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Review
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Clinical efficacy of various modifications of glass ionomer cement as a restorative material in primary teeth: A systematic review

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Highlights

- Glass ionomer cements are widely used in pediatric dentistry but have limitations, prompting modified formulations with improved clinical performance.
- RMGIC, HVGIC, nano-filled, and bioactive materials show better durability, wear resistance, and caries prevention.
- The review supports a more tailored selection of restorative materials based on clinical outcomes, emphasizing the potential of bioactive and nano-modified GICs in improving pediatric dental care.

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Abstract

This systematic review aimed to assess the clinical performance of modified glass ionomer cements (GICs) in restoring primary teeth. The focus was on evaluating their longevity, marginal adaptation, wear resistance, caries prevention, and overall durability in primary teeth. Following PRISMA 2020 guidelines and PROSPERO registration, a systematic search was conducted across PubMed, Scopus, and Google Scholar for studies published between 2014 and 2024. Sixteen eligible studies were included. Risk of bias was assessed using the Cochrane ROB 2 tool. Clinical performance was evaluated based on standardized criteria, including USPHS, FDI, and Ryge systems. Resin-modified GIC (RMGIC) and high-viscosity GIC (HVGIC) demonstrated better marginal integrity and wear resistance than conventional GIC. Nano-modified GICs, such as Ketac Nano, showed improved mechanical strength and esthetics. Bioactive and alkasite-based materials (e.g., Cention N) offered therapeutic benefits like fluoride release and remineralization, along with good clinical durability. Conventional GICs showed higher failure rates, particularly marginal breakdown, while modified GICs exhibited reduced failure over 12–36 months. However, variations in evaluation criteria and limited long-term data on newer materials restricted the strength of comparisons. The study concluded that modified GICs, particularly RMGIC, HVGIC, and bioactive formulations, show promising clinical performance in primary teeth restorations. Their selection should consider caries risk and cavity size. While current evidence supports their use, future studies with standardized protocols and long-term follow-ups are necessary to establish their sustained efficacy.

Keywords: Deciduous; Dental Restoration; Glass Ionomer Cements; Pediatric Dentistry; Tooth

INTRODUCTION

Early childhood caries has been a global healthcare concern. Restoring a primary tooth with caries helps to preserve the arch length as well as function like mastication and phonetics. In the past restoration of caries in both primary and permanent tooth was done using silver amalgam however concerns over potential mercury toxicity and aesthetics led to the development of tooth colored materials. [1-4]

Glass ionomer cement (GIC) was invented by Wilson and Kent in 1969 and has been available for over 30 years and has potential advantages over amalgam, but is slow setting and has low fracture toughness and poor wear resistance.[5-7]

Glass ionomer cements (GICs) are water-based substances that harden by an acid-based setting reaction between fluro-aluminum silicate glass and polyalkenoic acid. They are utilized as full restorative materials in the proximal and occlusal cavities of teeth, as bases and liners, as fissure sealants, as adhesives for orthodontic brackets, and as atraumatic restorative treatment materials, particularly in paediatric dentistry.[7-11]

The property of GIC to bond chemically to tooth structure, reduces the need for extensive tooth preparation, which is advantageous in treating children who may have difficulty cooperating during dental procedures. Researchers have made repeated efforts to refine conventional GIC by adjusting its chemical composition, aiming to improve properties such as durability, appearance, and ease of manipulation.[8]

To overcome the reported problems conventional GIC such as low wear resistance and fracture toughness, Resin-modified GICs (RMGIC) were developed. Studies comparing the two materials suggest that RMGICs have superior properties compared to conventional GIC.[12] Other modifications have been developed, for instance, using nano clay, hydroxyapatite powders, metallic powders, bioactive glass particles, and discontinuous glass fibers as filler particles.[1] Recently, the cellulose nanocrystals (CNCs) were introduced in the GIC to improve physicochemical qualities required in therapeutic settings.[14]

High viscosity GIC is also one of the modifications and has gained popularity in Paediatric Dentistry. [14] The Glass powder has finer particles and powder to liquid ratio is high (3:1 or 4:1) in high viscosity GIC. It also has better surface abrasion and compressive strength, when compared to conventional GIC which makes it suitable for use as a restorative material in posterior teeth.[15]

While setting if GIC is exposed to moisture it leads to reduced translucency and surface wear. It is suggested to use certain materials to protect the GIC surface. Petroleum, adhesives, and varnishes can be utilized as GIC coatings, and petroleum jelly is one of those because it is regarded safe and biocompatible; However, petroleum jelly is rapidly removed by washing, so a longer-lasting surface coating is desired, because GIC needs isolation from moisture during setting. So, a new generation nanofilled self-adhesive light cured protective coating was developed. This modification was intended to increase the wear resistance of the material.[5,11]

The main focus of this systematic review is to evaluate the clinical efficacy of different modifications of GIC in restoring primary teeth. This evaluation is crucial as it determines the long-term success of dental restorations in paediatric patients. Understanding the modification of GIC that provides the best clinical outcomes in terms of longevity, durability, and overall performance is essential for dental practitioners to make informed decisions regarding the choice of restorative materials for primary tooth restorations.

METHODS

This systematic review was prepared according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines 2020 and is registered in PROSPERO (CRD42024587685).

Information Sources and Search Strategy

Various online search engines such as PubMed, Web of Science and Scopus were searched. A search of the grey literature was performed in Google Scholar and systemic snowball search of citations were performed. The search strategy included the use of text words and MeSH terms for the time period of 2014-2024. Various search terms like primary teeth, modifications, clinical efficacy, resin modified GIC, glass ionomer cements, clinical effectiveness along with Boolean AND OR operators were used.

This systematic review included articles published in English between 2014 and 2024, focusing on randomized controlled trials, observational studies, and clinical trials evaluating restorative materials for primary teeth without pulp therapy. Only studies involving at least one modification of glass ionomer cement (GIC) were considered. Exclusion criteria comprised early reports of longer studies, in vitro or animal studies, narrative reviews, editorials, non-English publications, articles with unavailable full texts, and studies using the atraumatic restorative treatment (ART) technique.

The target population consisted of pediatric patients with carious lesions requiring restorative intervention. The interventions examined included conventional GIC and its modifications, compared against other restorative materials or different GIC formulations. Key outcomes assessed were the clinical performance of restorations, presence of secondary caries, marginal discoloration and adaptation, restoration longevity, retention and wear, anatomical form, fluoride release and its caries-preventive effects, patient/parent satisfaction, and adverse events related to the restorations.

The search and screening process were carried by two authors independently. After gathering all information, screening was performed to eliminate duplicate articles and those that did not match the inclusion criteria. The exclusion criteria was than further applied.. The whole process was reviewed by the other three authors to eliminate any possible bias.

Data Extraction Process

The studies that fulfilled the inclusion criteria were further processed for data extraction. The data was arranged in excel sheet according to first three authors, type of study, year of study, sample size, population, intervention, control and outcome. The data extraction was done by two authors and reviewed by the other three authors.

RESULTS

Search and Selection

The preliminary search of electronic databases and grey literature identified 1,730 records. Following the removal of duplicates and screening of titles and abstracts, 147 articles were retained for full-text review. Of these, 131 were excluded after applying predetermined exclusion criteria, which included in vitro research, non-English publications, narrative reviews, editorials, incomplete datasets, and studies based on atraumatic restorative treatment (ART). Finally, 16 randomized controlled trials were included in the qualitative synthesis. The study selection process is depicted in the PRISMA 2020 flow diagram (Figure 1).

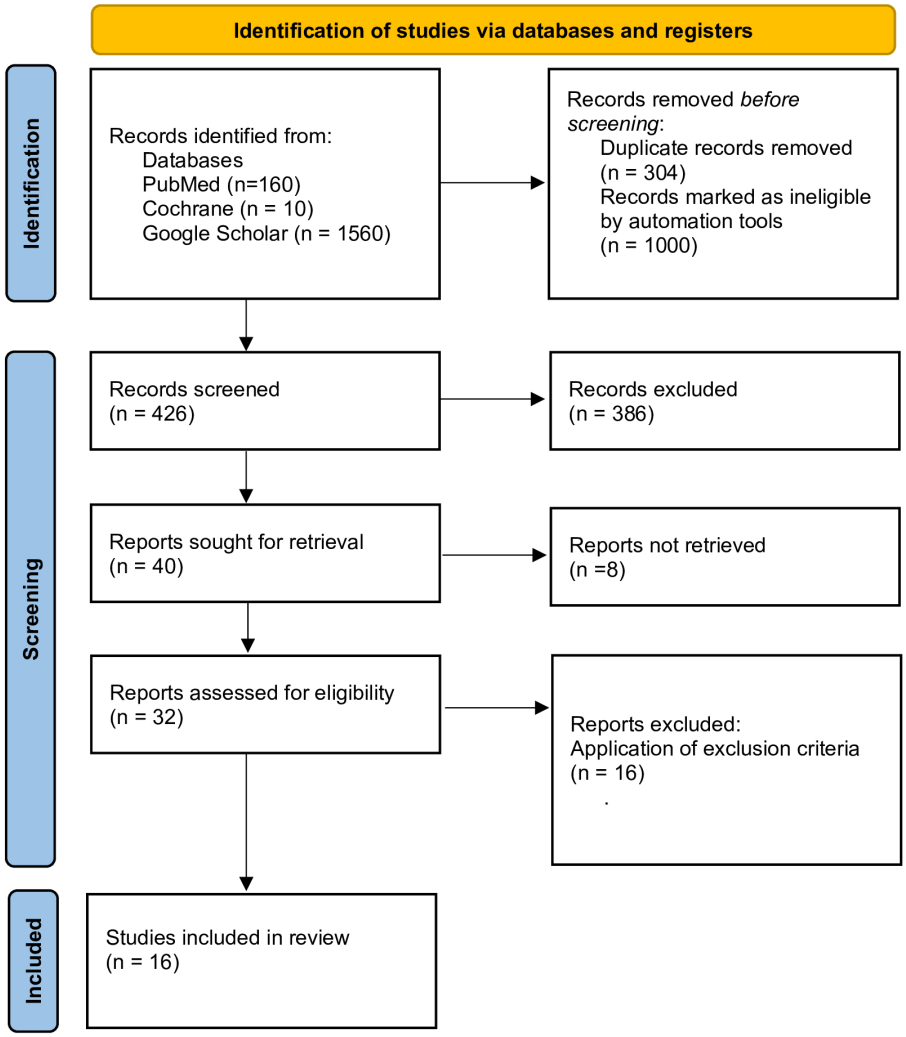

Figure 1. PRISMA Flowchart illustrating the identification, screening, and inclusion process of studies based on PRISMA 2020. Sixteen randomized controlled trials were included in the final qualitative synthesis after screening 1,730 initial records and applying eligibility criteria

Description of Included Studies

A summary of the 16 eligible clinical studies, published between 2014 and 2024, is presented in Table 1. These investigations varied in terms of participant demographics, types of modified glass ionomer cements (GICs) tested, comparator restorative materials, outcome measures, and evaluation criteria. The modifications examined encompassed resin-modified, high-viscosity, nano-filled, bioactive, and alkasite-based GIC formulations.

Outcomes were commonly assessed using standardized clinical indices such as the United States Public Health Service (USPHS) criteria, the Fédération Dentaire Internationale (FDI) guidelines, and the Ryge system. Overall, most studies demonstrated favorable clinical behavior of modified GICs, particularly in marginal integrity, resistance to wear, and restoration longevity, highlighting their suitability for pediatric restorative dentistry.

Table 1. Characteristics of the clinical studies included in the systematic review (2014–2024)

Study (Author)	Year	Population	Intervention	Comparison	Evaluation Criteria	Follow-up	Outcome	Result
Phonghanyudh et al.	2014	Primary molars	Fuji IX GP	Composite resin	USPHS	6 & 12 mo	Class II	Both effective
Mufti AS	2014	27 children, 4–10 yrs	RMGIC	GIC	USPHS	6 mo	Marginal adaptation	Vitremer better
Sengul et al.	2015	41 children, high caries risk	RMGIC, GCR, Compomer	GCR	FDI	-	Biological success	RMGIC best
Donmez et al.	2016	31 children, 4–7 yrs	Light-cure GIC	Composite	FDI	-	Marginal adaptation	More deterioration in GIC
Tal et al.	2017	44 children, 6–12 yrs	EQUIA	None	Clinical/ radiographic	-	Overall success	93.5% success
Dermata et al	2018	Children 4–7.5 yrs	Vitremer	Composite	USPHS (mod.)	6 & 12 mo	Occlusal wear	Similar except wear
El-Housseiny et al.	2019	Children 4–8 yrs	Glass Carbomer	RMGIC, CR	USPHS (mod.)	-	Marginal adaptation	Carbomer not satisfactory
Kupietzky et al.	2019	87 children	GIC (Equia)	Composite	Radiographic + Clinical	-	Success metrics	Composite 3x better
Dermata et al.	2020	Children 4–8 yrs	Nano-filled GIC	RMGIC	USPHS (mod.)	12, 24, 36 mo	Multiple	Similar short-term; RMGIC better at 36 mo
Hodhod et al.	2021	13 patients, 4–8 yrs	Fuji IX + Chitosan	HVGIC	USPHS (mod.)	6 mo	Wear resistance	No sig. diff.
Gok Baba et al.	2021	4–7 yrs	Glass hybrid HVGIC, Zn-HVGIC	Compomer	USPHS (mod.)	3–12 mo	Clinical success	Compomer superior
Deepika et al.	2022	Bilateral occlusal lesions	Bioactive RMGIC	Giomer	USPHS (mod.)	6 & 12 mo	Caries prevention	Bioactive RMGIC effective
Bhat et al.	2023	Children 4–9 yrs	Cention N	RMGIC, Composite	FDI	-	Clinical performance	Cention N best overall
Kataria et al.	2023	3–8 yrs	Cention N, GC 9 Extra	Ketac Universal	USPHS (mod.)	6 & 12 mo	Radiographic & clinical	Cention N outperformed
Ali et al.	2023	4–7 yrs	Glass carbomer, Ketac N100	Light-cure GIC	Ryge + MGI	-	Gingival health	Nanofilled better
Farag et al.	2024	24 children, 4–6 yrs	Equia Forte + Coat	RMGIC	USPHS (mod.)	1–12 mo	Longevity	No significant difference

List of abbreviations used: GIC = Glass Ionomer Cement; RMGIC = Resin-Modified Glass Ionomer Cement; USPHS = United States Public Health Service Criteria; FDI = Fédération Dentaire Internationale Evaluation; CR = Composite Resin; GCR = Glass Carbomer Restorative; Evaluation duration varies; not all studies had exact matching follow-up times

Risk of Bias Assessment

Risk of bias was independently appraised using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool for randomized trials and the ROBINS-I tool for non-randomized studies. Evaluated domains included the adequacy of randomization, adherence to intended interventions, completeness of outcome data, accuracy of outcome measurement, and selective reporting. Any differences in judgment were resolved through discussions with other reviewers. Most randomized trials were rated as having "some concerns," largely due to insufficient reporting of allocation concealment and limited blinding procedures. A few studies achieved "low risk," adhering to rigorous methodological standards with pre-specified outcomes and validated evaluation methods. In contrast, two non-randomized studies were deemed to carry a "serious" risk of bias because of confounding variables, retrospective study design, and substantial participant attrition. Despite variability, most included studies employed robust and widely accepted evaluation systems such as modified USPHS and FDI criteria, ensuring reliable assessment of restoration performance. Figure 2 summarizes the overall distribution of risk of bias across the included studies, indicating that while several trials met high methodological standards, others demonstrated notable weaknesses, especially regarding randomization processes and handling of incomplete data.

DISCUSSION

The clinical efficiency of various modifications of glass ionomer cement (GIC) has been extensively evaluated in pediatric dentistry, particularly for restoring primary molars. This systematic review summarizes findings from randomized controlled trials (RCTs) that assessed the performance of conventional GIC, resin-modified GIC (RMGIC), and advanced GIC formulations such as bioactive and nano-modified GICs across different criteria, including marginal adaptation, wear resistance, caries prevention, and gingival health.

The findings from this systematic review provide valuable insights into the clinical efficacy of various modifications of GIC in primary tooth restorations.

The studies revealed variability in the marginal adaptation of GIC modifications. Donmez et al.[16] observed that light-cured GIC showed greater deterioration in marginal adaptation compared to composite resins over time. Meanwhile, Kupietzky et al.[17] reported composite resins being three times more successful in maintaining marginal integrity than conventional GIC, suggesting that while GIC provides adequate initial results, its durability may not match that of composite materials. Advances in material formulations, however, have improved these properties in newer GIC modifications.

Surface texture and wear resistance were common areas of concern for traditional GIC. Composite resins and newer materials such as compomer showed better occlusal wear resistance compared to GIC.[18] However, innovations such as high-viscosity GICs (HVGICs) and bioactive GICs have demonstrated improvements in wear resistance, making these materials more competitive in clinical settings.

Nano-modified GICs are another noteworthy innovation, integrating nanotechnology to address the mechanical limitations of traditional GIC. Dermata et al.[19] demonstrated that nano-filled GICs, such as Ketac Nano, exhibited superior outcomes in clinical parameters like surface texture, marginal integrity, and anatomical form compared to traditional and resin-modified GICs. The incorporation of nanoparticles improves material strength, wear resistance, and aesthetics without compromising the fluoride-releasing capacity of the material.

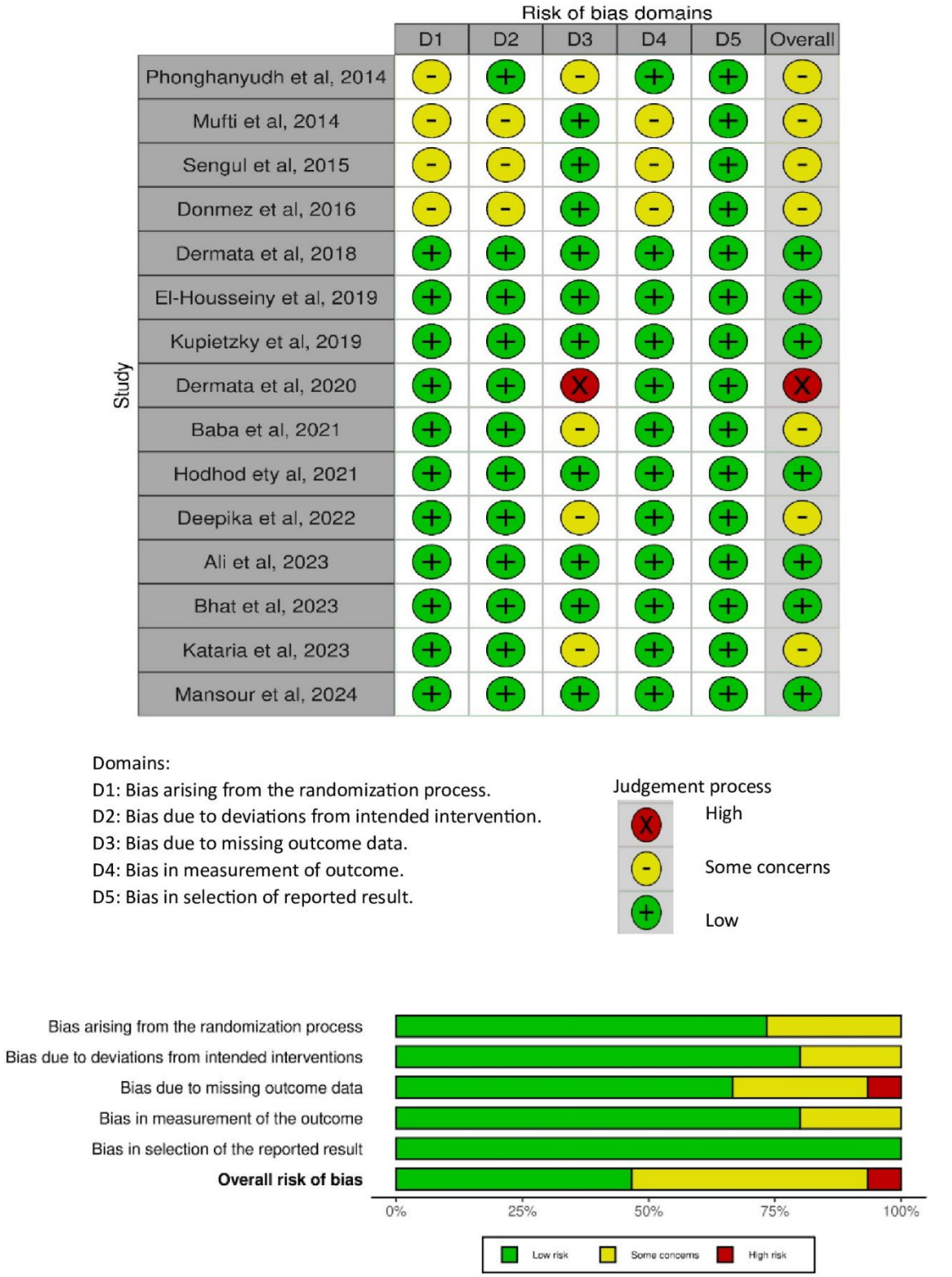

Figure 2. Risk of bias summary using the Cochrane RoB 2.0 tool across five domains for the 16 included studies. Color codes indicate risk levels: green (low), yellow (some concerns), and red (high). Most studies showed low to moderate risk.

Nano-modified GICs have been particularly effective in overcoming the brittleness and surface roughness often associated with conventional GICs.[19-21] These materials provide a smoother finish, reducing plaque accumulation and promoting better gingival health, as observed in the studies by Dermata et al.[19] and Hodhod et al.[22] Furthermore, their enhanced mechanical properties make them suitable for stress-bearing areas, broadening their application in pediatric restorative procedures.

One of the most significant findings of this review is the emergence of bioactive RMGIC and alkasite materials (e.g., Cention N) as promising alternatives. Deepika et al.[23] demonstrated that bioactive RMGIC exhibited superior restorative properties compared to Giomer and conventional GIC, with better marginal integrity and reduced secondary caries incidence. Similarly, Bhat et al.[24] found that Cention N outperformed both RMGIC and composite resin in FDI criteria evaluations, particularly in terms of anatomical form and surface texture.

These materials combine the benefits of resin-based composites (mechanical strength, polishability) with bioactive properties (ion release, remineralization potential), making them particularly advantageous in high-caries-risk pediatric patients. Their ability to chemically bond to tooth structure and release calcium, phosphate, and fluoride over time positions them as potential game-changers in pediatric restorative dentistry. The cariostatic properties of GIC modifications were evident across multiple studies.25-28 Bioactive materials, such as bioactive RMGIC, demonstrated superior outcomes in preventing recurrent caries, as shown by Deepika et al.23 This aligns with the findings of Farag et al.29, who reported no significant differences between bioactive GIC and resin-reinforced GIC regarding caries prevention, suggesting that bioactive materials may provide comparable clinical viable alternative to composite resins in certain clinical scenarios.

The studies reviewed employed different evaluation criteria, including USPHS, FDI, and Ryge's criteria, making direct comparisons challenging. Shorter-term studies (6–12 months) generally reported high success rates for all GIC modifications, but longer-term evaluations (24–36 months) revealed more pronounced differences. For instance, Dermata et al.[11] found no significant differences between nano-filled GIC and RMGIC at 12 months, but by 36 months, RMGIC showed better marginal adaptation. This shows the importance of extended follow-ups in assessing restorative material performance.

Marginal breakdown was the most frequently reported failure, particularly in restorations placed with conventional and light-cured glass ionomer cements. Secondary caries was commonly observed, especially in restorations involving non-bioactive materials. Restoration fractures were frequently reported, notably in large cavities restored with conventional glass ionomer cement. RMGIC and HVGIC showed lower failure rates in these categories, reinforcing their suitability for pediatric applications where durability is critical.

While this review provides robust evidence supporting the efficacy of modified GICs, several limitations must be acknowledged. The heterogeneity in study designs and evaluation criteria, such as variations in assessment scales (e.g., USPHS vs. FDI criteria), makes direct comparisons between materials challenging. Additionally, the long-term performance of newer materials like bioactive RMGICs and alkasite-based restoratives (e.g., Cention N) remains underexplored, as most studies were limited to 12-month follow-ups, necessitating further research to validate their durability. Another critical limitation is the variability in operator technique, including differences in moisture control, curing protocols, and cavity preparation, which may influence

outcomes and limit generalizability.

A notable gap in the included studies is their reliance on ideal clinical conditions. Most procedures were performed under rubber dam isolation, which minimizes salivary contamination but is often difficult to achieve in uncooperative pediatric patients. Consequently, the superior performance of resin-based materials (e.g., Cention N, ACTIVA) in these studies may not fully translate to real-world scenarios where isolation is compromised. The reviewed trials exclusively involved cooperative children, raising questions about the efficacy of these modifications in less controlled settings, such as those with behavioral challenges or excessive salivation. Future studies should evaluate material performance under suboptimal conditions to better reflect clinical realities in pediatric dentistry.

Addressing these limitations through standardized protocols, extended follow-ups, and inclusive patient cohorts will strengthen the evidence base for restorative decision-making.

Further research into the long-term clinical performance of bioactive and nano-modified GICs is warranted. Larger, multicenter trials with extended follow-up periods are necessary to validate their advantages and establish standardized protocols for their application. Additionally, exploring combinations of bioactive and nano-technology in GIC formulations could yield materials that combine the therapeutic benefits of bioactivity with the enhanced durability and aesthetics provided by nanotechnology.

CONCLUSIONS

This systematic review consolidates current evidence on the clinical efficacy of various modifications of glass ionomer cement (GIC) in primary teeth restorations. The findings demonstrate that resin-modified GIC (RMGIC) and high-viscosity GIC (HVGIC) offer notable advantages over conventional GIC in terms of durability and marginal integrity. In addition, bioactive and alkasite-based materials, such as Cention N and bioactive RMGIC, represent a significant advancement by combining mechanical strength with therapeutic benefits like fluoride release and remineralization. The selection of restorative material should be tailored to each clinical case, taking into account factors such as cavity size, caries risk, and the desired longevity of the restoration. These findings underscore the need for continued innovation in pediatric restorative materials, with bioactive and alkasite formulations showing promising potential to redefine clinical practice standards. Future research should focus on long-term clinical evaluations using standardized protocols to establish the sustained efficacy of these materials.

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