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SYSTEMATIC REVIEW

Outcomes of silver-modified atraumatic restorative technique (SMART) in carious primary teeth: a systematic review and meta-analysis of randomised clinical studies

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Abstract

Background: This systematic review evaluated the outcomes of Silver Modified Atraumatic Restorative Treatment (SMART) in managing carious primary teeth. **Methods**: Following the International Prospective Register of Systematic Reviews (PROSPERO) registration and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a comprehensive search of ten databases identified randomised clinical studies published in English from January 2010 to May 2025. Study selection, data extraction, and quality assessment were independently conducted, with the risk of bias assessed using the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) tool and evidence levels determined via the Oxford Centre for Evidence-Based Medicine (OCEBM) tool. Data analysis included single- and two-arm meta-analyses, sensitivity analysis, subgroup analysis, meta-regression, and evaluation of publication bias. **Results**: Nine studies published between 2022 and 2025 were included, with eight used for meta-analysis. Most of the included primary studies originated from Egypt (n = 6) and India (n = 3). Weighted mean success rates for SMART were 94.9% (Confidence Interval (CI): (90.7, 99.1)), 82.0% (CI: (71.0, 93.0)), and 69.5% (CI: (52.4, 86.6)) at 3-, 6-, and 12-month follow-ups, respectively. Funnel plots indicated slight asymmetry at 3 and 12 months, while the 6-month plot appeared relatively symmetrical. A two-arm meta-analysis found SMART achieved success rates comparable to Atraumatic Restorative Treatment (ART) at 6- and 12-month follow-ups ($p > 0.05$), with no significant data heterogeneity. Subgroup analysis revealed higher success rates when marginal adaptation was used as the evaluation criterion compared to pain or mobility ($p < 0.05$). Meta-regression indicated that sample size did not affect heterogeneity, and Egger's test showed no publication bias was detected. **Conclusions**: Findings suggested that SMART appears to be an effective alternative for treating carious primary teeth, but further research is needed to standardise evaluation criteria and confirm long-term efficacy. **The PROSPERO Registration**: ID: CRD42023480630.

Keywords

Atraumatic restorative treatment; Deciduous teeth; Dental caries; Dental materials; Silver diamine fluoride

1. Introduction

Dentistry has seen a dramatic paradigm shift in recent years, particularly in the management of paediatric patients, towards the adoption of minimally invasive and patient-centred approaches [1, 2]. The conventional restorative procedures of caries management involving invasive dental preparations, such as drilling and filling, have posed both clinical and psychological challenges for children [3]. The traumatic and anxiety-inducing experiences associated with traditional dental restorations may result in uncooperative behaviour and complications in dental procedures. These have driven the development and popularisation of alternative minimally invasive approaches, one of which is the Atraumatic Restorative Treatment (ART). ART involves the removal of decayed tissue using hand instruments alone, typically without the need for anaesthesia or electrical equipment [4]. The dental cavity is then restored with an adhesive material such as glass ionomer cement (GIC). While this technique is generally well-accepted among children and parents [5], the success rate of ART has been shown to vary from 67% to 71%, depending on various factors, including operator skills, type of restoration, extent, and location of the lesion [6].

Silver diamine fluoride (SDF) has gained increasing recognition among researchers and dental practitioners [7]. Specifically, a 38% SDF solution with 44,800 ppm fluoride is advised for use in uncooperative children with a high risk of caries, especially those facing medical or behavioural challenges or those experiencing limited access to dental care [8]. SDF demonstrates a diverse array of therapeutic effects, encompassing bactericidal action, mitigation of collagen matrix breakdown, promotion of tooth remineralisation, and inhibition of cariogenic biofilms [9, 10]. The silver particles and high fluoride content of SDF were found to significantly inhibit cariogenic bacterial growth, preserve dentine collagen from breakdown, and enhance the remineralisation of enamel and dentine [11, 12]. Moreover, previous research has shown that SDF enhances dentine's resistance by interacting with hydroxyapatite to form calcium fluoride and silver phosphate, which reduce acid penetration and strengthen the affected dentine [13]. These actions not only arrest caries but also create a more favourable environment for the restorative material to bond effectively, enhancing the durability and longevity of the restoration.

However, a significant drawback associated with SDF is the development of black staining in arrested carious lesions [14]. In addition, it falls short of restoring tooth form or masticatory function, as it follows a non-invasive approach that leaves teeth unfilled. Notably, SDF has been combined with ART, resulting in the technique known as Silver Diamine Fluoride Modified Atraumatic Restorative Technique (SMART). This method stands out as a non-invasive, tooth-preserving, and cost-effective alternative when compared to conventional ART procedures [15, 16]. SMART entails the careful removal of carious lesions using hand instruments, followed by the application of SDF, and subsequent restoration with GIC. Moreover, it is applicable in diverse clinical settings, including primary care, school-based dental programs, and communities where access to advanced dental facilities is limited.

Despite the growing interest, there is currently insufficient clinical evidence in the literature to support the outcome of SMART in managing carious primary teeth. The authors also questioned whether SMART could be deemed a viable minimally invasive treatment option for carious primary teeth. Therefore, this systematic review aims to comprehensively analyse the available literature on the outcome of SMART in managing carious primary teeth, with a focus on evaluating its efficacy and clinical outcomes. Through a critical examination of the evidence, this review endeavours to guide dental professionals, researchers, and policymakers in making informed decisions regarding the incorporation of SMART into their clinical protocols.

2. Materials and methods

2.1 Study registration and framework

This systematic review adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [17], and is officially registered with The International Prospective Register of Systematic Reviews (PROSPERO) through the National Institute for Health Research (NIHR) at the University of York (ID: CRD42023480630), as well as the local National Medical Research Registration with registration ID: RSCH ID-23-05747-FGE. The research question was formulated using the PICO framework, which encompasses the Patient or Population, Intervention, Comparison, and Outcome of interest. The PICO criteria were as follows: Population (P): Paediatric dental patients (Excluding adult patients and permanent teeth); Intervention (I): Silver diamine fluoride with atraumatic restorative treatment/silver-modified atraumatic restorative technique (SMART); Comparison (C): Other minimally invasive dental treatments or conventional restorative treatments; and Outcome (O): The efficacy or success rate of SMART in treating carious primary teeth. In this context, achieving both clinical and radiographic success was deemed an overall success. The selected studies' success rate was calculated by dividing the number of successful cases by the total number of treated cases that attended follow-up evaluation. The PRISMA checklists provide further details and are available as **Supplementary materials 1,2**.

2.2 Eligible criteria

The PICO question of this systematic review was, "What is the treatment outcome of SMART in carious primary teeth?". Articles were included if they met the following criteria: (1) children received SMART intervention for primary dentition; (2) restorable caries-exposed primary teeth without signs and symptoms of irreversible pulpitis; (3) randomised controlled or clinical studies; (4) no restriction on the number of teeth treated; and (5) published in the English language. Meanwhile, the exclusion criteria were specifically defined as follows: (1) interventions other than SMART; (2) studies involving the adult population and permanent dentitions; and (3) case-control, cross-sectional, cohort studies, non-randomised controlled trials, *in-vitro* and *in-vivo* experimental studies, expert opinions, reviews, short communications, abstract proceedings, animal studies, case reports, and case series.

2.3 Search strategy

Three investigators (GSSL, ARBH, JJXY) independently conducted comprehensive primary data collection from 10 different electronic databases, including PubMed, Google Scholar, Scopus, Web of Science, Excerpta Medica Database (EMBASE), EBSCO, Cochrane Library, Open-Grey, Latin American and Caribbean Literature on Health Sciences (LILACS), and World-Cat. The search was conducted on 31 May 2025. The search strategy employed specific keywords such as "silver modified atraumatic restorative technique", "silver modified atraumatic restorative treatment", "silver diamine fluoride", "atraumatic restoration", "atraumatic restorative treatment", "atraumatic restorative technique", and "minimally invasive dentistry", using "OR" and "AND" Boolean operators. Screening encompassed articles published between January 2010 and May 2025. For reference management, EndNote X9 software (Clarivate Analytics, Philadelphia, PA, USA) was used. The titles and abstracts of the articles were initially screened by the two investigators before reviewing the full texts and removing duplicates. Then, the three investigators (GSSL, ARBH, JJXY) independently conducted a thorough review and reassessment of the reference lists of pertinent articles obtained through both electronic and manual searches.

2.4 Data collection process

Eligible articles' full texts were evaluated based on the listed inclusion and exclusion criteria to ascertain the relevance of their contents. To assess interrater reliability, Cohen's kappa coefficients were computed for each of the two phases (initial screening and full-text assessment). A fourth investigator (JEK) arbitrated disagreements. In the event that the full article was not accessible, the study's authors were contacted to obtain the necessary information. Information pertaining to study characteristics (title, authors, year of publication, study type, and country), participant characteristics (age, pre-treatment tooth condition, sample size, and number of teeth involved), treatments (type of treatment administered and the restorative material used), and outcomes (follow-up, evaluation criteria, clinical outcomes, radiographic outcomes, overall outcomes) was systematically extracted from each article.

2.5 Quality assessment

Given that all the studies included were randomised clinical trials, a uniform method for assessing the quality of each primary study was utilised. The risk of bias evaluation was conducted using the Cochrane Collaboration tool for assessing the risk of bias in randomised trials (RoB 2) [18]. Each assessment item was categorised as "high risk of bias", "low risk of bias", or "some concern" based on the predefined evaluation criteria. The RoB 2 assessments were independently conducted by two examiners (ARBH, JJYX). The level of evidence of each study was determined using the Oxford Centre for Evidence-Based Medicine recommendation (OCEBM) [19]. In circumstances where discrepancies emerged during the quality assessment, discussions were held with another three investigators (GSSL, JG, JEK) to reach a consensus and resolve any disagreements.

2.6 Data analysis

The primary focus of this study is to determine the outcomes of SMART on carious primary teeth based on the intention-to-treat analysis. The extracted proportions of the clinical, radiographic, and overall success rates of SMART on primary teeth from each study were pooled and estimated using a single-arm meta-analysis based on the DerSimonian-Laird random-effects model. This meta-analysis was conducted using the OpenMeta (Analyst) software (CEBM, Oxford, UK), setting the significance level at 0.05 and employing a 95% confidence interval (CI). Should the estimated upper limit of the 95% CI exceed 1.0, it will be capped at 1.0. In addition, the two-arm meta-analyses were carried out to compare SMART with other restorative techniques, adhering to the intention-to-treat principle for a more conservative estimation of success rates. In these analyses, odds ratios were calculated using the Review Manager (RevMan) (RevMan International, Inc., New York City, NY, USA) software, version 5.4.1. To assess the data heterogeneity across the included studies, Higgins' I^2 statistics were applied, categorising heterogeneity as acceptable ($I^2 <$ 30%), moderate ($I^2 = 30$–60%), or substantial ($I^2 > 60\%$) [20].

The authors hypothesised that variations in evaluation criteria among the primary studies could influence the heterogeneity of the data (study design was disregarded as all primary studies adhered to the same design). Consequently, subgroup analyses were undertaken to examine the effects of different evaluation criteria (marginal adaptation, pain, and pathological mobility) on the success rates of SMART on primary teeth. However, certain evaluation criteria were omitted from the subgroup analysis owing to a lack of sufficient data from the included studies. Furthermore, a meta-regression was performed to determine the impact of sample size on the outcomes. Egger's test was employed to detect any publication bias.

3. Results

3.1 Selected studies

The initial electronic search resulted in a total of 499 records, of which 461 remained after duplicate removal (Fig. 1). These records underwent screening of titles and abstracts, resulting in the exclusion of 428 articles, which were deemed irrelevant. A total of 33 full-text articles were assessed for eligibility based on the predefined criteria. Ultimately, 9 articles were selected for inclusion in the qualitative synthesis, and only 8 studies were chosen for inclusion in the meta-analysis conducted in this review.

3.2 Study characteristics

The characteristics of each article included are summarised in Table 1. All the studies were randomised controlled trials conducted on primary teeth, notably primary molars. Five studies focused on primary teeth assessed the comparison between SMART and ART [16, 21–24], one study evaluated SMART against conventional GIC [15], one study compared SMART with conventional pulp therapy which included indirect or direct pulp therapy followed by GIC and stainless steel crown [25], one study compared single- and two-visit SMART [26], and one study made a comparison among SMART, Hall technique, and conventional GIC method [27]. All studies were published between 2022 and 2025. No eligible studies published prior to 2022 met the inclusion criteria. Six originated from Egypt [16, 21–24, 27], and three from India [15, 25, 26]. The age range of the patients involved in these studies was between 3 and 9 years, with most of the studies focusing on carious primary teeth classified as International Caries Detection and Assessment System (ICDAS) 04, 05 and 06. The average Kappa score for inter-investigator reliability during the study selection was 0.82, indicating "perfect" agreement.

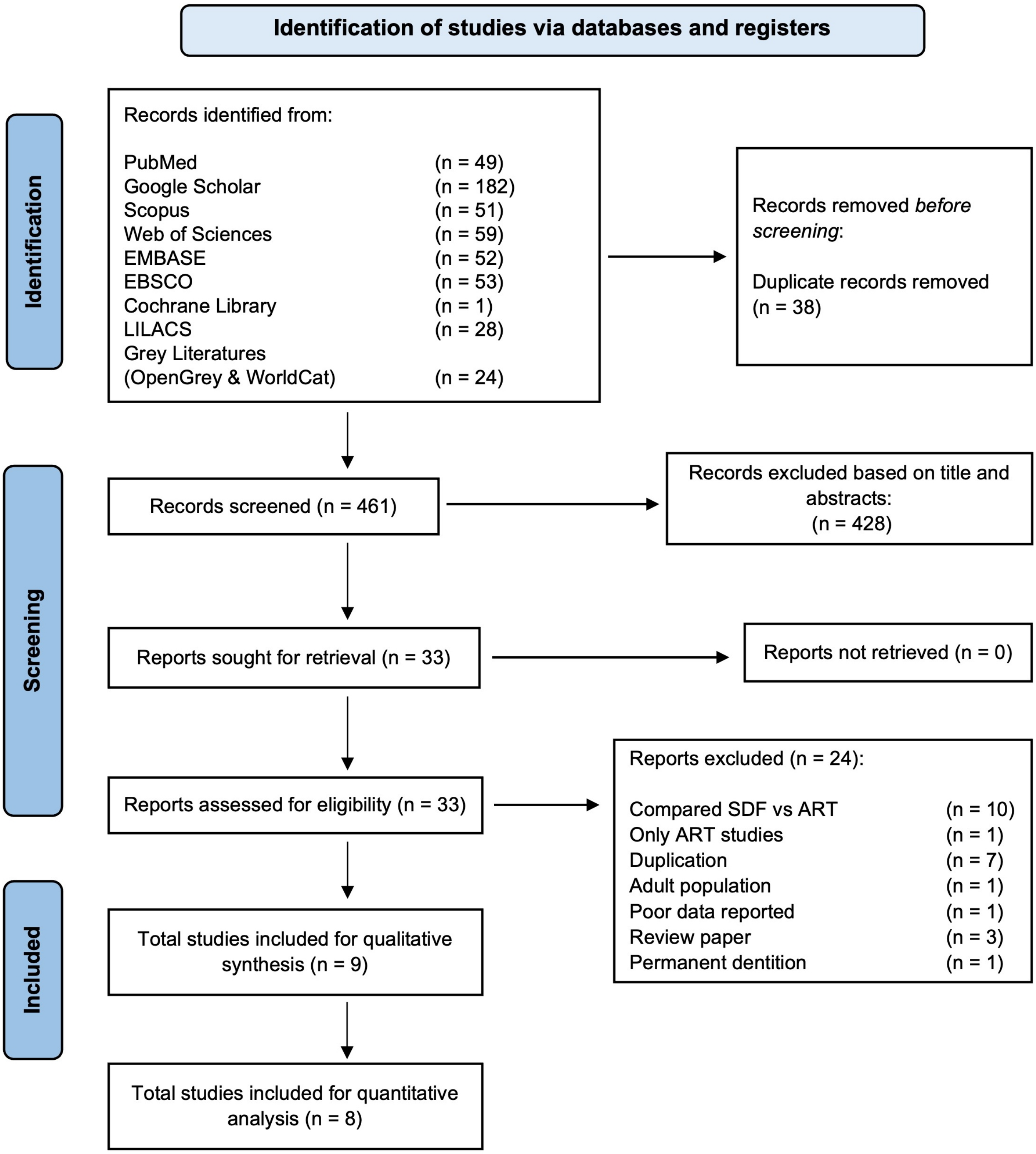

FIGURE 1. PRISMA flowchart. Study selection according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart. SDF: silver diamine fluoride; ART: atraumatic restorative treatment; EMBASE: Excerpta Medica Database; LILACS: Latin American and Caribbean Literature on Health Sciences.

3.3 Quality assessment of the selected studies

Based on the RoB 2 assessment in Table 2, only five studies were categorised as having a "low risk of bias" [15, 16, 24, 26, 27], while the remaining were assessed to have "some concerns" regarding their risk of bias. Only one study received a "some concern" rating for both Domain 2: Risk of bias due to deviations from the intended interventions and Domain 3: Risk of bias due to missing outcome data [22]. Moreover, three studies included were evaluated as having "some concern" for Domain 2 [22, 23, 25]. This was primarily because these studies utilised per-protocol analyses and did not account for dropouts, whereas Ahmad M *et al.* [22] did not report whether intention-to-treat or per-protocol analysis was employed. However, they were not deemed as "high risk of bias" since all dropout rates were considered negligible. All the studies included for the present review were ranked as Level 2 based on the evidence of OCEBM. The assessment of the risk of bias and the level of evidence's Cohen's kappa coefficient (κ) were evaluated at 0.78 and 0.82, respectively, signifying a "perfect" level of agreement [28].

TABLE 1. The characteristics of the included primary studies.

Study	Country	Patient age	Tooth condition	Sample size	comparators	Final restoration	Follow-up (mon)	Clinical evaluation criteria	Radiographic evaluation criteria	General outcome
Bansal K (2023)	India	4–8 yr	Caries with ICDAS 5 or 6; no sign of pulp disease; no clinical pulp exposure; no history of spontaneous pain; no physiologic mobility	Conventional (282 teeth); SMART (280 teeth)	SMART *vs.* conven-tional	GIC	6, 12, 18, 24	No intervention was required; no clinical signs or symptoms of pulp pathology or tooth exfoliated	n/a	No significant difference in the success rates between SMART and conventional GIC techniques in carious primary molars at 24 months, but SMART was significantly more acceptable to children.
Aly AAM (2023)	Egypt	5–9 yr	Active dentine carious lesion on occlusal surface (no existing restoration, no sign of pulpal or peri-radicular pathosis, and not more than 1/3 of the crown missing)	SMART (59 teeth), ART (60 teeth)	SMART *vs.* ART	GIC	6, 12	USPHS criteria: score A (Alpha) clinically ideal restorations; score B (Bravo) clinically acceptable situation; score C (Charlie) clinically unacceptable restorations	n/a	SMART and ART demonstrated similar clinical effectiveness and survival rates for single-surface occlusal restorations in primary molars, yet SMART required significantly less treatment time and was more cost-effective.
Mohammed SME (2022)	Egypt	3–6 yr	Restorable carious teeth; asymptomatic or reversible pulpitis	60 teeth (30 each group)	SMART *vs.* ART	GIC	6, 12	Recurrent caries, pain, clinical abscess, and mobility	n/a	The success rate of restoring the first primary molar using the ART alone was lower compared to using SMART technique after both 6 and 12 months of follow-up.

TABLE 1. Continued.

Study	Country	Patient age	Tooth condition	Sample size	comparators	Final restoration	Follow-up (mon)	Clinical evaluation criteria	Radiographic evaluation criteria	General outcome
Patel MC (2022)	India	4–8 yr	Asymptomatic dentinal caries (ICDAS 4–6); no spontaneous or nocturnal pain; no abscess; no sinus tract formation; no mobility and no periapical or furcation radiolucency; no internal or external resorption; no periodontal ligament widening	60 teeth (30 each group)	SMART *vs.* conventional (direct/indirect pulp cap + GIC + SSC)	GIC/GIC + SSC	3, 6, 12	Pain, tenderness on percussion, swelling, sinus tract formation, gingival redness, and/or pathologic mobility of the tooth	Internal and external root resorption, periodontal widening, interrupted lamina dura, and/or furcation radiolucency	At 12 months follow-up, both the conventional group (100% success) and SMART (96.15% success) showed similarly high clinical success rates.
Ahmad M (2022)	Egypt	4–6 yr	ICDAS 4, 5 or 6; absence of any pathology or pain except of sensitivity with eating; absence of internal or external root resorption, periapical or interradicular radiolucency	42 teeth (21 each group)	SMART *vs.* ART	RMGIC	3	n/a	Dentine density	The SMART group exhibited a statistically significant increase in radiographic dentinal density compared to the ART group.

TABLE 1. Continued.

Study	Country	Patient age	Tooth condition	Sample size	comparators	Final restoration	Follow-up (mon)	Clinical evaluation criteria	Radiographic evaluation criteria	General outcome
Shawki SA (2023)	Egypt	4–8 yr	Cavitated occlusal or occluso-proximal carious lesion which radiographically not involved the pulpal 1/3 of the dentin, no swelling, no previous infection and asymptomatic	90 teeth (30 each group)	SMART *vs.* Hall technique *vs.* conventional GIC	SMART: GIC; Hall technique (HT): Performed SSC; Conventional: GIC	1, 3, 6	Major failure: Pain, sepsis Minor failure: Premature exfoliation, caries at margin, lost restoration, occlusal wear of restoration	Absence of new carious lesion at the restoration margins; Absent pulp pathology; Absent pathological root resorption either external or internal; Absent pathological furcation involvement	At 1 and 3 months, no statistically significant differences were observed between groups in both clinical and radiographic success; but, by 6 months, HT group showed the highest success rates, followed by SMART group and the conventional GIC group.
Rady M (2023)	Egypt	4–7 yr	ICDAS 4 or 5; no spontaneous pain or pain not relieved by painkillers; non tender to percussion; no mobility; no sinus; no root resorption; no periapical or interradicular radiolucency	60 teeth (30 each group)	SMART *vs.* ART	GIC	3, 6, 9, 12, 24	Any one means failure: spontaneous pain, tooth mobility, sensitivity to percussion, and examination of any muco-buccal folds changes	n/a	A statistically significant decline in success rates for both groups, and no statistically significant difference in survival between the two groups.

TABLE 1. Continued.

Study	Country	Patient age	Tooth condition	Sample size	comparators	Final restoration	Follow-up (mon)	Clinical evaluation criteria	Radiographic evaluation criteria	General outcome
Abdelhamid MS (2025)	Egypt	4–6 yr	ICDAS 5 and 6; no clinical signs and symptoms indicating pulp involvement, no radiographic abnormalities	50 teeth (25 each group)	SMART *vs.* ART	High-viscosity GIC	3, 6, 12	Conventional visual/tactile method using a WHO probe	Pixel grey value on two areas on radiographic image	No statistically significant differences between the two groups in clinical outcomes, radiographic gray values, pain, and oral health-related quality of life, except for parental esthetic perception, which significantly favored the ART group.
Sharawat N (2025)	India	4–9 yr	Asymptomatic dentinal cavitated lesion; children with Frankl's positive or definitely positive behavior; no known silver allergy. Carious lesion should not extend beyond the middle third of dentin radiographically	150 teeth (75 each group)	SMART (1 visit *vs.* 2 visits)	GIC	6, 12	Restorations appeared satisfactory with no signs and symptoms and no further intervention was required or if the tooth was exfoliated without any signs or symptoms	n/a	Both single-visit and two-visit SMART restorations demonstrated comparable success rates at 12 months, with no statistically significant difference between the groups.

n/a: not available; ART: Atraumatic Restorative Treatment; GIC: glass ionomer cement; HT: Hall technique; ICDAS: International Caries Detection and Assessment System; SSC: stainless steel crown; SMART: Silver Modified Atraumatic Restorative Treatment; USPHS: United States Public Health Services; RMGIC: resin-modified glass ionomer cement; WHO: World Health Organization.

TABLE 2. Risk of bias and level of evidence of the included studies.

Study	Revised Cochrane risk-of-bias tool for randomized trials (RoB 2)						Level of Evidence
	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5	Overall Risk	
Bansal K (2023)	Low	Low	Low	Low	Low	Low	2
Aly AAM (2023)	Low	Low	Low	Low	Low	Low	2
Mohammed SME (2022)	Some concern	Low	Low	Low	Low	Some concern	2
Patel MC (2022)	Low	Some concern	Low	Low	Low	Some concern	2
Ahmad M (2022)	Low	Some concern	Some concern	Low	Low	Some concern	2
Shawki SA (2023)	Low	Low	Low	Low	Low	Low	2
Rady M (2023)	Low	Some concern	Low	Low	Low	Some concern	2
Abdelhamid MS (2025)	Low	Low	Low	Low	Low	Low	2
Sharawat N (2025)	Low	Low	Low	Low	Low	Low	2

Domain 1: Risk of bias arising from the randomization process.
Domain 2: Risk of bias due to deviations from the intended interventions.
Domain 3: Risk of bias due to missing outcome data.
Domain 4: Risk of bias in measurement of the outcome.
Domain 5: Risk of bias in selection of the reported result.
RoB: Risk of Bias.

3.4 Outcomes of SMART

Five studies comparing the efficacy of SMART and ART in treating carious primary teeth suggest that SMART generally provides better clinical and radiological outcomes [16, 21–24]. Mohammed SME *et al.* [21] and Rady M *et al.* [23] observed that SMART resulted in fewer incidences of pain, pathological mobility, and sensitivity to percussion at both 6-month and 12-month follow-ups. Additionally, Aly AAM *et al.* [16] concluded that SMART demonstrated higher success rates in terms of marginal adaptation, secondary caries, restoration retention, and post-operative hypersensitivity at both 6-month and 12-month follow-ups. Ahmad M *et al.* [22] reported a greater increase in radiographic dentine density over 3 months with SMART as opposed to ART. Nonetheless, Abdelhamid MS *et al.* [24] noted no statistical difference in terms of efficiency and remineralization effects between SMART and ART.

In contrast, two studies compared SMART with conventional GIC restorative techniques and found varying results; Bansal K *et al.* [15] reported lower success rates for SMART at 6-month, 12-month, 18-month, and 24-month follow-ups. Shawki SA *et al.* [27], however, found similar success rates for both techniques at 1-month and 3-month follow-ups, with SMART exhibiting a higher success rate at the 6-month evaluation. Shawki SA *et al.* [27] also noted that the Hall technique demonstrated the highest success rate and outperformed both SMART and conventional GIC during all follow-up assessments. On the other hand, Patel MC *et al.* [25] compared SMART with vital pulp therapy followed by GIC restorations and stainless-steel crowns, wherein SMART exhibited a lower success rate. Sharawat N *et al.* [26] compared single- versus two-visit SMART on carious primary molars and showed no statistically significant difference in the success rates.

3.5 Single-arm meta-analysis

Among the nine articles reviewed, only eight reported on either the clinical or radiographic or both clinical and radiographic outcomes of SMART in primary teeth that can be used for statistical analysis [15, 16, 21, 23–27]. Ahmad M *et al.* [22] evaluated the radiographic success of SMART based on dentin density, using evaluation criteria that differed from those of other studies. Therefore, it was excluded from the meta-analysis. The weighted mean clinical, radiographic, and overall success rates of SMART for treating carious primary teeth at the 3-month, 6-month, and 12-month follow-ups are shown in Table 3. The overall success rates were calculated and analysed through a single-arm intention-to-treat meta-analysis, provided that at least three primary studies reported such outcomes (Fig. 2). For the 3-month follow-up, four studies were included [23–25, 27], yielding a weighted mean overall success rate of 94.9% (CI: (90.7, 99.1)), with an I^2 of 10.91%, indicating no observed data heterogeneity. During the 6-month follow-up period, eight studies contributed to the analysis [15, 16, 21, 23–27], with a weighted mean overall success rate of 82.0% (CI: (71.0, 93.0)) and an I^2 of 92.97%, suggesting substantial data heterogeneity among the studies. Meanwhile, for the 12-month follow-up, seven studies were analysed [15, 16, 21, 23–26], resulting in a weighted mean overall success rate of 69.5% (CI: (52.4, 86.6)), with an I^2 of 95.22%, further indicating substantial data heterogeneity.

Funnel plots were generated to examine potential small-study effects at each follow-up time point (3, 6, and 12 months) (Fig. 3). The 3-month funnel plot showed slight asymmetry, with a concentration of smaller studies on one side of the

TABLE 3. Clinical, radiographical, and overall success of SMART on carious primary teeth based on intention-to-treat analysis.

Study	Clinical					Radiographic			Overall				
	Month												
	3	6	12	18	24	3	6	12	3	6	12	18	24
Bansal K (2023)	n/a	167/280	112/280	97/280	84/280	n/a	n/a	n/a	n/a	167/280	112/280	97/280	84/280
Aly AAM (2023)	n/a	49/59	48/59	n/a	n/a	n/a	n/a	n/a	n/a	49/59	48/59	n/a	n/a
Mohammed SME (2022)	n/a	23/30	18/30	n/a	n/a	n/a	n/a	n/a	n/a	23/30	18/30	n/a	n/a
Patel MC (2022)	28/30	26/30	25/30	n/a	n/a	28/30	25/30	25/30	28/30	25/30	25/30	n/a	n/a
Shawki SA (2023)	28/30	26/30	n/a	n/a	n/a	30/30	28/30	n/a	28/30	26/30	n/a	n/a	n/a
Rady M (2023)	26/30	24/30	16/30	n/a	16/30	n/a	n/a	n/a	26/30	24/30	16/30	n/a	16/30
Abdelhamid MS (2025)	25/25	25/25	23/25	n/a	n/a	n/a	n/a	n/a	25/25	25/25	23/25	n/a	n/a
Sharawat N (2025)	n/a	132/150	113/150	n/a	n/a	n/a	n/a	n/a	n/a	132/150	113/150	n/a	n/a

n/a: not available.
Radiographic outcomes at the 18-month and 24-month follow-ups were not reported.
Bansal K (2023): The data from the intention-to-treat analysis was used, while the data from the per-protocol analysis was omitted.
Aly AAM (2023): success criteria, including marginal adaptation, secondary caries, colour match, retention, and post-operative hypersensitivity, were pooled.
Rady M (2023): success criteria, including pain, change in muco-buccal fold, and sensitivity to percussion, were pooled.
Sharawat (2025): success rates of both single- and two-visit SMART were pooled.

pooled effect estimate. Meanwhile, the 6-month plot showed a relatively symmetrical distribution of studies around the pooled success rate, while the 12-month funnel plot demonstrated some degree of asymmetry.

3.6 Leave-one-out sensitivity analysis

Sensitivity analyses were conducted on the success rates of SMART in treating carious primary teeth at the 3-month, 6-month, and 12-month follow-ups. At the 3-month follow-up, the highest and lowest weighted mean success rates were 96.1% (CI: (92.1, 100)) and 91.9% (CI: (86.3, 97.5)) upon the exclusion of Rady M *et al*. [23] and Abdelhamid *et al.* [24], respectively. For the 6-month follow-up, the success rates varied with the highest at 86.7% (CI: (80.7, 92.8)) and the lowest at 79.4% (CI: (68.7, 90.2)), following the omission of Bansal K *et al.* [15] and Abdelhamid *et al.* [24], respectively. During the 12-month follow-up, the removal of Bansal K *et al.* [15] and Abdelhamid *et al.* [24] resulted in the highest and lowest weighted mean success rates of 76.0% (CI: (66.5, 85.4)) and 65.6% (CI: (48.0, 83.3)), respectively.

3.7 Two-arm meta-analysis

A two-arm meta-analysis was conducted to compare the outcomes of SMART and ART in the management of carious primary teeth. Among the studies that compared SMART and ART, only four were eligible for inclusion in the analysis at both the 6-month and 12-month follow-up intervals [16, 21, 23, 24]. Since only two studies were comparing SMART and ART at the 3-month follow-up [23, 24], the analysis for this interval was excluded. An intention-to-treat pairwise analysis revealed that the application of SMART in treating carious primary teeth resulted in higher success rates than the conventional ART at both 6-month (odds ratio: 1.62, CI: (0.89, 2.97)) and 12-month (odds ratio: 1.56, CI: (0.90, 2.69)) follow-ups (Fig. 4). However, no significant differences were observed in the overall success rates between SMART and ART at the 6-month ($p = 0.12$) and 12-month ($p = 0.11$) intervals. The level of data heterogeneity ($I^2 = 0\%$) in the two-arm meta-analyses was deemed acceptable, with no data heterogeneity.

3.8 Subgroup analysis and meta-regression

As the 3-month follow-up demonstrated acceptable data heterogeneity, subgroup analysis was therefore not undertaken.

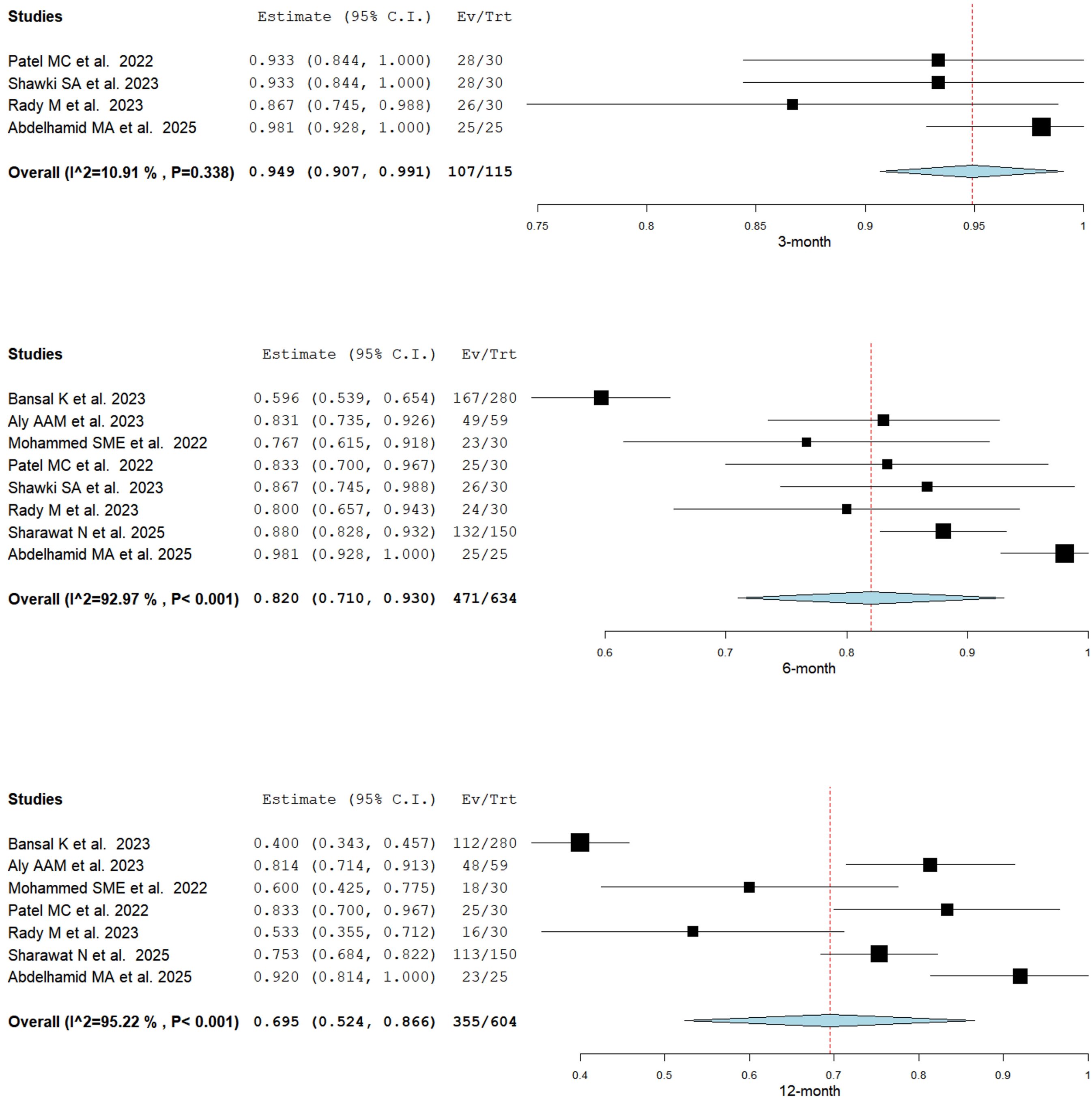

FIGURE 2. Single-arm meta-analysis. Single-arm meta-analysis showing the overall success rates of SMART on carious primary teeth at the 3-month, 6-month, and 12-month follow-ups, respectively. CI: Confidence Interval; Ev/Trt: Events/Treatment.

Only three evaluation criteria, reported in at least three of the included primary studies, were utilised in this subgroup analysis (see Table 4). Other evaluation criteria, including secondary caries, colour match, material retention, post-operative hypersensitivity, radiographic furcation, pathological root resorption, and changes in anatomical form, could not be analysed due to a scarcity of available studies for comparison. When marginal adaptation served as the evaluation criterion, the weighted mean overall success rates of SMART for carious primary teeth at the 6-month and 12-month follow-ups were 91.1% (CI: (76.4, 100)) and 86.5% (CI: (76.1, 96.9)), respectively. These rates were significantly higher ($p < 0.05$) compared to those not employing marginal adaptation as an evaluation criterion, which was 78.8% at the 6-month and 62.4% at the 12-month follow-ups.

On the other hand, when pain served as the criterion for evaluation, the weighted mean overall success rates of SMART in treating primary carious teeth were significantly lower at the 6-month (81.8%, CI: (69.3, 94.4)) and 12-month (67.4%, CI: (48.1, 86.7)) follow-ups ($p < 0.05$) compared to those studies that did not consider pain as a criterion (6-month: 83.1%; 12-month: 81.4%). Similarly, when using pathological mobility as the evaluation criterion, the weighted mean overall success rates of SMART for the treatment of primary carious teeth at

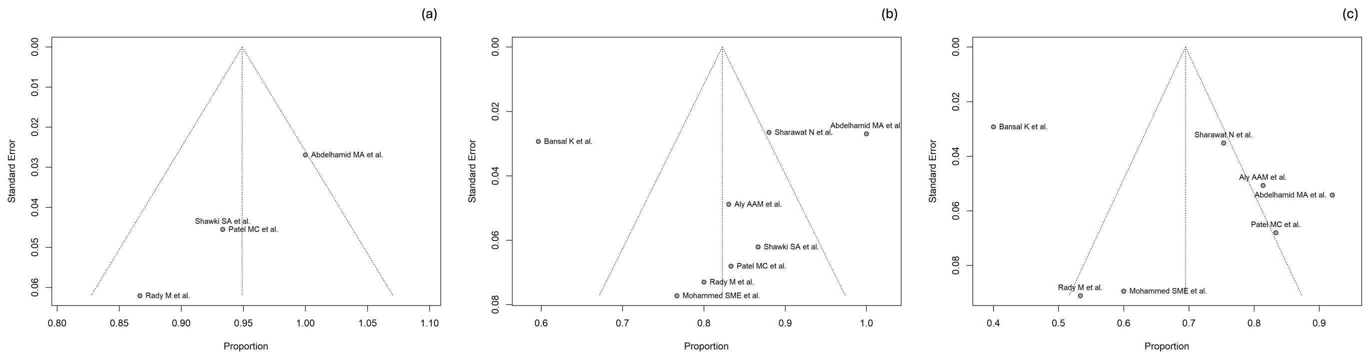

FIGURE 3. Funnel plots. Funnel plots assessing small-study effects at (a) 3-month, (b) 6-month, and (c) 12-month follow-up intervals, respectively.

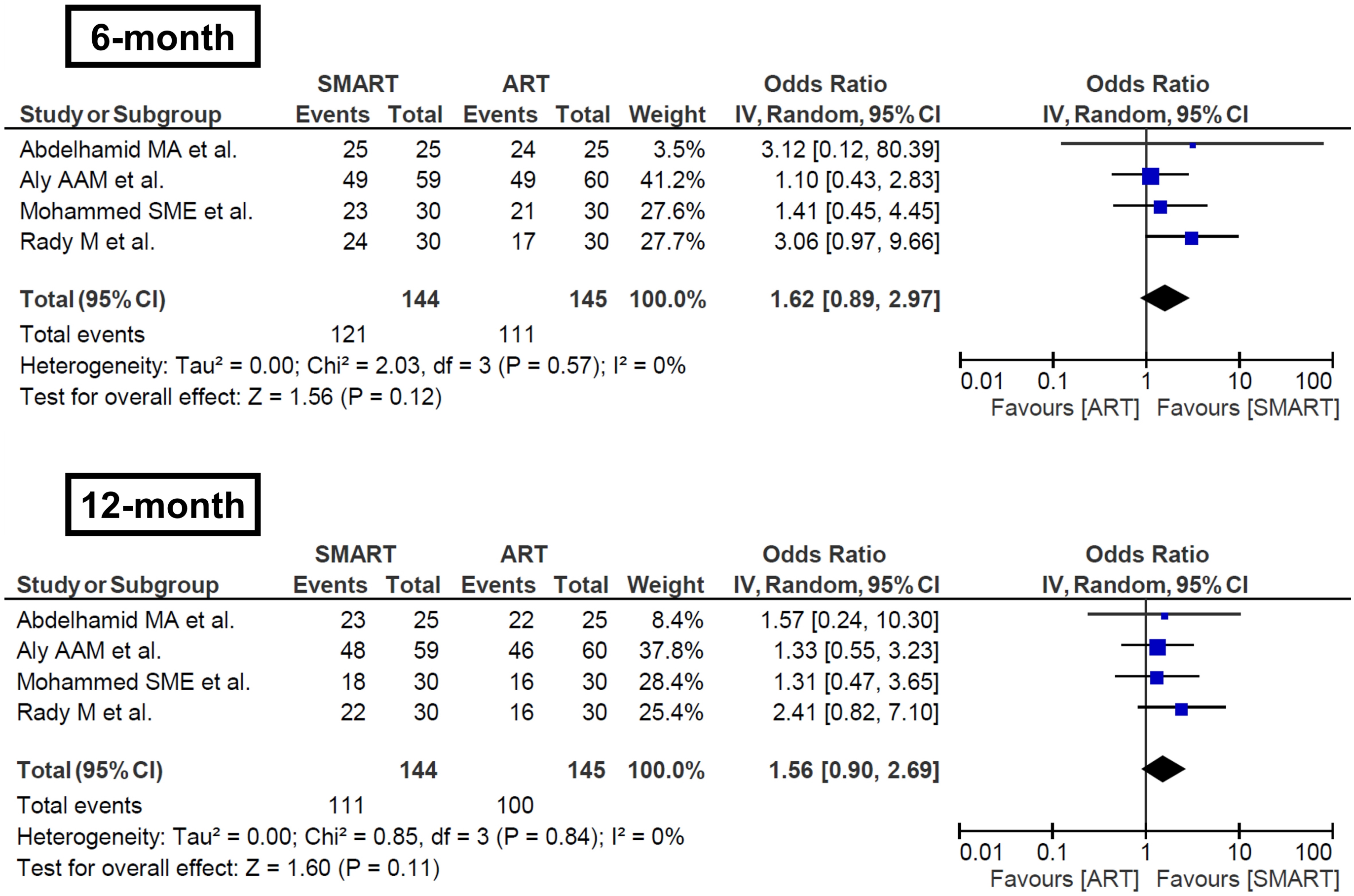

FIGURE 4. Two-arm meta-analysis. Two-arm meta-analysis comparing SMART and ART in treating carious primary teeth at the 6-month and 12-month follow-ups, respectively. CI: Confidence Interval; SMART: Silver Modified Atraumatic Restorative Treatment; ART: Atraumatic Restorative Treatment; IV: Inverse Variance.

the 6-month (74.0%, CI: (60.3, 87.6)) and 12-month (58.9%, CI: (36.9, 80.8)) follow-ups were significantly lower ($p < 0.05$) than those studies that did not use pathological mobility as an evaluation criterion (6-month: 89.7%; 12-month: 82.2%). Based on the meta-regression analysis presented in Table 5, the sample size of each study at the 6-month and 12-month follow-ups significantly influences ($p < 0.05$) the weighted mean overall success rates of SMART on carious primary teeth, whereas the sample size of included studies at the 3-month follow-up has no significant impact on the meta-analysis results.

3.9 Publication bias

Egger's test revealed no significant evidence of publication bias in the overall success rates of SMART on carious primary teeth at the 3-month, 6-month, and 12-month follow-ups, respectively (Egger's test: p-values = 0.06, 0.11, and 0.07, respectively).

4. Discussion

The present review evaluated the outcomes of using SMART in managing carious primary teeth. This minimally invasive

TABLE 4. Subgroup analyses detailing the weighted mean success rates (%) of SMART based on marginal adaptation, pain, and pathological mobility as evaluation criteria.

	Yes			No		
	Weighted mean (%)	Confidence intervals		Weighted mean (%)	Confidence intervals	
		Lower bound	Upper bound		Lower bound	Upper bound
Marginal adaptation as evaluation criteria						
6-month	91.1	76.4	100.0	78.8	66.3	91.4
12-month	86.5	76.1	96.9	62.4	42.8	82.0
Pain as evaluation criteria						
6-month	81.8	69.3	94.4	83.1	73.5	92.6
12-month	67.4	48.1	86.7	81.4	71.4	91.3
Pathological mobility as evaluation criteria						
6-month	74.0	60.3	87.6	89.7	82.6	96.8
12-month	58.9	36.9	80.8	82.2	72.7	91.8

TABLE 5. Meta-regression evaluating the effect of the sample size of each study on the weighted mean overall success rates of SMART on carious primary teeth.

	Coefficient	Confidence intervals		Standard error	*p*-value
		Lower bound	Upper bound		
3-month	1.289	0.866	1.711	0.216	0.117
6-month	0.911	0.829	0.992	0.041	0.003*
12-month	0.819	0.685	0.953	0.069	0.012*

**: Significant at 0.05.*

approach has been shown to be cost-effective and requires significantly less treatment time than traditional ART, making it suitable for uncooperative children [15, 16]. Unlike conventional restorations, it often eliminates the need for local anesthesia, thereby reducing stress and discomfort for paediatric patients. Based on the single-arm meta-analysis, it can be observed that SMART generally showed favourable overall success rates of 94.9% at 3-month, 82.0% at 6-month, and 69.5% at 12-month follow-ups, respectively. This can be primarily attributed to the unique properties and multifaceted action of SDF used in SMART, with literature reporting its effectiveness in halting caries progression in primary teeth [29]. Although GIC releases fluoride, its release level is significantly lower than that of SDF [25]. Therefore, in SMART restorations, GIC primarily combats caries not through fluoride release but by reducing biofilm retention and sealing the remaining cavity [30]. Nonetheless, it was observed that the overall success rates of SMART in treating carious primary teeth exhibited a decline over time, with a notable decrease below 70% at the 12-month follow-up. While SDF exhibits a potent initial antimicrobial effect, its efficacy in preventing new caries or halting the progression of existing carious lesions may wane over time without subsequent applications. This could potentially lead to caries development beneath or adjacent to restorations. Therefore, it can be postulated that such a situation will impact the treatment outcome.

The reduction in the success rate of the present findings could also be explained by the physical wear and chemical degradation of GIC, which is frequently used in SMART [31]. Such degradation, particularly in regions of high-stress areas, can lead to marginal leakage, material breakdown, and the development of secondary caries [32]. Despite prior research indicating that SDF does not adversely affect the microleakage of GIC restorations on carious primary dentine [33], the potential for SDF to clinically impede the chemical bonding between GIC and the tooth surface remains elusive [34].

The two-arm meta-analysis demonstrated that SMART exhibited a higher success rate compared to ART in treating carious primary teeth, but the observed difference was not statistically significant. One conceivable explanation for this outcome might be the employment of GIC as the final restorative material in both SMART and ART procedures. However, despite the standardised use of GIC as the final restorative material, technical aspects likely play a significant role in treatment success, including the application of SDF and the quality of the GIC restoration. For instance, Bansal K *et al.* [15] elucidated that operator technique might impact the seal's efficacy, noting reduced success rates of SMART versus traditional GIC, ascribed to obstructed dentinal tubules by residual silver particles. This obstruction, presumed result of insufficient water rinsing post-SDF application, adversely influenced the bond strength to GIC. A more recent study has also found that rinsing SDF prior to GIC restoration appeared to mitigate its detrimental impact on the adhesive strength of the glass ionomer cement onto carious dentine surfaces [35]. Furthermore, biological factors such as saliva composition, dietary habits, oral hygiene practices, and individual susceptibility to caries can affect the long-term outcomes of

SMART. Variations in children's cooperation and their ability to maintain oral hygiene may also impact SMART's long-term success [36]. Nevertheless, the limited evidence comparing SMART and ART underscores the need for further research to ascertain whether SMART offers a higher success probability than ART.

The subgroup analysis revealed that the chosen evaluation criteria significantly influenced SMART's success rates in treating primary carious teeth, with variable outcomes noted for marginal adaptation, pain, and pathological mobility. Marginal adaptation, which assesses the seal quality between the restoration and tooth, was found to result in higher success rates in the present findings. This criterion assesses the technical quality of the restoration, which directly affects the longevity and effectiveness of the treatment in preventing secondary caries and ensuring restoration durability [37]. The authors postulated that studies using marginal adaptation as an evaluation criterion may lead to a higher success rate, attributed to the direct visual and tactile assessment of the restoration's integrity clinically. It is worth noting that visual inspection cannot detect microleakage at the tooth-restoration interface, which is supported by a previous systematic review, noting no significant difference in terms of marginal adaptation between GIC and composite resin over a period of time [38].

Conversely, when pain or pathological mobility are used as criteria, the success rates of SMART were noted to be significantly lower. These criteria are more subjective and reflect the child's clinical experience and the restoration's functional performance over time. Pain as an evaluation criterion might lower success rates because it can be influenced by a variety of factors beyond the quality of the restoration, including patient sensitivity, operator technique, or underlying issues not directly related to the treatment [39]. Pathological mobility, indicating structural or periodontal instability, similarly suggested more complex underlying issues that could negatively impact the perceived success of the treatment. Therefore, the variability in evaluation criteria of the current included studies highlights the critical need for standardised criteria in evaluating the outcome of SMART to ensure study comparability and the accurate synthesis of data. Such standardisation is vital for avoiding overestimation or underestimation of results, thereby enhancing evidence-based practice and improving patient care through clear, reliable assessments of treatment efficacy.

Funnel plots were used to explore potential small-study effects across the three follow-up periods (3, 6, and 12 months). The 3-month funnel plot showed slight asymmetry, suggesting the possibility of small-study effects, which could be attributed to the overrepresentation of smaller studies with favourable early outcomes. In contrast, the 6-month funnel plot appeared more symmetrical, with data points evenly dispersed on both sides of the central estimate. This indicates a lower likelihood of such bias at this intermediate time point. The clustering of studies toward the top of the funnel also highlights consistent precision among the larger studies included in the analysis. The 12-month funnel plot exhibited moderate asymmetry, which may reflect clinical heterogeneity across studies and the potential selective reporting of longer-term outcomes, especially in trials with smaller sample sizes or higher dropout rates. These findings are supported by the results of our meta-regression analysis, which revealed that the sample size of included studies significantly influenced the pooled success rates at the 6-month and 12-month follow-ups. Interestingly, no such effect was observed at the 3-month follow-up, where the sample size did not significantly impact the pooled success rates. Together, these findings signify the importance of interpreting success rates in the context of study size and follow-up duration.

Based on the quality assessment of the included studies, several studies were rated as "some concern" for Domain 2 (Risk of bias due to deviations from intended interventions), highlighting a recurring issue with how interventions are administered and maintained throughout the trial period. Undeniably, randomised studies frequently face challenges such as non-compliance, patient dropout, and missing outcomes. Patient dropout poses a considerable challenge in randomised trials, occurring either during treatment or the evaluation phase [40]. Such dropouts can jeopardise the random group allocation's balance, thereby affecting internal validity. Dropouts will also compromise the external validity by limiting its broader applicability while diminishing its statistical power to discern treatment differences by reducing sample size [41]. This complex consequence emphasises the necessity to address patient dropout in randomised studies to guarantee reliable and robust findings. A possible remedy is the use of intention-to-treat analysis, which considers all participants as per their original group assignment, disregarding any noncompliance, deviations from the protocol, withdrawals, or events post-randomisation [42]. Conversely, per-protocol analysis excludes patients who deviated from the protocol, which may introduce attrition bias. This form of bias arises when the characteristics of the compared patient groups diverge due to exclusions [42, 43]. However, it is essential to note that overly concentrating on intention-to-treat analyses without sufficiently considering dropout rates could distort the estimation of treatment effects, especially in studies experiencing high dropout rates [43].

Several limitations in the current review warrant cautious interpretation. Notably, the appearance of dark discolouration at the margins of restorations in the SMART group posed challenges in maintaining post-treatment blinding [15]. A lack of sufficient studies also precluded subgroup analysis of other evaluation criteria, including secondary caries, colour matching, material retention, post-operative hypersensitivity, radiographic furcation, pathological root resorption, parental acceptance, and changes in anatomical form. Furthermore, initial differences between groups, delineated by lesion type, where some studies utilised ICDAS scoring for patient and tooth selection [15, 22–25], while others based their selection on caries location, such as occlusal and proximal sites [16, 21, 27], may have affected the overall outcomes. It is imperative to emphasise that the present two-arm meta-analysis offers a provisional assessment of the clinical efficacy of ART and SMART restorations in primary dentition, constrained by a one-year follow-up duration due to the paucity of evidence concerning the enduring outcomes of SMART beyond 12 months. Although two included studies reported outcomes extending to 18- and 24-month follow-ups [15, 23], the limited number and variability of these long-term data did not permit meta-analysis. As such, the current findings predominantly reflect short- to medium-term outcomes. Consequently, potential restorative issues, such as the development of secondary caries, might remain undetected, and predictions concerning the extended economic implications of both treatment strategies have yet to be outlined [44]. Since all the included studies originated from only two countries, Egypt and India, this may limit the generalisability of the findings. While these studies provide valuable insights, their outcomes may be influenced by local healthcare infrastructure, clinical protocols, patient populations, and operator training, which differ from those in other regions.

In addition to variations in evaluation criteria, several other factors may have contributed to the substantial heterogeneity observed, particularly at the 6- and 12-month follow-ups. Clinically, operator technique, including variations in hand excavation, SDF application protocol, and mixing or placement of GIC, may influence the outcome [45]. Differences in lesion classification methods, such as the use of ICDAS versus visual or tactile diagnosis, may also influence treatment decisions and perceived success rates. Methodologically, the heterogeneity may stem from variations in the study setting, population characteristics (age, caries risk, behaviour rating), and follow-up intervals, which ranged from 3 to 24 months. Furthermore, differing definitions of "success" (clinical *vs.* radiographic criteria or a combination) and the inconsistent use of intention-to-treat versus per-protocol analyses may also introduce bias and variability in effect size estimates. Statistically, the relatively small sample sizes and wide confidence intervals observed in some primary studies likely reduced the power and precision of the pooled estimates, further contributing to heterogeneity. Plus, the restriction to English-language studies may have led to the exclusion of pertinent data and insights from a wider array of research contexts. Data on caries depth and cavity classification (*e.g.*, Class I or II surface lesions) were also generally lacking. Although we conducted subgroup analyses based on clinical indicators such as marginal adaptation, pain and pathological mobility, most studies did not provide sufficient detail regarding the exfoliation status of primary teeth or account for physiological mobility due to age.

To deepen our understanding of SMART's long-term efficacy in carious primary teeth, conducting further unbiased and meticulously designed clinical trials with adequate follow-up periods is imperative. Such trials should emphasise assessing the clinical outcomes and durability of single- or multi-surface SMART versus ART restorations in primary molars, alongside evaluating SMART's cost-effectiveness. Although minimally invasive dental treatments such as ART have been widely accepted by children and their parents [5], the extent to which SMART is similarly accepted remains unclear in the literature, warranting further investigation. Nevertheless, SMART emerges as a particularly suitable option for community-based initiatives, notably in scenarios demanding urgent cavity restoration post-SDF treatment, especially among underserved or special healthcare needs groups [16, 44]. Future research should also concentrate on standardising evaluation criteria and methodologies across studies to diminish heterogeneity and enhance result comparability. This would facilitate a more profound exploration into SMART's long-term clinical and radiographic effectiveness, thereby offering more insight into its sustained efficacy and durability.

5. Conclusions

The present systematic review and meta-analysis offer valuable insights into the efficacy of SMART in managing carious primary teeth. This minimally invasive approach, which combines the bactericidal and remineralising properties of SDF with the restorative capabilities of GIC, demonstrates favourable outcomes across short to medium follow-up periods. Despite comparable outcomes with ART, the overall findings suggested that SMART could serve as a viable alternative restorative treatment in primary carious teeth. Nonetheless, the limited published evidence highlights the need for further high-quality research to standardise evaluation criteria, reduce bias, and validate the long-term efficacy and applicability of SMART in diverse clinical contexts to fully ascertain its role within global paediatric dental care frameworks.

ABBREVIATIONS

ART, Atraumatic Restorative Treatment; CI, Confidence interval; GIC, glass ionomer cement; ICDAS, International Caries Detection and Assessment System; OCEBM, Centre for Evidence-Based Medicine; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols; PROSPERO, Prospective Register of Systematic Reviews; RoB, Risk of Bias; SMART, Silver Modified Atraumatic Restorative Technique; SDF, Silver Diamine Fluoride; NIHR, National Institute for Health Research.

AVAILABILITY OF DATA AND MATERIALS

Raw data supporting the findings of this study are available from the corresponding author on request.

AUTHOR CONTRIBUTIONS

GSSL—involved in the study's conceptualisation; methodology; software; formal analysis; data curation; visualisation; and writing of the original draft. ARBH and JJXY—contributed to the methodology; data curation; visualisation; and writing of the original draft. GJ and JEK—were involved in the methodology; data curation and writing of the original draft. YDA, FB and MHMH—contributed to the data validation; review and editing of the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/2006244538819985408/attachment/Supplementary%20material.zip.

REFERENCES

[1] Gatón-Hernandéz P, Serrano CR, da Silva LAB, de Castañeda ER, da Silva RAB, Pucinelli CM, *et al*. Minimally interventive restorative care of teeth with molar incisor hypomineralization and open apex—a 24-month longitudinal study. International Journal of Paediatric Dentistry. 2020; 30: 4–10.

[2] Lin GSS, Chan DZK, Lee HY, Low TT, Laer TS, Pillai MPM, *et al*. Effectiveness of resin infiltration in caries inhibition and aesthetic appearance improvement of white-spot lesions: an umbrella review. Journal of Evidence-Based Dental Practice. 2022; 22: 101723.

[3] Ramos-Gomez FJ, Crystal YO, Domejean S, Featherstone JD. Minimal intervention dentistry: part 3. Paediatric dental care—prevention and management protocols using caries risk assessment for infants and young children. British Dental Journal. 2012; 213: 501–508.

[4] Ebrahimi M, Shirazi AS, Afshari E. Success and behavior during atraumatic restorative treatment, the Hall Technique, and the stainless steel crown technique for primary molar teeth. Pediatric Dentistry Journal. 2020; 42: 187–192.

[5] Lin GSS, Cher CY, Cheah KK, Koh SH, Chia CHL, Lim VR, *et al*. Acceptability of atraumatic restorative treatment and Hall Technique among children, parents, and general dental practitioners: a systematic review and meta-analysis. Quintessence International. 2022; 53: 156–169.

[6] Jiang M, Fan Y, Li KY, Lo ECM, Chu CH, Wong MCM. Factors affecting success rate of atraumatic restorative treatment (ART) restorations in children: a systematic review and meta-analysis. Journal of Dentistry. 2021; 104: 103526.

[7] Seifo N, Cassie H, Radford JR, Innes NPT. Silver diamine fluoride for managing carious lesions: an umbrella review. BMC Oral Health. 2019; 19: 145.

[8] Crystal YO, Marghalani AA, Ureles SD, Wright JT, Sulyanto R, Divaris K, *et al*. Use of silver diamine fluoride for dental caries management in children and adolescents, including those with special health care needs. Pediatric Dentistry Journal. 2017; 39: 135–145.

[9] Chu CH, Mei L, Seneviratne CJ, Lo EC. Effects of silver diamine fluoride on dentine carious lesions induced by Streptococcus mutans and Actinomyces naeslundii biofilms. International Journal of Paediatric Dentistry. 2012; 22: 2–10.

[10] Rosenblatt A, Stamford TC, Niederman R. Silver diamine fluoride: a caries "silver-fluoride bullet". Journal of Dental Research. 2009; 88: 116–125.

[11] Zhao IS, Gao SS, Hiraishi N, Burrow MF, Duangthip D, Mei ML, *et al*. Mechanisms of silver diamine fluoride on arresting caries: a literature review. International Dental Journal. 2018; 68: 67–76.

[12] Mubaraki H, Ingle NA, Baseer MA, AlMugeiren OM, Mubaraki S, Cicciù M, *et al*. Effect of silver diamine fluoride on bacterial biofilms-a review including *in vitro* and *in vivo* studies. Biomedicines. 2023; 11: 1641.

[13] Satyarup D, Mohanty S, Nagarajappa R, Mahapatra I, Dalai RP. Comparison of the effectiveness of 38% silver diamine fluoride and atraumatic restorative treatment for treating dental caries in a school setting: a randomized clinical trial. Dental and Medical Problems. 2022; 59: 217–223.

[14] Crystal YO, Kreider B, Raveis VH. Parental expressed concerns about Silver Diamine Fluoride (SDF) treatment. Journal of Clinical Pediatric Dentistry. 2019; 43: 155–160.

[15] Bansal K, Shamoo A, Mani K, K PD, Verma A, Mathur VP, *et al*. Silver diamine fluoride modified atraumatic restorative treatment compared to conventional restorative technique on carious primary molars—a randomized controlled trial. Journal of Dentistry. 2023; 138: 104698.

[16] Aly AAM, Aziz AMA, Elghazawy RK, El Fadl RKA. Survival analysis and cost effectiveness of Silver Modified Atraumatic Restorative Treatment (SMART) and ART occlusal restorations in primary molars: a randomized controlled trial. Journal of Dentistry. 2023; 128: 104379.

[17] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. The BMJ. 2021; 372: n71.

[18] Higgins JPT, Sterne JAC, Savović J, Page MJ, Hróbjartsson A, Boutron I, *et al*. A revised tool for assessing risk of bias in randomized trials. Cochrane Database of Systematic Reviews. 2016; Suppl 1: 29–31.

[19] Oxford Centre for Evidence-Based Medicine, OCEBM Levels of Evidence Working Group. The oxford levels of evidence 2. 2011. Available at: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence (Accessed: 01 June 2025).

[20] Lin GSS, Hisham ARB, Cher CY, Cheah KK, Ghani NRNA, Noorani TY. Success rates of coronal and partial pulpotomies in mature permanent molars: a systematic review and single-arm meta-analysis. Quintessence International. 2021; 52: 196–208.

[21] Mohammed SME, Awad SM, Wahba AH. Comparison of clinical outcomes of silver-modified atraumatic restorative technique *vs*. atraumatic restorative technique in primary teeth: a randomized controlled trial. The Journal of Contemporary Dental Practice. 2022; 23: 1140–1145.

[22] Ahmad M, Khattab N, Amer M. Radiographic assessment of silver modified atraumatic restorative technique in comparison to atraumatic restorative technique. Egyptian Dental Journal. 2022; 68: 1183–1190.

[23] Rady M, Sabbah A. A 24-month clinical assessment of active dentin caries arresting by silver diamine fluoride in primary molars: a randomized clinical trial. Egyptian Dental Journal. 2023; 69: 899–910.

[24] Abdelhamid MS, El Tawil SB, Moheb DM. Clinical and radiographic evaluation after the use of silver modified atraumatic restorative treatment versus atraumatic restorative treatment in the management of occlusal caries of primary molars in preschool children: a randomized clinical trial. Cuestiones de Fisioterapia. 2025; 54: 1600–1617.

[25] Patel MC, Makwani DA, Bhatt RK, Raj V, Patel C, Patel F. Evaluation of silver-modified atraumatic restorative technique versus conventional pulp therapy in asymptomatic deep carious lesion of primary molars—a comparative prospective clinical study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2022; 40: 383–390.

[26] Sharawat N, Bansal K, Mathur VP, Tewari N, Morankar R, Mishra R. Evaluation of the success of single-visit versus two-visit silver modified atraumatic restorative technique (SMART) in primary molars—a randomized controlled trial. Journal of Dentistry. 2025; 156: 105661.

[27] Shawki SA, Al-Bauomy SY, Mostafa MH. Clinical and radiographic outcomes of two biological approaches versus the conventional one for management of dental caries in primary teeth. Al-Azhar Journal of Dental Science for Girls. 2023; 10: 217–226.

[28] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977; 33: 159–174.

[29] Surendranath P, Krishnappa S, Srinath S. Silver diamine fluoride in preventing caries: a review of current trends. International Journal of Clinical Pediatric Dentistry. 2022; 15: S247–S251.

[30] Chibinski AC, Wambier LM, Feltrin J, Loguercio AD, Wambier DS, Reis A. Silver diamine fluoride has efficacy in controlling caries progression in primary teeth: a systematic review and meta-analysis. Caries Research. 2017; 51: 527–541.

[31] Nica I, Stoleriu S, Iovan A, Tărăboanță I, Pancu G, Tofan N, *et*

al. Conventional and resin-modified glass ionomer cement surface characteristics after acidic challenges. Biomedicines. 2022; 10: 1755.

[32] Alsari A, Ghilotti J, Sanz JL, Liena C, Folguera S, Melo M. Comparative evaluation of the microleakage of glass ionomers as restorative materials: a systematic review of *in vitro* studies. Applied Sciences. 2024; 14: 1729.

[33] Osama S, Badran AS, Awad BG. Effect of silver diamine fluoride on the microleakage of flowable resin composite and glass ionomer cement restorations to carious primary dentin: an-*in vitro* study. BMC Oral Health. 2024; 24: 91.

[34] Jiang M, Mei ML, Wong MCM, Chu CH, Lo ECM. Effect of silver diamine fluoride solution application on the bond strength of dentine to adhesives and to glass ionomer cements: a systematic review. BMC Oral Health. 2020; 20: 40.

[35] Rinsathon J, Wiriyasuebpong S, Thariya K, Jiradechochai P, Phetsuk P, Bouanil S, *et al*. Bonding performance of glass ionomer cement to carious dentin treated with different surface treatment protocols using silver diamine fluoride. Scientific Reports. 2023; 13: 14233.

[36] Kitsaras G, Goodwin M, Kelly MP, Pretty IA. Bedtime oral hygiene behaviours, dietary habits and children's dental health. Children. 2021; 8: 416.

[37] Ebaya MM, Ali AI, Mahmoud SH. Evaluation of marginal adaptation and microleakage of three glass ionomer-based class V restorations: *in vitro* study. European Journal of Dentistry. 2019; 13: 599–606.

[38] Albelasy EH, Hamama HH, Chew HP, Montaser M, Mahmoud SH. Secondary caries and marginal adaptation of ion-releasing versus resin composite restorations: a systematic review and meta-analysis of randomized clinical trials. Scientific Reports. 2022; 12: 19244.

[39] Nagarwal P, Rana V, Srivastava N, Kaushik N, Pruthi T. Reliability of three pain assessment tools in children requiring dental treatment: a comparative clinical study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2023; 41: 126–132.

[40] Dixon LJ, Linardon J. A systematic review and meta-analysis of dropout rates from dialectical behaviour therapy in randomized controlled trials. Cognitive and Behavioral Practice. 2020; 49: 181–196.

[41] Cramer H, Haller H, Dobos G, Lauche R. A systematic review and meta-analysis estimating the expected dropout rates in randomized controlled trials on yoga interventions. Evidence-Based Complementary and Alternative Medicine. 2016; 2016: 5859729.

[42] McCoy CE. Understanding the intention-to-treat principle in randomized controlled trials. The Western Journal of Emergency Medicine. 2017; 18: 1075–1078.

[43] Gupta SK. Intention-to-treat concept: a review. Perspectives in Clinical Research. 2011; 2: 109–112.

[44] Fa BA, Jew JA, Wong A, Young D. Silver modified atraumatic restorative technique (SMART): an alternative caries prevention tool. The Stomatology Edu Journal. 2016; 3: 243–249.

[45] Oliveira GL, Carvalho CN, Carvalho EM, Bauer J, Leal AMA. The influence of mixing methods on the compressive strength and fluoride release of conventional and resin-modified glass ionomer cements. International Journal of Dentistry. 2019; 2019: 6834931.

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