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Clinical Outcome Success of Silver-Modified Atraumatic Restorative Treatment (SMART) in Treating Children with Dental Caries in Primary Teeth: A Systematic Review

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Abstract

Objective: A novel approach called silver-modified atraumatic restorative therapy (SMART) integrates glass ionomer cement (GIC) restorations with silver diamine fluoride (SDF). This new method combines the ability of GIC to seal the tooth and sever the nutrition that bacteria require to proliferate, with the bactericidal power of SDF. The purpose of this review is to evaluate and compare the available data regarding the efficacy of the SMART approach in treating children's carious primary teeth.

Materials and Methods: The earliest date accessible up until February 15, 2024, was thoroughly searched in databases including Scopus, PubMed, Cochrane, Science Direct, Lilacs, Science Direct, Web of Science, and Google Scholar. The review only comprised randomized controlled trials. The PICO strategy (P: Children with dental caries in primary teeth; I: SMART; C: Conventional drill and fill method or atraumatic restorative treatment [ART] therapy; O: Clinical success) was adopted. Risk of bias assessment and quality of evidence were assessed using the RoB-2 tool and GRADE tool, respectively.

Results: Four full-text publications that met the eligibility criteria underwent additional processing for data extraction and qualitative analysis. In three studies, no difference was found in the clinical performance of SMART and conventional drill and fill/ART therapy, whereas in one study, the clinical performance of SMART was found to be better than the conventional ART therapy.

Conclusion: SMART and conventional drill and fill/ART techniques have comparable clinical performance for carious primary teeth of children. SMART can be used to treat asymptomatic deep carious lesions as well as apprehensive children. However, the cost-effectiveness of SMART restorations needs to be investigated in a variety of demographics.

Keywords
- treatment outcome
- dental atraumatic restorative treatment
- dental restoration
- dental caries
- tooth deciduous
- silver diamine fluoride

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Introduction

According to the World Health Organization (WHO) Global Oral Health Status Report (2022), oral diseases affect 3.5 billion people worldwide, and dental caries impact is estimated to be 46.2 and 53.8% in children with primary and permanent dentition, respectively.[1] One of the challenging issues faced by dentists is managing dental caries in primary teeth of young children.[1] In the conventional drill-and-fill method, a dental bur attached to a high-speed handpiece is used to remove the carious tissue from a cavitated carious lesion.[2] Children become fearful of dental burs because of their noise and tactile sensation in the mouth, which makes them uncooperative and makes dental operations harder to complete.[3] Despite the high treatment costs and health hazards associated with hospital hospitalizations,[4] pharmacological care of uncooperative pediatric dentistry patients often requires sedation and general anesthesia.[5] For young children with dental caries, these behavioral problems pose a significant barrier to successful restorative treatment.[6]

Dental caries management has undergone a revolution because of minimal intervention dentistry (MID), particularly for young children.[7] Children generally embrace atraumatic restorative treatment (ART), which is also a cost-effective MI strategy.[8] However, it was discovered that the procedure was challenging to employ in cavities with restricted accessibility and that, when performed for long duration, could cause operator fatigue.[9] Also, ART requires twice as much time as the traditional rotary tool use.[10,11]

Silver diamine fluoride (SDF; Ag $(NH3)_2F$) is another MI therapy option. It is referred to as a "silver-fluoride bullet" since it can arrest dental caries while also preventing the development of new lesions. Because fluoride has the ability to remineralize and silver nitrate has antibacterial properties, this inexpensive treatment is quite successful.[12] Due to the ease of use of the method, very young and recalcitrant children may benefit from SDF caries treatment.[13] However, black staining is a significant downside of SDF that creates aesthetic problems.[14,15] Moreover, although SDF treatment can stop a lesion from spreading, it cannot repair tooth structure or masticatory function because it is a noninvasive procedure that leaves teeth unfilled.[16]

Due to the above-mentioned drawbacks of the conventional drill-and-fill method and ART therapy, a novel approach called silver-modified atraumatic restorative therapy (SMART) has been developed. SMART is the application of SDF followed by the placement of glass ionomer cement (GIC) to help arrest the progression of a cavity without the need for local anesthesia and drilling. GIC is the preferred material for SMART restorations because it is the only restorative material that is water based and has a significant anticaries effect,[17–19] with less recurrent decay at the margins[20,21] and adjacent surfaces.[22–24] The long-term release of fluoride ions supports remineralization,[25] and as these ions are released from the GIC, they are also able to be "recharged" by ions from other sources such as fluoride toothpaste.[26] GIC restorations have been shown to be antibacterial and to decrease the acidogenicity of the biofilm, most likely from the fluoride release.[27] SDF is the choice of material for SMART as it is a noninvasive method of arresting caries that is painless, safe, and cost-effective.

This new method combines the ability of GIC to seal the tooth and sever the nutrition that bacteria require to proliferate, with the bactericidal power of SDF. In addition to arresting caries, using SMART may improve enamel remineralization and preserve pulp vitality.[28,29]

The SMART approach appears to be a useful tool for treating carious teeth, according to multiple clinical trials.[30–33] However, there is a paucity of systematic reviews assessing the efficacy of the SMART approach in treating children's carious teeth. Therefore, the purpose of this review is to evaluate and compare the available data regarding the efficacy of the SMART approach in treating children's carious teeth.

Materials and Methods

The systematic review was carried out following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines.[34] The study's protocol and details are registered in PROSPERO (Registration number: CRD42024504988). The focused question was as follows: Is the SMART approach effective in treating children's primary carious teeth? The PICO component framework consisted of

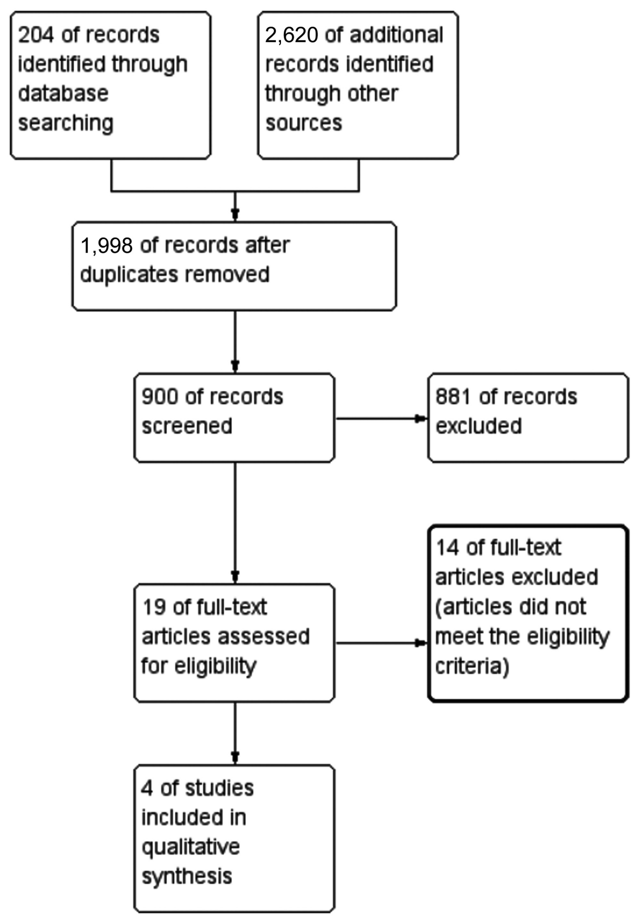

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart.

Population: Children with dental caries in primary teeth; Intervention: SMART; Comparator: Conventional drill and fill method or ART therapy; and Outcome: Clinical success

To locate relevant documents, a thorough search was conducted from the earliest period available to February 15, 2024, using databases like PubMed, Cochrane, Scopus, Lilacs, Science Direct, Web of Science, and Google Scholar. A manual search of important journals, conference proceedings, unpublished articles, and cross-references was done in order to find further publications. If the articles were not published, the authors were informed.

A combination of the keywords "primary teeth," "silver diamine fluoride modified atraumatic restorative treatment," "conventional restoration," "atraumatic restorative treatment," and "clinical success" was used in the search strategy.

Randomized controlled trials (RCTs) conducted on children with dental caries in particular and studies comparing the clinical success of SMART with the conventional drill-and-fill method or ART therapy were included in the review. Articles assessing the clinical success of SMART as a secondary outcome, studies on SMART therapy with no comparator, as well as case reports, cross-sectional studies, longitudinal studies, case control studies, cohort studies, in vitro studies, and reviews were excluded.

Independently, the reviewers (S.M. and R.M.) looked over the study titles. Duplication led to the exclusion of articles that were located in various databases. It was deemed appropriate for abstract reading if the article title contained the search terms. The articles were evaluated for full-text reading if the abstracts were based on the study's objective. Following the acquisition of the full-text records, their eligibility was evaluated. The articles were subjected to additional processing for data extraction if they met the eligibility requirements (►**Fig. 1**). The full-text articles' reference lists were looked through manually to find more research.

An Excel spreadsheet (MS Excel 2020) was used to enter the following details independently by two reviewers: author details, study year, study location, study design, participant description, study duration, evaluation criteria, intervention, clinical outcome, and inference of the included study. Google Translate was used to translate publications written in different languages into English.[35] In the cases where full-text publications were not available, the relevant authors were contacted to request the complete texts or other information that was lacking. Disagreements were resolved through discussions.

The Risk-of-Bias tool for Randomized Trial Version 2 (RoB 2) was utilized to evaluate the risk of bias in the included studies.[36] Based on the following categories, the bias was classified as "high risk," "unclear risk," or "low risk": generation of random sequences, the concealment of allocation, the blinding of personnel and participants, the blinding of outcome assessment, the incomplete outcome data, the selective reporting, and other factors. A study was deemed "low risk" if every requirement was met. If any one of the criteria was not met, the study was labeled as "high risk." If one criterion was "unclear risk" and no other criterion was "high risk," the study was classified as having "unclear risk." Disagreements were resolved by consensus.

Using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) assessment tool, the level of evidence in the included studies was evaluated.[37] The quality of the evidence was divided into four categories: very low, low, moderate, and high. To evaluate the quality of the evidence, the GRADE categories of publication bias, consistency, indirectness, risk of bias, and imprecision were used.

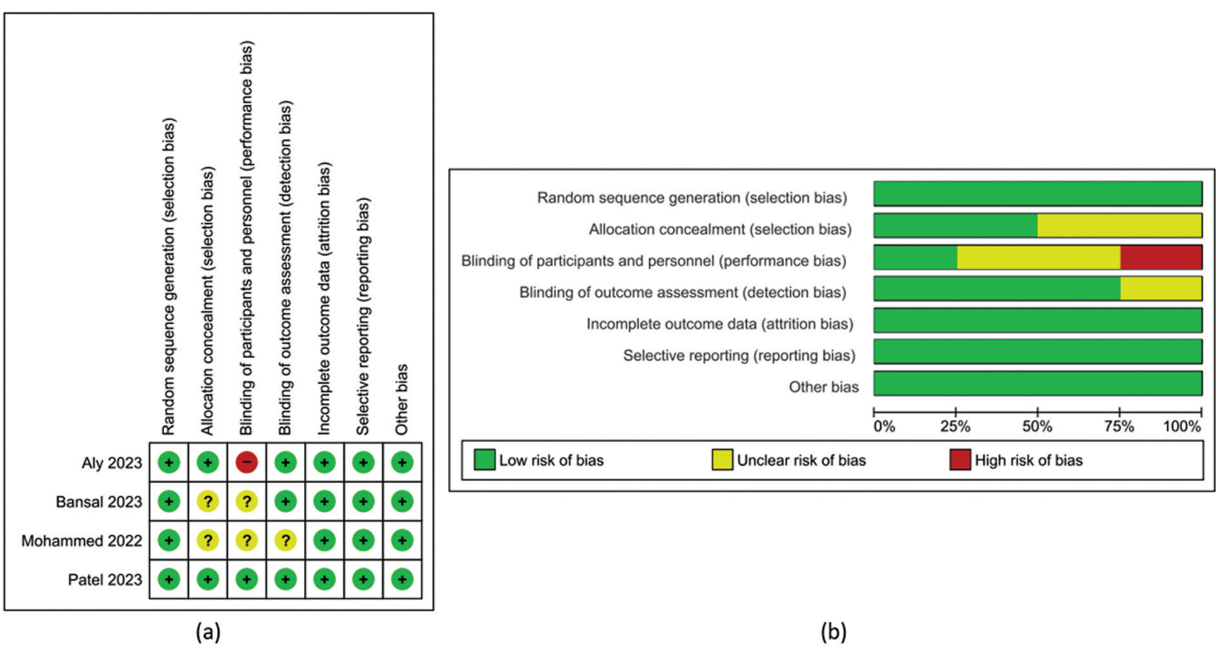

Fig. 2 (**a**) Risk of bias summary. (**b**) Risk of graph.

Results

After using key terms to examine six databases (PubMed, Cochrane, Scopus, Web of Science, Lilacs, Science Direct, and Google Scholar), a total of 2,824 articles were discovered. After removing duplicates, 1,998 articles were discovered. After reading the titles, 900 articles were selected for abstract screening. Out of the 900 articles, 881 articles were excluded as they did not meet the eligibility criteria. After reading the abstracts of 19 studies, 4 articles were selected for full-text reading and subsequently processed for qualitative analysis[30–33] (►**Fig. 1**). The characteristics of the included studies are given in ►**Supplementary Table 1** (available in the online version only). The list of excluded studies is presented in ►**Supplementary Table 2** (available in the online version only).[38–52]

All the studies were RCTs.[30–33] One was a split-mouth trial,[33] whereas three of them were parallel trials.[30–32] In two studies, the comparison group was the conventional drill-and-fill method using GIC restoration,[30,31] whereas in the other two studies the conventional ART method using GIC restoration was in the comparison group.[32,33] In two studies, both the participants and the researcher were blinded.[30] In two studies, the researcher was blinded, whereas no information was given regarding the participants.[31,32] No information regarding blinding of both participants and researcher was given in one study.[33] The mean age of the study participants in the included studies ranged from 3 to 13 years. The included studies had a minimum sample size of 60 teeth and a maximum sample size of 562 teeth.

Two studies each were conducted in India[30,31] and Egypt.[32,33] One study was funded by the All-India Institute of Medical Sciences, New Delhi.[31] The remaining three studies were not funded.[30,32,33]

In all the studies,[30–33] the intervention group received SMART (SDF + GIC). In one these studies,[30] the participants received a crown additionally. In two studies,[32,33] the control group received ART; one study received conventional pulp therapy[30] and one study received the conventional GIC restoration.[31] In two studies,[32,33] the outcome was assessed at 6 and 12 months posttreatment. In one study,[30] the outcome was assessed at 3-, 6-, and 12-month intervals. In one study,[31] the outcome was assessed at 6-, 12-, 18-, and 24-month posttreatment.

In one study,[30] the clinical evaluation was done by assessing pain, tenderness on percussion, swelling, sinus tract formation, gingival redness, and pathologic mobility. In one study,[31] the clinical evaluation was done using the Innes et al criteria. In one study,[32] the clinical evaluation was done using the Modified United States Public Health Service criteria. In one study,[33] the clinical evaluation was done based on the presence of recurrent caries, pain, clinical abscess, and mobility.

In three studies,[30–32] no difference was found in the clinical success rate of SMART and conventional drill-and-fill method/ART therapy, whereas in one study, the clinical success rate of SMART was found to be better than the conventional ART therapy.[33] However, the findings were statistically insignificant.[33] In one study,[32] SMART (7.8 minutes) was found to be more economical and the application was less time-consuming as compared to the conventional ART group (15 minutes). In another study,[31] SMART (79%) was found to be more acceptable to children as compared to the conventional drill-and-fill method (56%).

Risk of Bias and Quality of Evidence

One study[30] was classified as having a low risk of bias, two studies[31,33] as unknown risk, and one study[32] as high risk. ►**Fig. 2** presents an overview of the risk of bias. The evidence quality was rated as "moderate," indicating that the true effect is most likely not too dissimilar from the estimated effect. Because there was a "high risk of bias" in one study[32] and an "unclear risk of bias" in two studies,[31,33] the risk of bias was rated as "serious."

Discussion

Preserving the primary teeth until they naturally exfoliate is crucial for oral health and facial development.[53] One of the most prevalent pediatric diseases that can be prevented is dental caries.[54] However, without proper care, it frequently does not go away on its own and can worsen until the tooth is completely destroyed and requires extraction.[55] As a commitment to an application for the approval of SDF as a medication to treat severe early childhood caries (ECC), the Food and Drug Administration (FDA) granted breakthrough treatment classification in 2016.[56] In order to effectively control caries in children and adolescents, especially those with special health care needs, the American Academy of Pediatric Dentistry suggested in 2017 that the use of SDF should be given priority.[57]

With a pH of 10 to 12, SDF is a basic solution containing 38% w/v $Ag(NH3)_2F$. To form fluorohydroxyapatite, which is more thermodynamically stable and prevents demineralization, the hydroxyl group of hydroxyapatite crystals is replaced by the fluoride (44,800 ppm) of SDF. Through cell wall penetration, disruption of cellular respiration, and interference with cell replication, the silver ions (Ag, 25% w/v) in SDF function as an antibacterial agent.[58] SDF can be applied in combination with the atraumatic restorative approach, which involves the use of an excavator to remove specific caries, followed by the application of SDF and the placement of GIC (SMART). By sealing the restoration and boosting pulp vitality and remineralizing the carious lesion, the SMART technique aids in the eradication of cariogenic bacteria.[59] Furthermore, SDF has no negative effects on the bond strength between carious dentin and GIC.[60]

The purpose of this review was to evaluate and compare the available data regarding the efficacy of the SMART approach in treating children's primary teeth with dental caries. In our review, no statistically significant difference was found between SMART and the conventional drill-and-fill method/ART therapy in managing carious primary teeth in any of the included studies. The reason could be the use of SDF prior to restorative placement in the SMART approach, which slows the progression of carious lesions.[61] Also, SDF under GIC restoration in the SMART procedure increases GIC's antibacterial activity and remineralization, and strengthens ART's resistance to the advancement of caries.[62] Similar findings were seen in the study conducted by Jiang et al where no significant difference between SDF treated by ART (ART done 10 weeks after the application of SDF) and the conventional ART method was found.[63]

Since this was the first systematic review to compare the clinical success rate of SMART with the conventional drill-and-fill/ART methods, a direct comparison with existing systematic reviews was not possible. However, in a study conducted by Wakhloo et al,[7] a comparison between SDF application and ART was done and no statistical difference was found between the groups.

SMART restorations showed a significant ($p < 0.001$) color change as compared to conventional therapy. However, a black lesion is not seen as a side effect when employing SDF as a treatment option; rather, it is an indication of caries arrest,[64] which is why it was not included as a failure indicator in this review.[43] Additionally, Mabangkhru et al[65] concluded that SDF does not negatively impact parental satisfaction regarding the aesthetic appearance of their children's teeth. Duangthip et al[14] found that parent satisfaction with their children's dental appearance post-SDF application after 30 months was 71%.

In addition, it was found that the SMART technique (7.8 minutes) required less time to use and was more cost-effective than the conventional ART group (15 minutes) in the study conducted by Aly et al.[32] Similar findings were seen in the study conducted by Jiang et al, where the mean time used to place an ART restoration in an SDF-treated caries lesion was shorter than that in an untreated lesion (4.8 vs. 5.1 minutes, $p = 0.006$). When compared to ART restorations, the SMART technique's shorter working time considerably lowers both the labor and capital expenditures of the former. The reason for short working time for SMART could be that there is selective caries removal before SDF application in SMART that saves time as compared to complete caries excavation in ART or the drill-and-fill method.[66] One U.S. study's results also indicated that, when compared to traditional restorative treatment, SDF could lower overall costs per child by $119 to $338. As a result, the study concluded that, by avoiding more costly treatment options, the benefits of SDF outweighed the costs associated with its application.[67] Treatment options with different starting costs in health economic evaluations may show a shifting or even reversed cost-effectiveness rating over time if the initially less expensive approach necessitated more follow-up visits and consequently greater expenses.[68,69] According to our research, even though SMART is more costly than just using SDF in the short term, long-term consequences like worsening oral health and quality of life, food entrapment from cavitation, and the possibility of fracture and loss of cavitated molars if teeth are not restored could result in more costly interventions down the road.

Limitations

Notwithstanding the meticulous methodology employed, this evaluation is inevitably subject to certain limitations. The overall quality of the research may has been compromised by the presence of high risk of bias in one study and unclear risk of bias in the other two. The majority of the included studies had a 1-year follow-up duration. Due to the short study time, assumptions on the long-term economic effects of both treatment techniques could not be captured, and potential restorative problems such as the development of secondary caries could not be identified. The evaluation method of the clinical outcome success was different for all the studies, making the data heterogenic. Furthermore, as dental treatment costs were determined using the Egyptian market pricing for materials and average dentist salary, our review's findings regarding costs might not apply to other populations. Cost-effectiveness findings from RCTs in one nation may not be readily transferable to other nations.[70]

Future Recommendations

In order to verify the comparability of clinical performance and survivability of SMART restorations, a longer follow-up period is required. Further studies are required to compare the acceptability of SMART as compared to other MID techniques. The cost-effectiveness of SMART restorations needs to be investigated in a variety of demographics. It is important to evaluate the longevity of SMART sealants on healthy but high caries risk teeth. In order to counteract the color of SDF, more research on SDF and the SMART approach can be conducted with aesthetic crowns.

Conclusion

Within the limitations, it can be concluded that SMART and conventional drill-and-fill or ART techniques have comparable clinical performance for managing carious primary teeth of children. SMART may be used to treat asymptomatic deep carious lesions in children as well as in apprehensive children. However, to validate the results of this review, more trials are required.

Authors' Contributions

S.M. was responsible for the concept, design, and definition of intellectual content, literature search, data acquisition, data analysis, and manuscript preparation. R.M. was responsible for data acquisition, manuscript editing, and manuscript review.

Declaration

The manuscript has been read and approved by all the authors, the requirements for authorship as stated earlier in this document have been met, and each author believes that the manuscript represents honest work.

Conflict of Interest

None declared.

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