texture. This may be due to the use of the silicone-based sealant on the surface of the glass carbomer material.

No statistically significant difference was found between the TEP and GC groups in terms of marginal adaptation at 1 week. However, there was a statistically significant difference between TEP and GC groups only in terms of 6 month Bravo scores (p=0.006; p<0.05). However, percentages of Alpha, Bravo, and Charlie scores of the GC group were 70%, 20%, and 10%, respectively, after 12 months. Therefore, a statistically significant difference was observed between the two groups in this regard (p=0.014; p<0.05). Although there was no polymerization shrinkage in the glass carbomer material unlike the resin composite, significantly lower values were obtained in terms of marginal adaptation. This may be due to the fact that GC was less resistant to occlusal forces than the resin composite (84% filler by weight and 70% filler by volume). This result was compatible with the findings reported in the 6 month clinical follow-up study by Glavino and others[20] who used GC as a fissure sealant.

Secondary caries formation, incidence of which is directly proportional to follow-up period, is one of the criteria to consider for evaluating the clinical success of restorations.[21] Some clinicians suggest that a 4-6 year follow-up is needed to determine the clinical success of any restoration.[22] In this study, no statistically significant difference was found between the restorative materials in terms of secondary caries formation. This may be due to the fact that the clinical follow-up period was limited to 12 months. Also, the presence of silicate and fluoride in the content of GC may be one of the factors preventing secondary caries formation.

In clinical practice, nanohybrid composites are preferred because these materials have strong mechanical properties, similar to hybrid composites, and also have good polishing properties similar to microfill composites.[23] When the teeth restored with TEP were evaluated for color matching, a Bravo score was obtained in only two restorations at the end of the 12 months. The high success rate (96% Alpha, 4% Bravo) may be due to the high polishing feature of nanohybrid composites.

Considering the marginal discoloration results in the GC group at the end of 12 months, the TEP group was observed to have 100% Alpha scores whereas the GC group had 14% Charlie scores where restorations were required to be replaced. This may be attributed to the fact that GC materials are less resistant to masticatory forces than TEP. Although these results were obtained after a 1-year clinical follow-up, longer-term clinical follow-up is needed for the reliability of the marginal discoloration results of both materials.

GC is condensed and shaped by processing the surface with the help of a hand instrument following the application on the cavity with finger pressure. The consistency of GC is more liquid than the composite, making it difficult to give a natural anatomical form. However, no significant difference was observed in this study when compared with resin composite. In a clinical follow-up study by Subramaniam and others[24] using GC fissure sealant, nanoparticle content of glass carbomers was reported to increase the compressive stress and wear resistance. In contrast to this study, the GC material had a Charlie score of 8% according to anatomic form in the present study. This means that GC is not resistant to masticatory forces like resin composites.

Postoperative sensitivity, which is defined as a spontaneous or short-term pain sensation developed in response to a stimulus following the completion of restorations, is an important criterion in the evaluation of clinical studies.[25,26] Pain threshold varying by person, dentist's sensitivity, and differences in the application procedure make the evaluation of the sensitivity criterion difficult.[27] There was no statistically significant difference between the restorative materials used in terms of postoperative sensitivity (p>0.05). During the application stages of GC, no acid etching process and no additional bonding agent are required. These may be effective for the prevention of sensitivity problems.

CONCLUSION

Within the limitations of this study, the following were concluded:

1. Although similar results were obtained after 1 year of clinical follow-up for all restorative materials, a statistically significant difference was observed for marginal adaptation and marginal discoloration.
2. When the restorations made using glass carbomer filling materials were evaluated in terms of anatomic form, retention, and marginal adaptation, restorations with the Charlie score at 6 and 12 months were replaced.
3. Given the results, the glass carbomer (GC) material is recommended only as a short-term interim restoration. Further development to improve its physical properties is needed to improve the clinical performance when compared with composite resin.

Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversight committee guidelines and policies of Bezmialem Vakif University. The approval code was 03/05/2017-7923.

Conflict of Interest

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

(Accepted 6 October 2021)

REFERENCES

1. Jackson RD & Morgan M (2000) The new posterior resins and a simplified placement technique *Journal of the American Dental Association* **131(3)** 375-383.
2. Wilson AD (1972) A new translucent cement for dentistry: The glass-ionomer cement *British Dental Journal* **132** 133-135.
3. Ikemura K, Tay FR, Endo T, & Pashley DH (2008) A review of chemical-approach and ultramorphological studies on the development of fluoride-releasing dental adhesives comprising new pre-reacted glass ionomer (PRG) fillers *Dental Materials Journal* **27(3)** 315-339.
4. Gordan VV, Mondragon E, Watson RE, Garvan C, & Mjör IA (2007) A clinical evaluation of a self-etching primer and a giomer restorative material: Results at eight years *Journal of the American Dental Association* **138(5)** 621-627.
5. Shafiei F & Abouheydari M (2015) Microleakage of class V methacrylate and silorane-based composites and nano-ionomer restorations in fluorosed teeth *Journal of Dentistry* **16(2)** 100-105.
6. Anshul K (2011) Nano-filled resin-modified glass-ionomer cement: "nano-ionomer" Ketac N100.
7. Van RD, Davidson C, De AG, & Feilzer A (2004) *In situ* transformation of glass-ionomer into an enamel-like material *American Journal of Dentistry* **17(4)** 223-227.
8. Menne-Happ U & Ilie N (2013) Effect of gloss and heat on the mechanical behaviour of a glass carbomer cement *Journal of Dentistry* **41(3)** 223-230. 10.1016/j.jdent.2012.11.005
9. Gorseta K, Glavina D, Borzabadi-Farahani A, Van Duinen RN, Skrinjaric I, Hill RG, & Lynch E (2014) One-year clinical evaluation of a glass carbomer fissure sealant, a preliminary study *European Journal of Prosthodontics and Restorative Dentistry* **22(2)** 67-71.
10. Gok Baba M, Kirzioglu Z, & Ceyhan D (2020) One-year clinical evaluation of two high-viscosity glass-ionomer cements in class II restorations of primary molars *Australian Dentistry Journal* **66(1)** 32-40. 10.1111/adj.12802
11. Gugnani N, Pandit IK, Srivastava N, Gupta M, & Sharma M (2011) International caries detection and assessment system (ICDAS): A new concept *International Journal of Clinical Pediatric Dentistry* **4(2)** 93-100. 10.5005/jp-journals-10005-1089
12. Franco EB, Benetti AR, Ishikiriama SK, Santiago SL, Lauris JRP, Jorge MFF, & Navarro M (2006) 5-year clinical performance of resin composite versus resin modified glass ionomer restorative system in non-carious cervical lesions *Operative Dentistry* **31(4)** 403-408.
13. Türkün LS, Türkün M, & Özata F (2003) Two-year clinical evaluation of a packable resin-based composite *Journal of the American Dental Association* **134(9)** 1205-1212.
14. Zhang W, Chen X, Fan M, Mulder J, & Frencken JE (2017) Retention rate of four different sealant materials after four years *Oral Health and Preventative Dentistry* **15(4)** 307-314. 10.3290/j.ohpd.a38743
15. El-Housseiny AA, Alamoudi NM, Nouri S, & Felemban O (2019) A randomized controlled clinical trial of glass carbomer restorations in Class II cavities in primary molars: 12-month results *Quintessence International* **50(7)** 522-532. 10.3290/j.qi.a42573
16. Hu X, Zhang W, Fan M, Mulder J, & Frencken JE (2017) Frequency of remnants of sealants left behind in pits and fissures of occlusal surfaces after 2 and 3 years *Clinical Oral Investigations* **21(1)** 143-149. 10.1007/s00784-016-1766-7
17. Chen X, Du M, Fan M, Mulder J, Huysmans M-C, & Frencken JE (2012) Effectiveness of two new types of sealants: Retention after 2 years *Clinical Oral Investigations* **16(5)** 1443-1450
18. Olegário IC, Hesse D, Mendes FM, Bonifácio CC, & Raggio DP (2018) Glass carbomer and compomer for ART restorations: 3-year results of a randomized clinical trial *Clinical Oral Investigations* 1-10.
19. Zoergiebel J & Ilie N (2013) Evaluation of a conventional glass ionomer cement with new zinc formulation: Effect of coating, aging and storage agents *Clinical Oral Investigations* **17(2)** 619-626.
20. Glavina D, Goršeta K, Vranić DN, & Škrinjarić I (2010) Retention of glass carbomer sealant after 6 months of clinical trial *Journal of Dental* Research **89(Special Issue B)** abstract 4534.
21. Brunthaler A, König F, Lucas T, Sperr W, & Schedle A (2003) Longevity of direct resin composite restorations in posterior teeth: A review *Clinical Oral Investigations* **7(2)** 63-70.
22. van Dijken JW & Pallesen U (2014) A randomized 10-year prospective follow-up of Class II nanohybrid and conventional hybrid resin composite restorations *Journal of Adhesive Dentistry* **16(6)** 585-592.
23. Fontes ST, Fernández MR, Moura CMd, & Meireles SS (2009) Color stability of a nanofill composite: Effect of different immersion media *Journal of Applied Oral Science* **17(5)** 388-391.
24. Subramaniam P, Jayasurya S, & Babu KG (2015) Evaluation of glass carbomer sealant and a moisture tolerant resin sealant–A comparative study *International Journal of Dental Science and Research* **2(2-3)** 41-48.
25. Liberman R, Ben-Amar A, Gontar G, & Hirsh A (1990) The effect of posterior composite restorations on the resistance of cavity walls to vertically applied occlusal loads *Journal of Oral Rehabilitation* **17(1)** 99-105.
26. Opdam N, Feilzer A, Roeters J, & Smale I (1998) Class I occlusal composite resin restorations: *In vivo* post-operative sensitivity, wall adaptation, and microleakage *American Journal of Dentistry* **11(5)** 229-234.
27. Walter M, Wolf B, Schmidt A, Boening K, & Koch R (2001) Plaque, gingival health and post-operative sensitivity in titanium inlays and onlays: A randomized controlled clinical trial *Journal of Dentistry* **29(3)** 181-186.