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Glass Hybrid Glass Ionomer Restorative Materials: A Literature Review

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Abstract

The emergence of glass hybrid glass ionomers (GH-GICs) represents a significant innovation in restorative dentistry, addressing the limitations of traditional materials through enhanced mechanical strength, fluoride release, and ease of application. Given the absence of prior comprehensive literature reviews on this topic, this systematic review was conducted to provide general practitioners with essential insights. A comprehensive literature search was performed in the PubMed, Scopus, and Web of Science databases from 2010-2023, using terms related to GH-GICs, their properties, and their clinical performance. The studies included were published in English and included *in vitro* and *in vivo* research as well as randomized controlled trials. Compared with conventional glass ionomers, GH-GICs exhibit improved mechanical properties, fluoride release, and remineralization potential, showing clinical performance comparable to that of resin composites in small to moderate class I and class II posterior restorations. However, limitations such as marginal adaptation, surface wear, and reduced aesthetics persist, particularly in larger restorations. While resin coatings improve initial wear resistance, their limited longevity and reduced fluoride release present additional concerns. GH-GICs remain promising for specific clinical scenarios, especially in high-caries-risk, pediatric, and geriatric patients, but further long-term studies are needed to confirm their efficacy fully and extend their applications.

Keywords: bulk-fill, glass hybrid, glass ionomers, high viscosity, restorative dentistry

Introduction

Resin composites are highly desirable for their aesthetic and physical qualities but are hindered by the time-consuming technique needed, particularly in deep cavities.(1) To simplify procedures and save time, bulk-fill materials such as bulk-fill resin composites and high-viscosity glass ionomer cements (HV-GICs) have been developed.(2,3) Bulk-fill resin composites offer a promising, time-efficient alternative to conventional resin composites for posterior restorations. Nevertheless, further long-term randomized clinical trials are needed to fully validate their clinical effectiveness.(1,2,4)

Recently, HV-GICs have gained attention as bulk-fill materials, combining the benefits of conventional low-viscosity glass ionomer cements with improved handling properties and mechanical strength. The latest advancement in HV-GICs is the introduction of glass hybrid glass ionomer cements (GH-GICs), which are being promoted for broader clinical applicability. This paper reviews the literature on GH-GICs, focusing on their properties, applications, and clinical implications in restoring permanent teeth.

Search strategy and inclusion criteria

A systematic literature search was conducted to identify relevant studies on GH-GICs. The search was performed via electronic databases such as PubMed, Scopus, and Web of Science, with search terms including "glass hybrid glass ionomer," "high-viscosity glass ionomer," "bulk-fill," "restorative dentistry," "Equia Forte," "Equia," "mechanical properties," "clinical performance," and "fluoride release." Boolean operators (AND, OR) were used to refine the search. Studies published in english from 2010-2024 that focused on the properties, clinical applications, and performance of GH-GICs, as well as comparisons with other restorative materials, were included. Both *in vitro* and *in vivo* studies, including randomized controlled trials and laboratory studies, were considered. Duplicates were removed, and articles were screened on the basis of titles, abstracts, and full-text reviews. The reference lists of the selected articles were also examined to ensure comprehensive coverage of the relevant literature.

Results of the literature search

High viscosity glass ionomers

During the 1990s, industry coined the term 'high viscosity glass ionomer cement' to describe improved glass ionomer cement (GIC).(5) These materials contain high-molecular-weight polyacrylic acid and surface-modified fillers, which increase their reactivity and produce high cross-linkages in the set matrix.(6) Additionally, they are mixed in a higher powder–liquid ratio than conventional GICs are, increasing their performance.(7,8)

HV-GICs exhibit superior physical and mechanical properties, particularly in terms of wear resistance, along with a faster setting time, enabling restorations to be completed in a single visit. Compared with their conventional counterparts, they possess a more translucent appearance due to the inclusion of fine glass particles.(7,9) The enhanced attributes of HV-GICs broaden their applications,(6,10-14) making them versatile for various clinical applications where resin composites and amalgams might not perform optimally.(15-24)

Microlaminated GICs have been introduced to widen the indications for using HV-GICs in the posterior region, where HV-GICs are combined with a light-cured coating. In 2007, the Equia restorative system (GC America, Alsip, IL, USA), comprising Equia Fil–a self-adhesive bulk-fill HV-GIC–and Equia Coat–a highly nanofilled light-cured resin coating–was introduced. Equia Fil, was optimized by the manufacturer to enhance cross-linkage within the GIC matrix. Paired with the Equia Coat, it was promoted as a suitable restorative material for posterior stress-bearing restorations.

The clinical performance of high-viscosity glass ionomers

Studies investigating the clinical performance of HV-GICs have demonstrated satisfactory performance in class I(24,26-30) and small-to-medium class II restorations,(9,27,30-32) with some studies recommending limiting the size of medium class II cavities to ensure that they do not exceed half the intercuspal width in the isthmus width.(33) Klinke *et al.,*(30) compared the clinical effectiveness of the Equia system to that of the conventional Fuji IX GP Fast (GC, Tokyo, Japan) coated with Fuji Coat LC (GC, Tokyo, Japan) on permanent posterior teeth in both class I and class II (two and three surfaces) cavities over a 4-year observation period. The results indicated comparable performance between the two materials in class I cavities. However, in class II fillings, the Equia restorative system displayed superior overall performance, with fewer failures observed during follow-up evaluations. Türkün

Table 1: Lists the HV-GIC products currently available on the market.

Product	Coat*	Manufacturer	Notes
-GC Fuji IX GP -GC Fuji IX GP Fast -GC Fuji IX GP Extra	G-Coat Plus (light cure 20 sec), GC Fuji Coat LC (light cure 10 sec), or GC Fuji Varnish (blow dry)	GC, Tokyo, Japan	Fuji IX GP Fast is the fast setting version of Fuji IX GP. This product achieves its initial set in only 3 minutes and 35 seconds after mixing; final finishing can begin in only 3 minutes after placement. Fuji IX GP Extra: This product contains a next generation glass filler which elicits higher translucency, fluoride release, reactivity and a faster setting time. It allows final finishing in only 2.5 minutes from initial mix.
-Riva Self Cure (Regular) -Riva Self Cure (Fast) -Riva Self Cure HV	Riva Coat (light cure resin coating)	SDI, Victoria, Australia	Riva Self Cure HV has a higher powder/liquid ratio (0.50/0.12 g) compared to the other two variants (0.42/0.12 g)
-Ketac Universal Aplicap -Ketac Molar Aplicap	Ketac Glaze (mainly for Ketac Molar Aplicap)	3M ESPE, Seefeld, Germany	Ketac Universal Aplicap is a user-friendly, versatile glass ionomer for quick, less demanding restorations, while Ketac Molar Aplicap is a tougher, packable choice for durable posterior restorations prioritizing strength over aesthetics or speed.
-Chemfil Rock	Surface protection recommended (e.g., resin-based coating or varnish)	Dentsply, Milford, USA	It uses a novel reactive zinc-modified fluoro-alumino-silicate glass filler
-Equia Fil	Equia Coat (A nanofilled, light-cured resin coating)	GC America, Alsip, IL, USA	In some markets, Equia Fil is sold as Fuji IX GP Extra and Equia Coat as G-Coat Plus.[14,25] The primary difference is that Equia Fil is Fuji IX GP EXTRA packaged within the Equia system, designed to be used with Equia Coat for enhanced properties, whereas Fuji IX GP EXTRA is the standalone GIC that doesn't require the coating.
-Gold label IX Extra Capsule -Gold label IX Extra	G-Coat Plus, GC Fuji Coat LC, or GC Fuji Varnish	GC America, Alsip, IL, USA	The Fuji IX GP EXTRA and Gold Label IX Extra are actually the exact same product — just branded differently depending on the market or region

*Although these materials can technically be used without a final coat, coating is strongly recommended to enhance wear resistance, surface hardness, and longevity.

and Kanik[33] conducted a six-year assessment of the long-term clinical efficacy of Equia Fil and Riva Self Cure (SDI, Victoria, Australia) both of which were coated with Equia Coat and a classical varnish (Fuji Varnish). Equia Fil exhibited acceptable clinical performance in class I restorations and moderate to large class II restorations over six years.

However, the clinical performance of the conventional GIC (Riva Self Cure) in moderate to large class II restorations was notably inferior to that of Equia Fil. Equia Fil demonstrated superior performance to Riva Self Cure in terms of anatomic form, color match, marginal adaptation, and retention rate throughout the evaluation period. Notably, both coatings applied to all the restorations were worn away after six months. Heck *et al.*,[32] conducted a long-term study over six years to assess the performance of two HV-GIC systems, the Fuji IX GP Fast/Fuji Coat LC and Equia Fil/Equia Coat restoration systems, which were applied as definitive restorations for class II cavities for permanent dentition. Both materials demonstrated acceptable and comparable survival rates, indicating their suitability for smaller class II cavities. Over the six years, both Equia Fil and Fuji IX GP Fast restorations showed significant deterioration in surface luster, marginal adaptation, material fracture, and retention, with no notable differences observed between the two materials. Hatirli *et al.*,[24] compared the two-year clinical outcomes of HV-GICs and nanohybrid resin composite restorations (GrandioSO, Voco). HV-GICs demonstrated comparable clinical performance to resin composite materials. HV-GICs presented lower marginal discolouration, greater surface wear and loss of anatomic form. The resin composite had a significantly better surface luster. Rożniatowski *et al.*,[31] conducted a clinical and radiological assessment comparing the Equia restorative system and resin composite material (Tetric EvoCeram, Ivoclar Vivadent). Their findings suggested that the resin composite and Equia systems exhibited similar efficacy over a 2-year observation period when used to restore approximal lesions in premolars and permanent molars. However, it is important to note that when HV-GICs were utilized, there was a greater risk of marginal adaptation deterioration, staining, and erosion. Uzel *et al.*,[27] compared the clinical performance of the Equia system on class I and II cavities with that of a bulk-fill resin composite (Tetric EvoCeram, Ivoclar, Vivadent) over 24 months in young adults. Both materials displayed good clinical performance. However, Equia showed more common chipping and surface degradation over the two years.

In summary, HV-GICs have proven to be effective restorative materials for class I and small-to-medium class II cavities, with specific materials such as Equia Fil often outperforming conventional GICs in terms of anatomic form, color match, and retention. While HV-GICs demonstrate comparable performance to resin composites in terms of retention and marginal discoloration, they face challenges in larger restorations, including marginal deterioration, surface wear, and reduced aesthetic performance. In contrast, the resin composites maintain better surface luster over time.

Glass hybrid glass ionomers

In 2015, Equia Forte (GC America, Alsip, IL, USA) was introduced as an innovative restorative system utilizing glass-hybrid technology. The system builds on the performance of the original Equia restorative line and comprises Equia Forte Fil and its corresponding light-cured surface sealant, Equia Forte Coat. Equia Forte Fil is a self-adhesive bulk-fill restorative material based on an enhanced GIC structure. It incorporates ultrafine, highly reactive fluoroaluminosilicate glass particles with a bimodal size distribution–a combination of larger conventional glass fillers and smaller, highly reactive nanofillers–improving the packing density and reactivity. These particles facilitate rapid ion release and robust matrix formation. The liquid component consists of a higher molecular weight polyacrylic acid combined with water and tartaric acid, which enhances handling and working time. Compared with traditional HV-GICs, this glass hybrid formulation results in improved ion availability, leading to enhanced cross-linking, a stronger glass-ionomer matrix, and superior flexural strength.[34] The system also includes Equia Forte Coat, a nanofilled, light-cured resin coating that contains a novel multifunctional methacrylate monomer. The manufacturer claims that this coating forms a dense, wear-resistant resin matrix that seals the surface, enhances aesthetics, and protects the restoration from early moisture contamination and dehydration.

In 2019, the Equia Forte HT (High Translucency) restorative system was launched, featuring an optimized formulation that offers improved translucency and aesthetics. Equia Forte HT maintains the same core glass hybrid structure but utilizes a refined and narrower particle size distribution, further enhancing handling properties and mechanical performance. Table 2 lists the GH-GICs products currently available on the market.

Mechanical properties

As restorative materials, GH-GICs must demonstrate adequate mechanical performance to replace missing tooth structures. Studies comparing GH-GICs to HV-GICs and resin composites have shown that GH-GICs, particularly Equia Forte and Equia Forte HT, exhibit comparable or slightly superior mechanical pro-

Table 2: GH-GICs products currently available on the market.

Product	Coat	Manufacturer	Notes
Equia Forte Fil	Equia Forte Coat	GC America, Alsip, IL, USA	
Equia Forte HT	Equia Forte Coat	GC America, Alsip, IL, USA	
Gold Label Hybrid	G-Coat Plus (light cure) or GC Fuji Varnish (blow dry)	GC America, Alsip, IL, USA	Available only in a hand mixed version

perties to HV-GICs, particularly when the Equia Forte Coat is applied.(34-40) The protective coating plays a critical role in maximizing the performance and surface durability. Fuhrmann *et al.,*(37) found that while fracture toughness was similar among GICs, the application of Equia Forte Coats significantly increased surface hardness, reaching levels comparable to those of resin composites such as Filtek Z250 and even exceeding those of Filtek Supreme Ultra. Similarly, Brkanović *et al.,*(8) reported that Equia Forte HT, both coated and uncoated, outperformed Fuji IX GP in terms of wear resistance, with coated samples showing notably greater durability.

However, despite these improvements, certain drawbacks persist. Voids may form during placement, particularly in hand-mixed versions, compromising the internal integrity of the material.(41-43) Cohesive failures have also been reported under functional loading, especially in larger restorations.(40,44) These failures highlight the intrinsic limitations in fracture toughness and fatigue resistance of GH-GICs. Notably, recent studies have consistently reported that these failures are often cohesive in nature–occurring within the material itself–while the bond to tooth structure remains intact.(45)

However, GH-GICs still lack resin composites in terms of key mechanical properties, such as compressive strength, fracture toughness, and surface hardness.(34,35,40) This is mainly due to the superior micromechanical bonding of resin composites, as well as their inherently higher material strength. Kutuk *et al.,*(46) compared Equia Forte to a microhybrid resin composite (G-ænial Posterior) and reported no significant difference in fracture resistance but significantly greater compressive strength in the resin composite. Valeri *et al.,*(47) noted that while resin composites such as Filtek Supreme Ultra showed superior wear resistance, Equia Forte HT–particularly when coated–demonstrated a substantial reduction in wear, highlighting the importance of the resin coating in enhancing clinical durability.

In addition to mechanical improvements, advancements in glass-hybrid technology have led to notable enhancements in the optical properties of GH-GICs. The introduction of Equia Forte HT marked a significant step forward in improving translucency, an essential factor for aesthetic integration with natural dentition. This improvement is attributed to the optimized particle size distribution, which allows the material to blend more harmoniously with the surrounding tooth structure. Studies comparing the optical properties of GH-GICs and resin composites have revealed mixed findings. Yeo *et al.,*(38) evaluated materials such as Equia Forte, Fuji IX, Filtek Z350, and Filtek One Bulk Fill and reported that resin composites presented significantly higher translucency levels than did GH-GICs. In contrast, Moshaverinia *et al.,*(39) found that Equia Forte HT outperformed Fuji IX and ChemFil Rock in translucency. Despite these advancements, resin composites remain the preferred choice for highly aesthetic restorations because of their superior ability to achieve high translucency and natural blending.

Resin coating

The application of a resin coating, such as Equia Forte Coat, is essential during the early maturation phase of GH-GICs.(48,49) This coating serves as a temporary barrier protecting the GIC from moisture imbalances during its initial setting phase (6 to 12 months). Resin coatings have been shown to improve surface hardness, flexural strength, surface roughness, and initial wear resistance.(48,49) Kanik *et al.,*(50) noted that resin coatings render GH-GICs wear resistant over extended durations, comparable to resin composites. Habib *et al.,*(51) found that coated GICs presented significantly greater flexural strength, reduced surface roughness, and improved marginal integrity. Fuhrmann *et al.,*(37) and Handoko *et al.,*(52) also reported significant increases in surface hardness with the application of resin coatings. Additionally, Jafarpour *et al.,*(53) demonstrated that resin coatings reduce water sorption and solubility, stabilizing the physical properties of the material.

Despite these benefits, resin coatings do not uniformly enhance all mechanical properties. For example, fracture toughness and elastic modulus remain largely unaffected, with some studies even suggesting that uncoated samples may exhibit higher elastic moduli.(37,38) Ong *et al.,*(54) concluded that the resin coating did not enhance the viscoelastic properties and was unnecessary for improving the elastic performance. Furthermore, the long-term effectiveness of resin coatings in achieving adequate wear resistance remains uncertain.(8,47,49,55)

In summary, GH-GICs, particularly Equia Forte and Equia Forte HT, represent significant advancements over traditional GICs, offering improved mechanical, optical, and biological properties. The application of resin coatings further enhances surface hardness and initial wear resistance, although their long-term effectiveness is limited. While GH-GICs outperform earlier GIC generations and are well suited for low-stress restorations, they still fall short of resin composites in key areas, such as compressive strength, fracture toughness, and translucency. However, their ease of use, cost-effectiveness, and caries-preventive properties make them valuable options for high-caries-risk patients and pediatric and geriatric populations. Future research should focus on developing more durable protective coatings and innovative formulations to increase the long-term performance of GH-GICs and bridge the gap with resin composites, expanding their role in modern restorative dentistry.

Properties of the fluoride release and remineralization of GH-GICs

GH-GICs retain the favorable biological properties of conventional GICs, including chemical bonding to the tooth structure, biocompatibility, and sustained fluoride release. Fluoride release is a hallmark of GH-GICs, offering both immediate and long-term caries prevention. The burst effect involves rapid fluoride release shortly after placement, providing an initial anticariogenic boost. This is followed by a sustained reservoir effect, where the material absorbs and rereleases fluoride over time, enhancing long-term protection.(56) The release of fluoride from GH-GICs contributes to the formation of fluorapatite, enhancing remineralization and inhibiting caries progression.(56,57) Studies indicate that Equia Forte can induce remineralization in carious dentine up to a depth of 2 mm.(58) Zebić *et al.,*(59) compared the fluoride release from three different GICs. They reported that Equia Forte released more fluoride than Fuji IX and Fuji II, which had the lowest fluoride concentration among the tested GICs. Moshaverinia *et al.,*(34) evaluated the fluoride release of three HV-GICs (Equia Forte Fil, Fuji IX, and Chemfil Rock). They reported that all the examined materials exhibited comparable initial fluoride-releasing properties, whereas Equia Forte Fil exhibited significantly greater amounts of fluoride release from the bulk of the material after 4 weeks. Similarly, another study reported that Equia Forte HT also exhibited superior fluoride-releasing capacity compared with Fuji IX GP and Chemfil Rock, further highlighting its potential role in preventing caries.(39)

However, applying a resin coating, while enhancing the mechanical properties and wear resistance of GH-GICs, presents a trade-off by reducing fluoride release. This reduction is attributed to the resin-based nature of the coating and the presence of nanofillers, which seal the microgaps in the material, thereby limiting the diffusion of fluoride ions.(60-63) As not all mechanical properties are consistently improved and the long-term benefits for wear resistance remain uncertain, the use of a resin coating should be considered selectively.(64) In clinical situations where sustained fluoride release and remineralization are important, its application may warrant careful reconsideration.(61)

Bonding to the tooth structure

Equia Forte, a GH-GIC, has demonstrated improved bond strength compared with its predecessor, Equia Fil, and other conventional HV-GICs. Studies have shown that Equia Forte has a relatively high shear bond strength (SBS) to enamel and dentin. Karadas *et al.,*(65) evaluated the SBS and adaptation at the interface between various capping materials (Biodentine), TheraCal LC, Ultrablend Plus, Calcimol LC, ApaCal ART, Ionoseal, Equia Forte and dentin. Compared with the other materials, Equia Forte presented significantly greater SBS. Despite their high viscosity, self-curing materials such as Biodentine and Equia Forte displayed superior adaptation to dentin compared with light-cured materials. Latta *et al.,*(66) reported that Equia Forte and Fuji II LC had comparable SBS and shear fatigue strength (SFS) values, both of which were significantly lower than those of the resin composite (Z100 Restorative) bonded with a universal adhesive (Prime&Bond Active). The resin composite provided superior bond durability, particularly to enamel and dentin, whereas Equia Forte and Fuji II LC showed similar clinical effectiveness in bonding to enamel and dentine.

The use of a dentin conditioner–commonly polyacrylic acid–is an optional but recommended step to increase the bond strength of GICs.(67) Research indicates that both the type of conditioner and the duration of its application can significantly impact bond strength outcomes.(68,69) Consequently, selecting the appropriate conditioner and application protocol should be tailored to the clinical situation and the desired level of adhesion.(70) In a study by Suresh *et al.,*(71) the effects of 10% polyacrylic acid and 37% phosphoric acid on permanent teeth were evaluated prior to the placement of a high-viscosity glass ionomer. The findings demonstrated that 37% phosphoric acid improved the penetration depth of the material into dentin, suggesting its potential advantage as a surface conditioner.

Equia Forte has shown favorable marginal integrity and minimal microleakage compared with conventional GICs and RMGICs. Singh *et al.,*[72] and Ali *et al.,*[73] confirmed Equia Forte's superiority over Fuji II LC and other conventional glass ionomers in reducing microleakage at the occlusal and cervical levels. A recent systematic review confirmed the suitability of Equia Forte for clinical scenarios requiring durable and reliable adhesion, particularly in cases susceptible to marginal leakage.[74]

GH-GICs reliably bond to tooth structures through chemical adhesion and micromechanical interlocking, demonstrating favorable marginal integrity and minimal microleakage. However, their bond strengths typically remain lower than those of resin composites combined with universal adhesives. This limitation should be considered during clinical decision-making, particularly in demanding adhesive scenarios.

Bonding to the resin composite

The utilization of universal bonding agents shows promise in improving the bond strength between resin composites and GH-GICs in layered restorations. Farshidfar *et al.,*[22] investigated the impact of two universal bonding agents (Clearfil Universal Bond and G-Premio Bond) on the microtensile bond strength (μTBS) of Equia Forte Fil, Riva SC, Fuji II LC, and Riva Light Cure combined with a resin composite (Kalore, GC) with or without 35% phosphoric acid. Both adhesive agents significantly enhanced the μTBS across all the materials, with RMGICs such as Fuji II LC and Riva Light Cure exhibiting higher μTBS values than Equia Forte Fil and Riva SC. Furthermore, the application of universal adhesive agents (in the etch and rinse mode) notably improved the μTBS of both conventional GICs and RMGICs to the resin composite compared with that without acid etching. In another study, Francois *et al.,*[75] explored the SBS and interface characteristics between a resin composite (Filtek Z350) and various materials, including Equia Forte Fil, Fuji IX, Fuji II LC, a bulk-fill flowable resin composite (SDR), and a regular flowable resin composite (Tetric Evo Flow), via different adhesive systems. The study concluded that the most effective bonding between the resin composite and HV-GICs was achieved via a universal adhesive in self-etch mode. Additionally, they observed intimate contact at all the interfaces examined, noting that the SBS to Equia Forte Fil varied significantly depending on the adhesive system used, with Scotchbond Universal in self-etch mode showing the highest SBS compared with the other systems.[75] Moreover, beyond enhancing interfacial adhesion, adhesives have also been reported to reinforce the underlying glass-hybrid substrate. Alqasabi *et al.,*[76] reported that these adhesive agents create a superficial laminate that increases surface hardness and reduces moisture-related degradation of GH-GICs.

However, although universal adhesives significantly enhance bonding between GH-GICs and resin composites, especially in self-etch or selective-etch modes, the bond strengths typically remain inferior to those of composite-to-composite bonding. This reflects the inherent limitations and complexity associated with layered restorations involving GH-GICs and resin composites, necessitating careful clinical consideration. Additionally, evidence regarding long-term aging effects on GH-GIC-to-composite bonding is limited, indicating the need for further investigations into durability and bond stability over time. Similarly, the potential influence of the GH-GIC layer thickness on the bond strength remains unclear and warrants future research to guide clinical protocols more effectively.

The clinical performance of GH-GICs

Several clinical studies have explored the efficacy of glass hybrid restorative systems in various clinical scenarios, including class I[25,28,30] and class II cavities.[29,77-79] A summary of these studies is presented in Table 3. GH-GICs have been established as viable choices for class I restorations[25,28,30] and small to large two-surface class II restorations.[77-79] El-Bialy *et al.,*[28] reported comparable clinical outcomes between Equia Forte Fil and Equia Fil in occlusal cavities among high-caries-risk patients after one year. Similarly, Uyumaz *et al.,*[25] demonstrated equivalent and successful clinical outcomes of Equia Forte HT coated with Equia Forte Coat compared with resin composites after one year. A long-term study comparing Equia Forte with a microfilled resin composite (Gradia Direct Posterior, GC) in class I and class II cavities over 10 years revealed comparable durability, clinical effectiveness, and maintenance of surface textures.[7]

Gurgan *et al.,*[77] evaluated Equia Forte against a microhybrid resin composite (G-ænial Posterior) in large, deep class II restorations. Despite the significant color discrepancy with glass hybrid restorations, Equia Forte exhibited a relatively high success rate after 2 years in extended class II cavities, similar to the tested resin composite. The glass hybrid restorative system showed no significant disparities in terms of retention, anatomical form, or proximal contact points. Wafaie *et al.,*[78] found that HV-GICs, including Equia Forte, performed adequately in small-to-medium class II cavities over five years but exhibited surface luster deterioration and color mismatch. Similarly, Miletic *et al.,*[79] observed comparable success between Equia Forte and a nanohybrid resin composite (Tetric EvoCeram) in moderate-to-large two-surface class II cavities at five years. However, Balkaya *et al.,*[29,80] reported superior clinical performance of resin composites over GH-GICs after one and two years, suggesting that caution should be taken in the use of GH-GICs for larger restorations. Gurses *et al.,*[81] Furthermore, HV-GICs exhibited lower clinical effectiveness than did bulk-fill resin composites in class II restorations.

Clinical evidence generally supports GH-GICs as promising alternatives under specific conditions. Indication criteria for selecting GH-GICs should consider caries risk, as these materials provide fluoride release and remineralization, making them suitable for high-caries-risk patients. The size and location of the cavity are also critical, with GH-GICs recommended primarily for class I cavities and small-to-medium-sized class II cavities where functional and esthetic demands are moderate. Additionally, these materials offer clinical convenience and are particularly beneficial in scenarios requiring rapid, straightforward placement, such as pediatric, geriatric, or medically compromised patients. Conversely, their reduced translucency and potential color mismatch limit their suitability for anterior restorations or highly visible posterior restorations. The observed performance deterioration in larger restorations and increased aesthetic demands highlight the need for clinicians to carefully balance these factors when choosing GH-GIC restorations. Further standardized long-term clinical trials are essential to clarify and refine these indications, guiding clinicians toward optimal clinical outcomes. Recognizing discrepancies in study designs, methodologies, and evaluation criteria among available studies emphasizes the need for standardized approaches to establish universally applicable clinical guidelines for GH-GIC use. A summary of the

Table 3: Summary of clinical and *in vitro* studies comparing glass HV-GICs and GH-GICs and other restorative materials.

A. Clinical studies investigating the performance and outcomes of HV-GICs and GH-GICs in class I and II restorations				
Study	**Year**	**Materials**	**Classes**	**Outcomes/Results**
Klinke *et al.,*[30]	2016	Equia system vs. Fuji IX GP Fast + Fuji Coat LC	Small to moderate class I and II	Comparable performance in class I; Equia system superior in class II restorations with fewer failures.
Türkün & Kanik[33]	2016	Equia system vs. Riva SC + Fuji Varnish	Moderate to large class I and II	Equia Fil showed better performance in class I and II restorations over 6 years; coatings wore off after 6 months.
Kharma *et al.,*[26]	2018	Equia system vs. microhybrid resin composite (Amelogen Plus)	Small class I	No statistical significance difference between both in anatomical shape, color, postoperative sensitivity, secondary caries, material handling, adaptation, and marginal staining after 9 months. Equia surface texture decreased overtime.
Balkaya *et al.,*[29]	2019	Equia Forte system, bulk-fill resin composite (Equia Forte system), microhybrid resin composite (Charisma Smart).	Small to moderate class I and II	Resin composites showed better clinical performance than Equia Forte system after 1 and 2 years.
Heck *et al.,*[32]	2020	Fuji IX GP Fast + Fuji Coat LC vs. Equia system	Small class II	Both materials showed acceptable survival rates; significant deterioration in surface luster, marginal adaptation, and retention over 6 years.

Gurgan *et al.,*[77]	2020	Equia Forte system vs. microhybrid resin composite (G-ænial Posterior)	Large class II	Equia Forte showed significant mismatch in color, both materials exhibited successful performance for the restoration of large class II cavities after 24 months.
El-Bialy *et al.,*[28]	2020	Equia Forte Fil vs. Equia Fil	Small class I	Comparable performance after 1 year in high-caries-risk patients.
Hatirli *et al.,*[24]	2021	Equia system vs. nanohybrid resin composite (GrandioSO)	Small class I	Equia system showed comparable performance to resin composite; lower marginal discolouration but greater surface wear.
Rożniatowski *et al.,*[31]	2021	Equia system vs. resin composite (Tetric EvoCeram)	Class II	Similar efficacy over 2 years; Equia had higher risk of marginal adaptation deterioration, staining and erosion.
Uzel *et al.,*[27]	2022	Equia system vs. bulk-fill resin composite (Tetric EvoCeram)	Small to moderate class I and II	Both materials showed good clinical performance; Equia had more chipping and surface degradation over 2 years.
Wafaie *et al.,*[78]	2022	Ketac Universal Aplicap, Equia Forte and Riva Self Cure HV vs. microhybrid resin composite (Filtek Z250)	Small to moderate class I and II	Although drawbacks in surface luster and color match appeared over the 5-year period, the three high-viscosity glass ionomers had successful clinical performance compared to Filtek Z250
Uyumaz *et al.,*[82]	2023	Equia Forte HT system vs. microhybrid resin composite (Charisma Smart)	Small class I	Resin composite outperform Equia Forte HT system in terms of color match and surface texture. Comparable clinical performance after 1 year.
Gurses *et al.,*[81]	2023	Two Bulk-fill Resin composites (Tetric EvoCeram Bulk-Fill and Filtek Bulk-Fill) vs. Equia Forte system.	Small to moderate class I and II	Both bulk-fill resin composites had comparable clinical performance; Equia Forte system showed lower clinical effectiveness after 2 years.
Miletić *et al.,*[79]	2024	Equia Forte system vs. nanohybrid resin composite (Tetric EvoCeram)	Small to moderate class I and II	Both materials showed satisfactory survival and success rates over 5 years.
B. *In vitro* studies investigating mechanical and physical properties of GH-GICs				
Kutuk *et al.,*[46]	2019	Equia Forte system vs. microhybrid resin composite (G-ænial Posterior)	No significant difference in fracture resistance; resin composite had higher compressive strength.	
Šalinović *et al.,*[40]	2019	Equia Forte Fil vs. Ketac Universal Aplicap vs. Equia Fil	No significant difference in compressive strength; Ketac Universal Aplicap had higher hardness values than Equia fil and Equia Forte fil.	
Moshaverinia *et al.,*[34]	2019	ChemFil Rock vs. Fuji IX GP vs. Equia Forte Fil	Equia Forte Fil had higher flexural strength and surface hardness than Fuji IX GP, with no significant difference in compressive or diametral tensile strength. Equia Forte released significantly more fluoride after 4 weeks compared to Fuji IX GP and ChemFil Rock. ChemFil Rock showed higher flexural strength (not statistically significant) but lower compressive strength and microhardness than Equia Forte Fil.	
Fuhrmann *et al.,*[37]	2020	Equia Forte vs. Ketac Universal Aplicap vs. ChemFil Rock vs. Fuji IX Extra vs. IonoStar Molar vs. resin composites (Filtek Z250 and Filtek Supreme Ultra)	The resin composite restorative materials had significantly greater fracture toughness than the glass-ionomer materials. There was no significant difference in fracture toughness between the glass-ionomer materials. Equia Forte Coat improved surface hardness but did not affect fracture toughness.	

Yeo *et al.*,[38]	2021	Filtek Z350 vs. Filtek One Bulk Fill vs. Fuji IX vs. Equia Forte	Resin composites had higher flexural strength and translucency than Equia Forte and Fuji IX. Fuji IX and Equia Forte had similar flexural strength. Coating did not enhance elastic modulus and may increase wear.
Habib *et al.*,[51]	2021	Equia Forte Fil vs. RMGIC (Fuji II LC) with and without coatings	Coating improved flexural strength, reduced surface roughness, and decreased microleakage.
Kunte *et al.*,[35]	2022	Fuji IX vs. Equia Forte Fil	Equia Forte showed slightly higher compressive and diametral tensile strength, but differences were not statistically significant.
Valeri *et al.*,[47]	2022	RMGIC (Ionolux) vs. Activa Bioactuce Restorative vs. Equia Forte HT system vs. resin composite (Filtek Supreme Ultra)	Ionolux and Activa Bioactive Restorative had comparable or less wear compared to Filtek Supreme Ultra, while Equia Forte HT wore twice as much compared to the resin composite.
Moshaverinia *et al.*,[39]	2024	Equia Forte HT vs. Fuji IX GP vs. ChemFil Rock	Equia Forte HT had improved translucency, compressive strength, flexural strength and fluoride release compared to Fuji IX. No significant difference was found in flexural strength values between Equia Forte HT and Chemfil Rock.
Abuzinadeh *et al.*,[83]	2024	Fuji IX, vs. Equia Forte vs. Fuji II vs. resin composite (Tetric-N-Ceram Bulk Fill)	Equia Forte had comparable compressive strength and microhardness to Fuji II and Fuji IX. The resin composite had the highest compressive strength and microhardness among all materials. The study results showed statistically insignificant differences in surface microhardness across all groups. Equia Forte was 40% lower microhardness values than the other materials.

included studies is presented in Table 3.

This review highlights several limitations within the literature on GH-GICs. First, there is significant variability in study designs, methodologies, evaluation criteria, and follow-up periods among clinical studies, complicating direct comparisons and generalized conclusions regarding long-term efficacy. Many existing studies have short-term follow-up periods (≤ 5 years), limiting the understanding of long-term clinical outcomes, especially concerning durability and aesthetic stability.

Additionally, the performance of the resin coatings used with GH-GICs has been inconsistently reported, with varying results in terms of long-term mechanical properties and fluoride release. This inconsistency suggests that resin coating formulations and application protocols require further refinement and standardized testing to clearly determine their long-term effectiveness.

Future research should focus on conducting long-term randomized controlled clinical trials with standardized methodologies to provide robust data on the longevity and clinical performance of GH-GIC restorations, particularly moderate-to-large posterior restorations. Studies examining long-term biological impacts, such as fluoride release and remineralization capacity in clinically relevant scenarios, are also needed. Furthermore, investigations into optimizing resin coatings, exploring new formulations, and assessing their effects on mechanical and biological properties will enhance the clinical applicability and reliability of GH-GICs. Such research directions will significantly inform clinical decision-making and expand the potential applications of these promising restorative materials.

Conclusions

GH-GICs represent a notable advancement in restorative dentistry, successfully addressing several limitations of conventional glass ionomer cements through improved mechanical performance, fluoride release, and ease of clinical application. Clinically, GH-GICs demonstrate comparable effectiveness to resin composites in class I and small to moderate class II posterior restorations. Despite these advancements, challenges remain, particularly in larger restorations, including marginal deterioration, surface wear, and limited aesthetic outcomes. While resin coatings enhance initial mechanical durability, their short-lived effectiveness and reduced fluoride release may limit long-term benefits. GH-GICs, therefore, are particularly recommended for specific patient groups, such as those with high caries risk and pediatric, geriatric, and medically compromised populations, where their biological advantages outweigh their aesthetic and mechanical limitations. Future research should prioritize long-term clinical evaluations and innovative enhancements in resin coatings to further expand the clinical applicability and durability of GH-GICs.

Conflicts of Interest

The author declare that they have no conflicts of interest.

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