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**Research Paper**

# Silver Diamine Fluoride in Pediatric Dentistry: A Systematic Review of Its Efficacy in Arresting Caries in Primary Teeth

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***Abstract:***

***Background***

*Dental caries in primary teeth is a widespread issue, ranking as one of the most prevalent conditions globally, as highlighted in the Global Burden of Disease 2010 Study. Despite preventive efforts, such as the use of fluoride toothpaste, many children, particularly those in underserved populations, continue to suffer from untreated caries. Conventional treatments for caries often involve invasive procedures, which can be challenging in pediatric patients due to behavioral or logistical barriers.*

***Objective***

*This systematic review aims to evaluate the effectiveness of silver diamine fluoride in preventing and arresting the progression of caries in primary teeth. The focus is to determine whether silver diamine fluoride can effectively prevent new carious lesions compared to a placebo or no treatment, and how it compares to other active caries management interventions.*

***Methods***

*A systematic review was conducted, adhering to PRISMA guidelines, with a focus on randomized or quasi-randomized clinical trials. Eligible studies included children aged 0-12 years who received topical silver diamine fluoride treatment. The primary outcome measured was the development of new caries lesions, and secondary outcomes included adverse events. A comprehensive search of multiple academic databases and trial registries was performed.*

***Results***

*Silver diamine fluoride demonstrated a significant effect in halting caries progression in primary teeth, with an effectiveness rate of 89%, surpassing placebo and other treatments. The application of silver diamine fluoride was found to be especially effective in arresting caries in children with high-risk factors, such as poor oral hygiene or multiple carious lesions. However, aesthetic concerns, particularly the black staining of treated areas, were noted as a limitation, though the treatment's efficacy often outweighed these.*

***Conclusion***

*Silver diamine fluoride is a cost-effective, minimally invasive solution for managing caries in primary teeth, particularly in children who face barriers to traditional dental care. Despite aesthetic concerns, its widespread use could significantly reduce the incidence of untreated dental caries in pediatric populations, especially in underserved communities. Future studies should explore long-term outcomes and improved formulations to mitigate staining issues.*

***Keywords****: Caries, Fluoride, Management, Primary teeth, Silver diamine flouride*

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## I. Introduction:

According to the Global Burden of Disease 2010 Study, untreated dental caries in primary teeth ranked as the tenth most prevalent condition out of 291 assessed health issues [1]. Parents have identified various obstacles to obtaining dental care for their children, including dental anxiety, financial constraints, scheduling conflicts, and transportation challenges [2]. When considering these barriers alongside evidence that existing early preventive strategies are not effectively curbing caries development, it becomes evident that innovative or alternative methods are needed to manage dental caries in pediatric populations [3].Silver diamine fluoride is a compound formed by combining silver nitrate with fluoride. It exhibits multiple anti-caries mechanisms, including suppressing the growth of cariogenic bacteria, preventing dentin collagen breakdown, and both inhibiting demineralization and encouraging remineralization of enamel and dentin [4]. The use of silver diamine fluoride for caries management has a long history, with its application documented in countries such as Japan, China, and various other South American countries [5, 6]. Across these settings, silver diamine fluoride has been utilized at concentrations ranging from 10% to 38% to arrest dental caries effectively [7]. In 2014, silver diamine fluoride was approved by the Food and Drug Administration (FDA) for treating tooth sensitivity. Shortly after, it began being used off-label in the United States for caries management [8]. The application of silver diamine fluoride is both straightforward and cost-effective [9], aligning with the principles of minimally invasive dentistry [10].Therefore, using silver diamine fluoride to treat carious lesions appears particularly beneficial for younger children who may be less cooperative and more vulnerable socially [11].Recent systematic reviews highlight the effectiveness of silver diamine fluoride in arresting dental caries in children [12]. Research indicates that silver diamine fluoride is significantly more effective in halting the progression of dental caries in primary teeth compared to other treatments or a placebo, with an effectiveness increase of 89% (ranging from 49% to 138%) [13].To date, the impact of silver diamine fluoride treatment on the formation of new dental caries has not been systematically studied. Specifically, the focus has been on whether silver diamine fluoride can prevent new lesions in untreated dental surfaces of children whose existing carious lesions have been treated with silver diamine fluoride, or in children who receive silver diamine fluoride treatment on all primary teeth, regardless of their caries status. This review primarily aims to assess whether silver diamine fluoride is more effective than a placebo or no treatment in preventing the onset of new carious lesions in primary teeth. Additionally, a secondary objective is to compare the preventive effect of silver diamine fluoride with that of other active treatments.

## II. Methodology

**Study Design**

The study is a systematic review that aims to evaluate the effectiveness of silver diamine fluoride in preventing the progression of dental caries in primary teeth. It includes randomized or quasi-randomized clinical trials with parallel-group designs.

**Inclusion Criteria**

The following criteria were used to select studies for inclusion:

- **Participants:** Children aged 0 to 12 years with dental caries in their primary teeth
- **Intervention:** Topical application of silver diamine fluoride, irrespective of concentration (ranging from 10% to 38%) or frequency of application.
- **Comparisons:** Studies comparing silver diamine fluoride to no intervention, placebo, or other active treatments (e.g., resin or glass ionomer pit and fissure sealants, other topical cariostatic agents, dental restorative materials).
- **Outcomes:**
  - **Primary outcome:** Development of new carious lesions, assessed at the surface, tooth, or patient level.
  - **Secondary outcomes:** Adverse events (self-reported or professionally diagnosed)

**Exclusion Criteria**

Studies were excluded if they:

- Were case series, expert guidelines, or letters to the editor
- Involved individuals older than 12 years
- Had less than one year of follow-up or lacked a control group

**Search Strategy**

A comprehensive search was conducted across multiple databases:

- **Databases:** CENTRAL, EMBASE, MEDLINE (via PubMed), SCOPUS, Web of Science, LILACS, BBO, SciELO.
- **Trial Registries:** Clinical Trials.gov, Brazilian Register of Clinical Trials, EU Clinical Trials Register, ISRCTN registry, Current Controlled Trials, ANZCTR, and the CAPES dissertations database.
- **Search Terms:** The search focused on terms related to the use of silver diamine fluoride for caries arrest or prevention. Studies were included if they focused on the preventive effects of silver diamine fluoride.

- **Search Date:** Initial search was performed in November 2024 and updated in April 2025 to include recent studies.

**Study Selection**

The screening process involved two independent reviewers who examined the titles and abstracts of identified studies. Full-text articles were then reviewed for eligibility based on the inclusion and exclusion criteria. Disagreements between reviewers were resolved through discussion or consultation with a third reviewer.

**Data Extraction**

Data were extracted independently by two reviewers using a standardized form. The following information was collected:

- **Study Characteristics:** Year of publication, sample size, study design, silver diamine fluoride concentration, application frequency, and follow-up period.
- **Outcomes:** Primary and secondary outcomes, including new carious lesions and any adverse effects.

**Risk of Bias Assessment**

The risk of bias for each study was assessed using the Cochrane Risk of Bias tool, which evaluates:

- Sequence generation
- Allocation concealment
- Blinding of participants and outcome assessors
- Incomplete outcome data
- Selective reporting

Studies were classified as having low, high, or unclear risk of bias for each domain. This assessment was considered in the synthesis and interpretation of the results.

**Data Analysis**

- **Quantitative Analysis:** The effectiveness of silver diamine fluoride in preventing caries was assessed by calculating risk ratios (RR) and 95% confidence intervals (CI). A meta-analysis was performed to pool data from studies with comparable outcomes.
- **Subgroup Analysis:** If sufficient data were available, subgroup analyses were conducted based on silver diamine fluoride concentration, frequency of application, and age group.
- **Statistical Methods:** RevMan (version 5.3) was used for the meta-analysis. The $I^2$ statistic was used to assess heterogeneity. A random-effects model was applied to account for clinical diversity between studies.

**Sensitivity Analysis**

Sensitivity analyses were performed by excluding studies with a high risk of bias to assess the robustness of the results.

**Ethics and Approval**

Since this systematic review used only published data, ethical approval was not required. The original researchers obtained ethical approval for the included studies.

The Prisma Flow Chart of the study is shown in **Figure 1**.

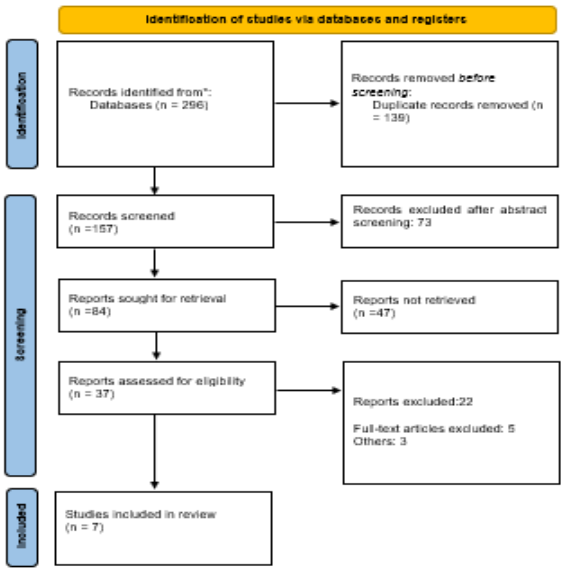


**Figure 1:** Prisma Flow Chart of the study

## III. Discussion:

Dental caries, though largely preventable, remains one of the most common and severe oral health issues affecting children globally, with particularly high prevalence among economically disadvantaged populations [14]. Untreated caries can lead to pain, compromised oral function, and a diminished quality of life in children. While widespread use of fluoride toothpaste has contributed to a global decline in caries rates, many young children—especially those in underserved communities—continue to experience significant rates of untreated decay [15]. These disparities often stem from limited access to dental services, high treatment costs, and various socioeconomic barriers including parental anxiety, financial stress, time constraints, and lack of transportation [16]. Traditional dental treatments have long relied on invasive techniques that remove decayed tissue and restore the tooth with fillings [17]. However, a shift toward minimally invasive dentistry has emphasized preserving healthy tooth structure and employing less invasive methods, particularly in public health settings. Among the innovations aligning with minimally invasive dentistry principles is silver diamine fluoride, a topical medicament that is gaining recognition for its affordability, safety, and proven efficacy in arresting dental caries [18].

Silver's antimicrobial properties have been known for centuries, and silver nitrate was historically used in the 19th century to treat cavities [19]. In the 1970s, silver fluoride began being used in public health initiatives, notably in Australia [20]. The modern formulation of silver diamine fluoride was developed in 1969 by Nishino in Japan, who combined the antibacterial benefits of silver with the remineralizing properties of fluoride [21]. Marketed as Saforide, this formulation was eventually approved in Japan and later received FDA clearance in the United States in 2014, becoming commercially available in 2015 [22]. A typical 38% silver diamine fluoride solution, such as Advantage Arrest, contains 24.4–28.8% silver, 5.0–5.9% fluoride, and maintains an alkaline pH of approximately 10 [23]. Silver diamine fluoride exerts its caries-arresting effects through multiple mechanisms. Silver ions deliver strong antimicrobial action by disrupting bacterial membranes, denaturing proteins, and inhibiting DNA replication [24].It is minimally invasive and highly effective treatment for managing dental caries, particularly in primary teeth and high-risk patients [25]. Its effectiveness stems from multiple mechanisms: fluoride promotes enamel and dentin remineralization while preventing further demineralization and silver ions exert strong antibacterial effects while also inhibiting collagen-degrading enzymes such as matrix metalloproteinases (MMPs) and bacterial collagenases, helping preserve the dentin matrix [26]. Upon application, silver phosphate and calcium fluoride form reservoirs of fluoride and phosphate, physically halting lesion progression. This chemical reaction causes the characteristic black staining of treated areas due to silver compound deposition [27].Clinically, it is indicated for use on both primary and permanent teeth, especially in patients for whom conventional restorative treatment is not feasible due to behavioral, medical, or logistical challenges [28]. It is best suited for cavitated lesions without pulpal involvement and should not be used on teeth with pulpitis, lesions close to the pulp as seen radiographically, or in patients with silver allergies. Aesthetic concerns, particularly staining, may lead some caregivers to decline its use, making informed consent and discussion of benefits and risks essential [29].Application involves cleaning debris from the lesion, isolating and drying the tooth, and applying a drop of silver diamine fluorine with a microbrush—enough for 5–6 teeth [30]. The area must remain isolated for three minutes, and patients should avoid eating or drinking for 30–60 minutes post-treatment [31]. Petroleum jelly can protect adjacent soft tissues from staining. A follow-up evaluation within 2 to 4 weeks is recommended to assess for caries arrest, typically seen as lesion darkening and hardening. Reapplication may be required, especially for children with poor oral hygiene or multiple lesions. For improved aesthetics or function, restorative materials like resin-modified glass ionomer or composite resin can be placed over arrested lesions using the Silver-Modified Atraumatic Restorative Technique (SMART) [32]. While biannual application is standard, evidence suggests more frequent applications—up to three times per year—may enhance effectiveness in high-risk populations.Numerous clinical studies and systematic reviews validate silver diamine fluorideefficacy [33]. Chibinski et al. found silver diamine fluorideto be 89% more effective than placebo in arresting caries in primary teeth [34], while Gao et al. reported an 81% arrest rate [35], and Fung et al. observed a 75% success rate with semiannual application, with anterior teeth showing better outcomes than posterior teeth [36]. In terms of prevention, studies by Oliveira [37], Contreras [38], and Chu demonstrated that children treated with silver diamine flouride developed significantly fewer new lesions over time than those in control groups [39]. Llodra et al. reported that primary teeth treated with silver diamine fluoride developed an average of 0.29 new lesions compared to 1.43 in untreated controls, with similar results in first permanent molars [40]. It is also compatible with restorative materials such as glass ionomers and composite resins, and pre-treatment with silverdiamine fluorine has been shown to reduce the risk of secondary caries beneath restorations. Compared to sodium fluoride varnish and acidulated phosphate fluoride gel, silver diamine flouride consistently outperforms both in caries prevention [41]. Safety data confirm its low toxicity risk, as a single drop of 38% silver diamine flouride contains only about 2.24 mg of fluoride—well below levels found in many fluoride treatments—and silver exposure levels remain far below harmful thresholds even with repeated use [42]. Side effects are generally mild and infrequent, including a metallic taste, temporary gingival

irritation, and the well-known black staining of lesions. To reduce staining, adjuncts like potassium iodide (KI) or glutathione have been investigated, though KI is contraindicated in pregnant or lactating women [43].Although silver diamine flouride does not restore tooth structure, it effectively arrests caries progression and complements restorative techniques such as SMART. As a result, it plays a critical role in advancing equitable, preventive, and patient-centered pediatric oral healthcare [44]. **Table 1** summarizes key evidence supporting silver diamine fluoride as an effective, non-invasive, and affordable option for arresting caries in children.

**Table 1:** Review of literature table

| Author(s) | Year | Study Design | Sample Size | Key Findings | Clinical Relevance |
|---|---|---|---|---|---|
| Zhi et al. [21] | 2012 | Randomized controlled trial | 375 children | Annual and biannual silver diamine flouride applications both effective; biannual slightly better | Repeated application improves outcomes |
| Horst et al. [8] | 2016 | Narrative review | N/A | Explained mechanism: silver diamine flouride promotes remineralization and bacterial inhibition | Useful for behavior management and non-invasive treatment |
| Crystal & Niederman [11] | 2016 | Review article | N/A | Highlighted efficacy, safety, and cost-effectiveness of silver diamine flouride | Silver diamine flouride is especially useful in underserved populations |
| Gao et al. [15] | 2016 | Systematic review & meta-analysis | 12 studies | Silver diamine flouride has high caries arrest effectiveness (up to 81%) | Supports silver diamine flouride as a non-invasive treatment for caries arrest |
| Duangthipet al.[36] | 2018 | Randomized controlled trial | 779 preschoolers | 38% silver diamine flouride biannually arrested caries more effectively than NaF or placebo | Supports inclusion in community dental programs |
| Oliveira et al. [37] | 2019 | Meta-analysis | 14 studies | 38% silver diamine flouride superior to 12% silver diamine flouride and sodium fluoride varnish | Concentration and frequency influence outcomes |
| Ruff et al.[45] | 2020 | Clinical study | 66 children | Parental acceptance increased with education; staining remains a concern | Need for communication on aesthetic side effects |

**Future Prospects**

1. **Improved Formulations**
   - Research is ongoing to reduce or mask staining (e.g., combining silver diamine fluoridewith potassium iodide or other agents).
   - Enhanced silver diamine fluoride formulations may include agents that improve bonding with restorative materials.
2. **Integration with Teledentistry**
   - Silver diamine fluoride may become part of remote caries management strategies where diagnosis and follow-up are done via telehealth.
3. **Expanded Use in Minimally Invasive Dentistry**
   - As the emphasis on minimally invasive techniques grows, silver diamine fluoride may be paired with other treatments like Hall technique crowns or SMART restorations (Silver-Modified Atraumatic Restorative Treatment) [46].
4. **Policy and Guidelines Adoption**
   - More countries and organizations (e.g., WHO, AAPD) are expected to integrate silver diamine fluorideinto standard pediatric care protocols, particularly in community health settings.
5. **Wider Acceptance Through Education**
   - Increased awareness among dental professionals and caregivers can boost the acceptability and use of silver diamine fluoride.
6. **Research on Long-Term Outcomes**
   - Ongoing studies may provide stronger evidence for long-term effectiveness, recurrence rates, and best practices for application schedule [47].

Artificial Intelligence (AI) is playing an increasingly vital role in preventive and minimally invasive pediatric dentistry, particularly in enhancing the use of silver diamine fluoride for managing caries in primary teeth. AI-powered diagnostic tools, such as deep learning models used in radiographic analysis, enable early and accurate detection of carious lesions, allowing for timely of silver diamine fluoride application before cavitation progresses [48]. These systems also support clinical decision-making by predicting which lesions are most suitable for non-invasive arrest with silver diamine flouride. In treatment planning, AI can recommend tailored silver diamine fluoride protocols based on individual factors such as age, caries risk, and lesion severity, improving both efficiency and outcomes. Furthermore, AI aids in monitoring and follow-up by using image recognition to track lesion progression and evaluate the effectiveness of silver diamine fluoride over time, while also flagging cases that may require reapplication or escalation of care [49]. AI-driven caries risk assessment tools can help identify patients who would benefit most from silver diamine flouride, particularly in community or school-based settings. On a broader scale, AI's capacity for data aggregation and analysis supports public health planning by optimizing the distribution of silver diamine flouride, enabling cost-benefit analyses, and facilitating outcomes tracking—especially in underserved populations. Collectively, these capabilities position AI as a powerful ally in expanding access to effective, non-invasive caries management strategies in pediatric dentistry [50].

## IV. Conclusion:

Silver diamine fluoride has revolutionized the management of dental caries in primary teeth by providing a safe, cost-effective, and minimally invasive alternative to conventional restorative treatments. Despite concerns related to aesthetic staining, its proven efficacy in arresting caries—particularly with repeated, high-concentration applications—makes it a powerful tool in pediatric dentistry. It is especially valuable for children who face barriers to traditional care, serving as an effective interim solution that halts disease progression and prevents new lesions. Its low cost, ease of application, and alignment with public health initiatives, including the Affordable Care Act and the Institute of Medicine's quality improvement goals, further underscore its potential to advance equitable oral healthcare. As clinical evidence and innovation continue to grow, it stands out as a transformative agent in both individual patient care and broader public health strategies.

**Conflicts of interest:** Nil

**Financial Support:** Nil

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