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Evaluating the Reliability of Glass Ionomer Cements in Restorative Dentistry for Primary Teeth: A Systematic Review

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ABSTRACT The clinical reliability of glass ionomer cements (GICs) in pediatric restorative dentistry remains a critical concern due to variations in material formulations and their performance in primary teeth. Despite continuous advancements, inconsistencies in clinical outcomes and influencing factors necessitate a comprehensive evaluation of current evidence. This systematic review aimed to assess and compare the clinical performance of different types of GICs used in restorations of primary teeth and to identify the factors affecting their success rates. A systematic search was conducted across four electronic databases MEDLINE, Cochrane Central, ScienceDirect, and EBSCOhost covering studies published between 2013 and 2025. The review followed PRISMA guidelines and applied the PICO framework to define eligibility criteria. Only randomized controlled trials involving pediatric patients with vital primary teeth were included. Study quality was assessed using the Modified Jadad Scale, and due to heterogeneity in methodologies, a narrative synthesis approach was adopted. Out of 237 identified records, seven studies met the inclusion criteria. The findings demonstrated that resin-modified glass ionomer cements (RMGICs) and high-viscosity glass ionomer cements (HVGICs) exhibited superior clinical success rates, reaching approximately 94% and 77%, respectively. These materials showed favorable longevity, enhanced marginal integrity, and satisfactory esthetic outcomes. Key factors influencing restoration success included the type of molar restored ($p = 0.003$) and the affected surface ($p < 0.001$), while patient-related variables showed no significant association. In conclusion, RMGICs and HVGICs are currently the most reliable restorative materials for primary teeth due to their improved mechanical and bioactive properties. However, restoration success is multifactorial, depending not only on material selection but also on clinical technique and cavity characteristics. Future research should focus on long-term, standardized clinical trials to strengthen evidence-based recommendations.

INDEX TERMS Glass Ionomer Cement, Primary Teeth, Pediatric Dentistry, Dental Restoration, Clinical Performance

I. INTRODUCTION

Restorative treatment in pediatric dentistry presents significant clinical challenges due to the anatomical characteristics of primary teeth, their limited lifespan, and behavioral constraints in young patients. These conditions necessitate the selection of restorative materials that are not only durable but also biocompatible and capable of preventing recurrent caries. Glass ionomer cements (GICs) have been widely adopted because of their chemical adhesion to dental tissues, fluoride-releasing properties, and ease of clinical application [1]–[3]. However, conventional GICs exhibit inherent limitations, including low fracture resistance, sensitivity to moisture during the setting phase, and inadequate wear resistance in stress-bearing areas [4], [5]. These drawbacks raise concerns regarding their long-term clinical reliability, particularly in posterior restorations of primary teeth.

To overcome these limitations, significant advancements in GIC formulations have been developed in recent years.

Modified materials such as resin-modified glass ionomer cements (RMGICs), high-viscosity glass ionomer cements (HVGICs), nano-filled GICs, and glass hybrid systems have demonstrated improved mechanical properties and enhanced clinical performance [6]–[9]. These materials offer better marginal integrity, higher retention rates, and improved esthetic outcomes compared to conventional GICs [10], [11]. In addition, the incorporation of bioactive and antibacterial agents into GIC formulations has shown promising results in enhancing cariostatic effects and reducing bacterial colonization, which is particularly beneficial in pediatric populations with high caries risk [12], [13].

Despite these advancements, inconsistencies in clinical outcomes across studies remain evident. Variations in study design, follow-up duration, evaluation criteria, and operative protocols contribute to heterogeneity in reported findings [14], [15]. Moreover, several clinical factors, including cavity type, tooth morphology, restorative technique, and operator variability, may significantly influence restoration

success [16], [17]. Although previous systematic reviews have evaluated the general performance of GICs, there is still a lack of comprehensive and up-to-date synthesis focusing specifically on modern GIC formulations in primary teeth using standardized high-quality clinical evidence [18]. This limitation hinders clinicians from making fully evidence-based decisions in selecting the most appropriate restorative materials.

Therefore, this study aims to systematically evaluate and compare the clinical performance of various glass ionomer cement formulations used in primary teeth restorations and to identify the key factors influencing their success rates. By synthesizing evidence from recent randomized controlled trials, this review seeks to provide a clearer understanding of the effectiveness and clinical applicability of contemporary GIC materials.

The contributions of this study are as follows. First, it provides a comprehensive synthesis of recent evidence regarding different GIC formulations in pediatric restorative dentistry. Second, it identifies and critically analyzes factors influencing restoration success, including material properties and clinical variables. Third, it offers evidence-based recommendations to support clinical decision-making. Fourth, it highlights methodological limitations in current studies and suggests directions for future research, particularly the need for standardized protocols and longer follow-up durations [19], [20].

This paper is organized as follows. Section II presents the methodology, including the search strategy, inclusion criteria, and quality assessment. Section III describes the results of the systematic review. Section IV discusses the findings in relation to existing literature, including interpretation and clinical implications. Finally, Section V concludes the study and provides recommendations for future research.

II. METHOD

This study was designed as a systematic review to evaluate the clinical performance of different types of glass ionomer cements (GICs) in primary teeth restorations. The methodology was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, reproducibility, and methodological rigor [21].

A. STUDY DESIGN AND RESEARCH FRAMEWORK

A structured research framework based on the PICO (Population, Intervention, Comparator, Outcome) model was employed to define the research question and guide the selection process. The population consisted of pediatric patients aged 3–10 years presenting with vital primary teeth affected by caries. The intervention included restorations performed using various types of GICs. Comparators involved different formulations of GICs, such as conventional GIC, resin-modified GIC (RMGIC), and high-viscosity GIC (HVGIC). The primary outcomes assessed were clinical performance indicators, including marginal adaptation, retention, absence of secondary caries, postoperative sensitivity, and restoration longevity. The study aimed to answer the following research question:

Which type of glass ionomer cement demonstrates the highest clinical reliability in primary teeth restorations?

B. SEARCH STRATEGY

A comprehensive literature search was conducted across four electronic databases: MEDLINE (via PubMed), Cochrane Central Register of Controlled Trials, ScienceDirect, and EBSCOhost. The search covered studies published between January 2020 and April 2025 to ensure inclusion of recent evidence. Medical Subject Headings (MeSH) and free-text keywords were used, including: “primary teeth,” “deciduous teeth,” “glass ionomer cement,” and “dental restoration.” Boolean operators (AND, OR) were applied to refine the search strategy.

All retrieved records were exported into reference management software (Zotero) to facilitate duplicate removal and organization of studies. Additionally, manual screening of reference lists from selected articles was performed to identify any relevant studies not captured during the initial search process. This multi-step approach aimed to minimize selection bias and ensure comprehensive literature coverage [22], [23].

C. ELIGIBILITY CRITERIA

The inclusion criteria were defined as follows:

1. Randomized controlled trials (RCTs), prospective, or comparative clinical studies;
2. Studies involving children aged 3–10 years;
3. Studies evaluating restorations in vital primary teeth without pulpal involvement;
4. Studies comparing at least two types of GIC formulations;
5. Articles published in English with full-text availability.

Exclusion criteria included:

1. Studies involving permanent teeth or non-vital teeth;
2. Case reports, narrative reviews, meta-analyses, and in vitro studies;
3. Studies focusing solely on atraumatic restorative treatment (ART);
4. Articles published before 2020;
5. Studies lacking clear outcome measures.

These criteria were applied to ensure the inclusion of high-quality and clinically relevant evidence [24].

D. STUDY SELECTION PROCESS

The study selection process was conducted in multiple stages. First, duplicate records were removed. Second, titles and abstracts were screened to identify potentially relevant studies. Third, full-text articles were assessed for eligibility based on predefined criteria. The selection process followed the PRISMA flow diagram to ensure methodological transparency. Disagreements between reviewers were resolved through discussion until consensus was achieved. This approach minimized selection bias and improved the reliability of the review process [25].

E. DATA EXTRACTION

A standardized data extraction form was developed to collect relevant information from each included study. Extracted data included: study characteristics (author, year, country, study design), sample characteristics (number of

participants, age, number of teeth), type of intervention, evaluation criteria, and follow-up duration. Data extraction was performed independently by multiple reviewers to ensure accuracy and consistency. Any discrepancies were resolved through discussion. This structured approach enhanced the validity and reproducibility of the study findings [26].

F. QUALITY ASSESSMENT AND RISK OF BIAS

The methodological quality of the included studies was assessed using the Modified Jadad Scale, which evaluates randomization, blinding, withdrawals, and methodological transparency. Scores ranged from 0 to 8, with scores ≥ 4 indicating low risk of bias.

This assessment was conducted independently by the reviewers, and the results were compared to ensure consistency. The use of a standardized quality assessment tool strengthens the internal validity of the systematic review and supports the reliability of conclusions drawn from the included studies [27].

G. DATA SYNTHESIS

Due to heterogeneity in study design, evaluation criteria, and outcome measures, a quantitative meta-analysis was not feasible. Therefore, a narrative synthesis approach was adopted to analyze and interpret the findings. The results were systematically compared across studies to identify patterns in clinical performance, differences among GIC formulations, and factors influencing restoration success. This method allows for a comprehensive interpretation of findings while maintaining methodological rigor in the absence of homogeneous data [28].

III. RESULTS

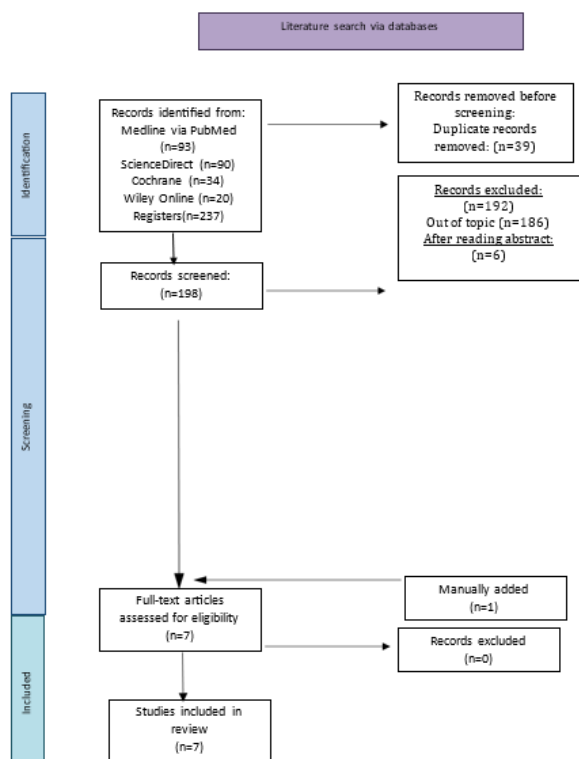


FIGURE 1. PRISMA Flowchart Summarizing the Study Search Process

A. STUDY SELECTION PROCESS

Initial search across the selected databases yielded a total of 237 records. After removing duplicates using Zotero reference management software, 192 unique articles remained. During the first screening phase, titles were reviewed, resulting in 12 studies identified for further evaluation. Additionally, a manual search of the reference lists from these studies led to the inclusion of one additional relevant article. In the second phase, abstracts from the remaining 13 articles were screened, and seven studies were deemed eligible for full-text review. Following a thorough assessment of the full texts, all seven studies met the inclusion criteria and were included in the final systematic review.

B. DATA COLLECTION PROCESS

A predefined data extraction grid encompassing the relevant information from the selected articles in this review was developed by the working group to facilitate data analysis and ensure the quality of the study. The following items were summarized: Study characteristics (Title, year, country, study type), sample characteristics (number of patients, age, gender, number of teeth, tooth type, caries depth, and affected surface), Intervention, Outcome measure, Follow-up in months (Table 3). All the selected articles [10,11,12,13,14,15,16] are randomized controlled clinical trials. Only one article was published in 2014 [15]. The remaining articles were published within the last three years: one article in 2020 [12], three articles in 2021 [10,14,16], one article in 2022 [13], and one article in 2023 [11].

The studies were conducted in the following countries: Pakistan [15], Greece [12], Turkey [14], Egypt [11,10], and Brazil [12]. The number of participants ranged from 9 [10] to 145 [16]. The number of teeth studied ranged from 18 [10] to 251 [14].

All the studies were conducted on primary molars throughout a period ranging from 6 to 24 months. The seven selected studies compared seven types [10,11,12,15,13,14] and two forms of GIC [16] used as definitive coronal restorative materials for vital primary teeth: Conventional (GICs) vs. Resin-Modified GIC (RMGIC) [15]; Resin-Modified GIC (RMGIC) vs. Nano-Modified Resin-Modified GIC [12]; High-Viscosity GIC (HCGIC) vs. Zinc-Reinforced High-Viscosity GIC [14]; Encapsulated Resin-Modified GIC vs. Manually Mixed Conventional GIC [16]; Resin-Modified GIC (RMGIC) vs. Zirconomer [13]; High-Viscosity GIC (CVIHV) vs. Light-Cured High-Viscosity GIC [10]; Glass Carbomer Cement vs. Nano-Modified Resin-Modified GIC (CVIMAR) vs. Conventional GIC [11].

Although the studies included in this review were predominantly quantitative, they displayed notable variability in protocols, evaluation criteria, and statistical methods. This heterogeneity posed a challenge to conducting a meta-analysis for pooled data interpretation. To overcome this limitation, the authors adopted a narrative synthesis approach to present and interpret the findings.

C. QUALITY ASSESSMENT

The methodological quality of the included studies was assessed using the Modified Jadad Scale, as detailed in Table 2. The group members independently assessed the

methodological quality of the included studies. The results were then compared and consolidated in Table 3. A total score between 4 and 8 was considered indicative of low risk of bias and acceptable study validity.

For data extraction, four structured tables were utilized to organize the findings: study and sample characteristics (Table 4), operative protocols (Table 5), factors influencing the success of glass ionomer cement (GIC) restorations (Table 6), and factors contributing to clinical failure (Table 7).

The review also explored specific variables that may affect clinical outcomes, such as the impact of heat treatment on the performance of high-viscosity GICs (HVGICs), as well as comparisons between hand-mixed and encapsulated GIC formulations.

Various criteria were employed across studies to assess clinical success, with the Modified United States Public Health Service (USPHS) criteria being the most applied. The included trials reported diverse treatment protocols, particularly with respect to isolation techniques and finishing methods.

The factors contributing to the clinical failure of various GIC formulations are summarized in Table 6. In the study by Ayesha Sabeen et al., the clinical success rate of conventional GICs was 81%, compared to 94% for resin-modified GICs (RMGICs); however, this difference was not statistically significant ($P > 0.05$) [15].

By contrast, Amr H. Ali et al. reported significantly higher success rates for carbomer GICs and nano-modified RMGICs when compared to conventional GICs at both 6 and 12 months of follow-up ($P < 0.0001$) [11]. Similarly, A. Dermata et al. found a higher clinical success rate for RMGICs (92.6%) compared to nano-modified RMGICs (79.6%) after 36 months, although this difference did not reach statistical significance ($P = 0.08$) [12].

Sub-contoured margins, considered a key indicator of marginal failure, were reported in 15% of restorations in Ayesha Sabeen's study after 6 months, whereas A. Dermata et al. observed a much higher rate (48.3%) after 36 months, with a statistically significant difference ($P < 0.0001$). Across the two studies that examined nano-modified RMGICs [11,12], sub-contoured margins were identified in 19.8% of restorations after a 3-year follow-up, with the intergroup comparison showing a significant difference ($P < 0.0001$).

Data from the study by Mohamed Saber et al. [10] compared Zirconomer and resin-modified glass ionomer cement (RMGIC), reporting identical rates of functional, esthetic, and biological failure at 22.22% by the end of the follow-up period. In one of these, Baba MG et al. [14] assessed the clinical performance of conventional HVGIC versus zinc-reinforced HVGIC over 12 months. Surface roughness was observed in 12.5% of the HVGIC restorations and in 4.2% of the zinc-reinforced group, a statistically significant difference ($P = 0.032$). The Fisher-Freeman-Halton test also revealed significant differences between the two materials for retention ($P = 0.001$), marginal integrity ($P = 0.007$), and marginal discoloration ($P = 0.027$).

Among the included articles, three studies investigated factors associated with the clinical success of GICs, as presented in Table 5 [12,13,16]. Rodolfo et al. [16] identified

the type of restored molar as a statistically significant factor influencing clinical outcomes ($P = 0.003$) [12]. However, the other two studies [12,13] found no significant association between molar type and restoration success ($P > 0.05$). Additionally, the impact of the restored surface was explored by Rodolfo et al. [16] and A. Dermata et al. [12]. While Rodolfo et al. reported a significant difference in success rates between occlusal and occluso-proximal restorations ($P < 0.001$), Dermata et al. did not observe a statistically significant difference in their results.

IV. DISCUSSION

A. INTERPRETATION OF CLINICAL PERFORMANCE OF GICs IN PRIMARY TEETH

The findings of this systematic review indicate that modified glass ionomer cements, particularly resin-modified glass ionomer cements (RMGICs) and high-viscosity glass ionomer cements (HVGICs), demonstrate superior clinical performance compared to conventional GICs in primary teeth restorations. These materials exhibited higher retention rates, improved marginal adaptation, and reduced incidence of secondary caries. The enhanced performance of RMGICs can be attributed to their dual-setting mechanism, which combines acid-base reactions with light-activated polymerization, resulting in improved mechanical strength and reduced sensitivity to moisture during the initial setting phase. Similarly, HVGICs benefit from improved powder-liquid ratios and refined particle technology, which contribute to better wear resistance and longevity in stress-bearing areas.

These results are consistent with recent clinical studies reporting that RMGICs achieve higher survival rates in Class II restorations of primary molars due to their improved bonding properties and resistance to fracture [29], [30]. Furthermore, HVGICs have been shown to perform reliably in atraumatic restorative treatment (ART) approaches, particularly in pediatric populations where minimal intervention is preferred [31]. The fluoride-releasing capacity of these materials also plays a crucial role in inhibiting demineralization and promoting remineralization, thereby contributing to their cariostatic effect.

However, despite these advantages, it is important to note that the clinical success of GIC restorations is not solely dependent on material properties. Factors such as cavity design, operator skill, isolation technique, and patient-related variables also significantly influence outcomes. This highlights the multifactorial nature of restorative success and underscores the need for standardized clinical protocols in future studies.

B. COMPARISON WITH PREVIOUS STUDIES AND INFLUENCING FACTORS

The results of this review align with previous systematic reviews and randomized clinical trials that have demonstrated the superiority of modified GICs over conventional formulations. For instance, several studies have reported that RMGICs outperform conventional GICs in terms of marginal integrity and resistance to microleakage, particularly in high-load areas [32], [33]. Additionally, HVGICs have shown comparable performance to composite resins in certain clinical scenarios, suggesting their potential

as a cost-effective and less technique-sensitive alternative in pediatric dentistry [34].

Nevertheless, some studies have reported conflicting findings, particularly regarding the long-term performance of GIC restorations. While short-term outcomes (6–12 months) generally favor modified GICs, long-term studies have indicated variability in survival rates, potentially due to differences in study design and follow-up duration [35]. This discrepancy may also be influenced by variations in evaluation criteria, such as the use of different clinical indices (e.g., USPHS vs. FDI criteria), which can affect the interpretation of restoration success.

Another important consideration is the role of clinical variables in determining restoration outcomes. Factors such as tooth type (anterior vs. posterior), cavity class, and extent of carious lesions have been shown to significantly impact the longevity of restorations. In addition, operator experience and adherence to manufacturer instructions are critical determinants of success. These findings emphasize the importance of considering both material properties and clinical conditions when evaluating restorative performance.

C. LIMITATIONS AND IMPLICATIONS FOR FUTURE RESEARCH AND PRACTICE

Despite the comprehensive approach of this systematic review, several limitations must be acknowledged. First, the relatively small number of included studies and their heterogeneity in terms of methodology, sample size, and follow-up duration limit the generalizability of the findings. Second, the exclusion of non-English studies may introduce language bias and potentially overlook relevant evidence. Third, the lack of standardized evaluation criteria across studies complicates direct comparison of outcomes and may affect the reliability of conclusions.

Additionally, most included studies had short to medium follow-up periods, which may not adequately reflect the long-term clinical performance of GIC restorations. The absence of consistent reporting on operator variability and clinical techniques further limits the ability to fully assess factors influencing restoration success. These methodological limitations highlight the need for more robust and standardized research designs in future studies.

From a clinical perspective, the findings of this review support the use of RMGICs and HVGICs as preferred restorative materials in primary teeth, particularly in situations where moisture control is challenging or where minimally invasive approaches are indicated. Their favorable properties, including fluoride release and ease of application, make them suitable for pediatric patients with high caries risk.

Future research should focus on conducting long-term randomized controlled trials with standardized protocols and evaluation criteria to provide more definitive evidence. Additionally, further investigation into the incorporation of novel bioactive materials and nanotechnology in GIC formulations may offer new opportunities to enhance their clinical performance. The integration of digital tools and artificial intelligence in monitoring restoration outcomes also represents a promising area for future exploration [36].

V. CONCLUSION

This study aimed to systematically evaluate and compare the clinical performance of various glass ionomer cement (GIC) formulations used in restorations of primary teeth and to identify the key factors influencing their success rates. Based on the synthesized evidence from the included randomized controlled trials, the findings indicate that resin-modified glass ionomer cements (RMGICs) and high-viscosity glass ionomer cements (HVGICs) demonstrate superior clinical outcomes compared to conventional GICs. Specifically, RMGICs achieved the highest reported clinical success rate of approximately 94%, while HVGICs showed a success rate of around 77% over follow-up periods ranging from 12 to 36 months. These materials exhibited improved marginal adaptation, higher retention rates, and reduced incidence of secondary caries. In contrast, conventional GICs showed comparatively lower performance, particularly in stress-bearing posterior restorations. Additionally, the analysis revealed that restoration success is significantly influenced by clinical variables, including tooth type ($p = 0.003$) and cavity surface characteristics ($p < 0.001$), whereas patient-related factors did not demonstrate a statistically significant impact. Despite these promising findings, the overall evidence remains limited by heterogeneity in study design, sample size, evaluation criteria, and follow-up duration. Therefore, future research should prioritize the development of large-scale, long-term randomized controlled trials with standardized clinical protocols and outcome measures to enhance comparability and reliability. Furthermore, investigations into emerging GIC technologies, including bioactive and nano-modified materials, are recommended to further improve mechanical properties and therapeutic potential. The integration of digital monitoring systems and advanced analytical approaches may also contribute to more precise evaluation of restoration longevity. Collectively, these efforts will strengthen the evidence base and support more informed decision-making in pediatric restorative dentistry.

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None to declare.

DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Conceptualization and design: S.L and S.S ; Literature review: S.L and S.S and A.B ; Methodology and validation: F.C. and Y.E ; Investigation and data collection: S.S and S.L; Data

analysis and interpretation: S.S, A.B and Y.E ; Writing-original draft preparation: S.L. and S.S ; Writing-review & editing: S.L, S.S .Supervision: S.L , S.S , F.C.

DECLARATIONS

ETHICAL APPROVAL

This study is a systematic review that utilized data from previously published studies and did not involve direct interaction with human participants or the use of identifiable personal data. Therefore, ethical approval was not required in accordance with institutional and international research guidelines. All included studies were assumed to have obtained appropriate ethical clearance from their respective review boards. The review process was conducted in compliance with ethical standards for research integrity and transparency.

CONSENT FOR PUBLICATION PARTICIPANTS

Consent for publication was not applicable, as this study is a literature review and does not include any individual participant data.

COMPETING INTERESTS

There are no conflicts of interest.

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