

Dental Caries Management in Children Using Silver Diamine Fluoride: A Comprehensive Contemporary Review

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ABSTRACT

Dental caries remains a widespread chronic disease in children, posing significant challenges in both clinical and public health domains. Silver Diamine Fluoride (SDF), a topical agent with dual antibacterial and remineralizing properties, has gained recognition as an effective, non-invasive solution for caries arrest in pediatric populations. This review offers a comprehensive evaluation of SDF, detailing its composition, physicochemical properties, mechanisms of action including antimicrobial and anti-enzymatic effects, clinical indications, application protocols, and safety profile. Special attention is given to its utility in children with early childhood caries (ECC), special health care needs, or limited access to conventional dental services. Additionally, the review discusses SDF's interactions with restorative materials such as glass ionomer cements and resin composites, and summarizes relevant research findings. By synthesizing current evidence, this review underscores the potential of SDF as a frontline agent in pediatric dental caries management within the framework of minimally invasive dentistry.

Keywords: Silver diamine fluoride, dental caries, Early childhood caries, remineralization, pediatric

1. INTRODUCTION

Dental caries remains the most prevalent chronic disease in children and a major public health challenge globally, despite decades of preventive efforts. Untreated caries can lead to significant pain, infection, psychosocial issues, and reduced academic performance in children, significantly impacting their quality of life. The conventional treatment for caries often involves mechanical removal of decayed tissue, which is invasive, costly, and particularly challenging in young or uncooperative children, often requiring general anesthesia.⁽¹⁾

In recent years, there has been a paradigm shift from surgical intervention to a more preventive, minimally invasive approach known as minimally invasive dentistry (MID). This approach emphasizes the arrest of caries progression rather than extensive tissue removal, especially when managing early childhood caries (ECC). Within this framework, the use of topical antimicrobial agents such as fluorides and silver compounds has gained increasing attention.⁽²⁾

Silver Diamine Fluoride (SDF), a colorless topical solution containing silver and fluoride ions in an ammonia base, has emerged as a simple, cost-effective, and clinically effective agent in arresting carious lesions, particularly in primary teeth. Silver provides antibacterial action, while fluoride promotes remineralization.⁽³⁾

This review article aims to provide a comprehensive overview of Silver Diamine Fluoride, including its mechanism of action, indications, contraindications, clinical application protocols, advantages, limitations, and current evidence in pediatric dentistry. It highlights SDF as a valuable adjunct in contemporary caries management strategies, especially for underserved populations and children with special health care needs.

2. HISTORY OF SILVER DIAMINE FLUORIDE

Silver has been used in Japan for over a thousand years as a dental cosmetic and caries preventive agent. In 1891, silver nitrate and amalgam were employed for their anti-caries properties, leading to the development of Howe's Solution. However, it wasn't until the 1960s that Silver Diamine Fluoride (SDF), a similar compound, gained recognition. SDF was approved in Japan by the Ministry of Health, with SAFORIDE being the first commercial product. In the 1980s, Dr. Graham Craig in Australia demonstrated the caries-arresting ability of silver fluoride in primary teeth. Western Australia implemented it in school dental programs, although the resulting black staining posed aesthetic concerns. In the 2000s, Dr. Geoffrey Knight introduced potassium iodide to reduce staining. The U.S. FDA approved SDF in 2014, making it available in 2015. In 2021, the WHO added SDF to its Essential Medicines List, recognizing its value in caries prevention, especially in non-specialized and resource-limited settings.^(4,5)

3. COMPOSITION AND PHYSICOCHEMICAL PROPERTIES

Silver diamine fluoride $\text{Ag}(\text{NH}_3)_2\text{F}$ is an alkaline, antibacterial topical solution with a high concentration of silver (254,709 ppm) and fluoride (44,860 ppm). SDF maintains a stable pH of 10.4 and is more chemically stable than silver fluoride alone. The solution has a specific gravity of 1.25 and emits a strong ammonia-like odour. Due to its light sensitivity, SDF is typically stored in opaque containers to preserve its chemical integrity over extended periods (Table 1).⁽⁶⁾

Table 1: Composition and functions of SDF

Compounds	Percentage composition	Functions
Silver	24–27%	Antimicrobial action
Fluoride	5–6%	Remineralization
Ammonia	7.5–11%	Stabilizing agent
Deionized water	62%	Liquid base

4. MECHANISM OF ACTION

The precise mechanisms of action of silver compounds in silver diamine fluoride (SDF) remain incompletely understood; however, several proposed pathways explain its therapeutic effects. Upon application, fluoride in SDF increases dentin resistance to demineralization and reduces acid penetration into deeper layers, with fluoride ions penetrating approximately 50–100 microns into dentin. This interaction results in the formation of calcium fluoride and insoluble silver phosphate, which serve as fluoride reservoirs and contribute to antimicrobial effects. Calcium phosphate also supports the formation of fluorohydroxyapatite, which is more acid-resistant than natural hydroxyapatite (Figure 1).⁽⁷⁾

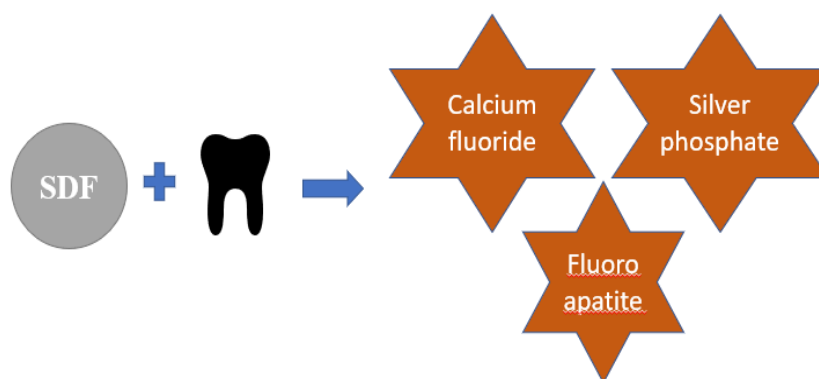


Figure 1: Interaction of SDF with tooth

SDF also exerts strong anti-enzymatic actions. It inhibits the activity of bacterial enzymes, such as glycosyltransferases, and reduces dextran-induced bacterial agglutination. Dentin treated with SDF becomes more resistant to enzymatic degradation, specifically from collagenase and trypsin, which play a critical role in dentinal collagen breakdown during caries progression. Moreover, SDF has demonstrated the ability to inhibit matrix metalloproteinases (MMPs), particularly MMP-2, MMP-8, and MMP-9. These enzymes, which are present in both saliva and dentin, contribute significantly to the degradation of the extracellular matrix in carious lesions. By inhibiting these MMPs, SDF arrests the progression of dentinal caries.^(7,8)

Another proposed mechanism is the "zombie effect," a unique antimicrobial phenomenon attributed to silver (Figure 2). This is explained by Le Chatelier's principle, where the equilibrium shifts to release silver ions from killed bacteria, which then target viable bacteria, creating a sustained antibacterial environment. This phenomenon underscores the long-lasting antimicrobial potential of SDF, as it not only kills pathogens directly but also transforms them into vectors of continued bacterial inhibition. Collectively, these mechanisms make SDF a powerful, minimally invasive tool for caries management, particularly in populations with limited access to conventional dental care.⁽⁹⁾

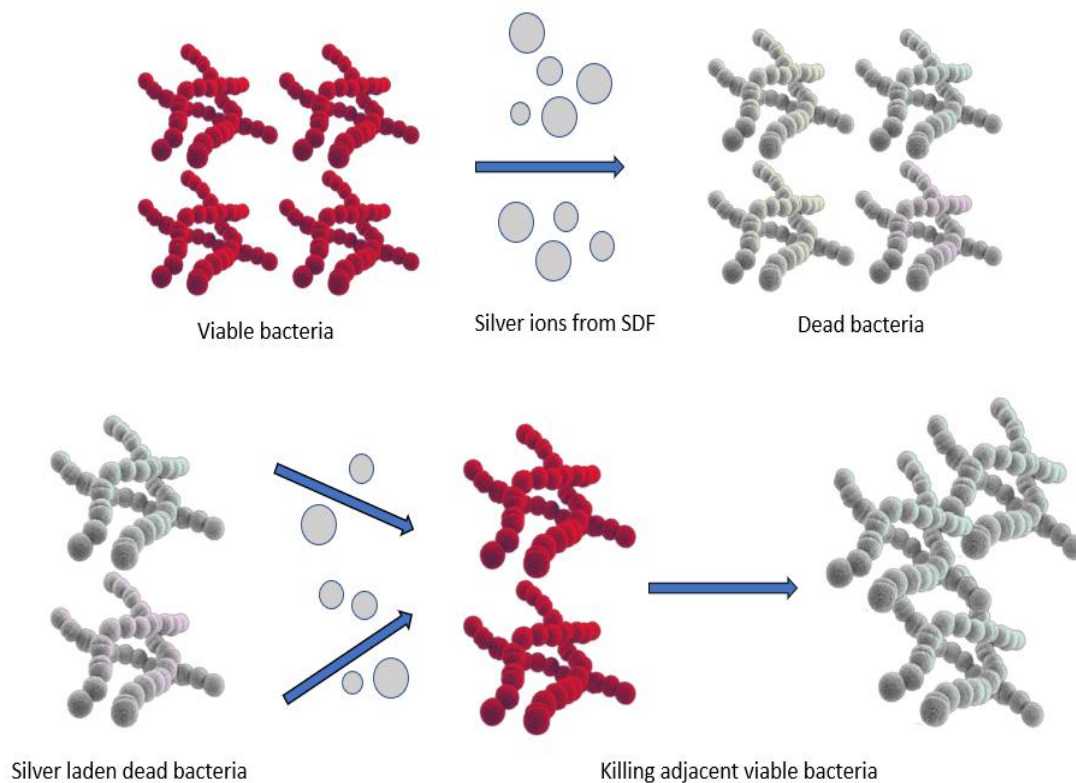


Figure 2: Zombie effect of SDF

5. INDICATIONS AND CONTRAINDICATIONS

According to the American Academy of Pediatric Dentistry (AAPD) guidelines, Silver Diamine Fluoride (SDF) is indicated for the following clinical scenarios.⁽¹⁰⁾

- **Early Childhood Caries (ECC):**
 - As a **definitive treatment**, applied initially and at **six-month intervals** in the absence of signs or symptoms of caries progression.
 - As an **interim therapeutic measure** in pre-cooperative children until traditional restorative care can be performed without the need for sedation or general anaesthesia.
- **Patients with Special Health Care Needs:**
 - For caries arrest in individuals who are unable to tolerate traditional dental procedures due to behavioural or medical management limitations.

- **High Caries Risk Individuals:**
 - Especially those presenting with multiple **active cavitated lesions** on anterior and posterior teeth.
- **Limited Access to Dental Care:**
 - Patients with geographical, financial, or logistical barriers to timely dental treatment.
- **Multiple Lesions Requiring Staged Treatment:**
 - When all carious lesions cannot be addressed in a single visit.
- **Difficult-to-Treat Lesions:**
 - Cavitated lesions that are accessible for topical treatment but challenging to restore conventionally.

Silver diamine fluoride (SDF) is contraindicated in certain clinical situations, including cases with frank pulpal exposure or symptoms suggestive of irreversible pulpitis, where its use may exacerbate underlying pathology. It should also be avoided in individuals with known hypersensitivity or allergic reactions to silver, fluoride, or ammonia, as these components may trigger adverse responses. Additionally, care must be taken to prevent direct application over open mucogingival lesions to avoid chemical irritation or tissue damage.⁽¹¹⁾

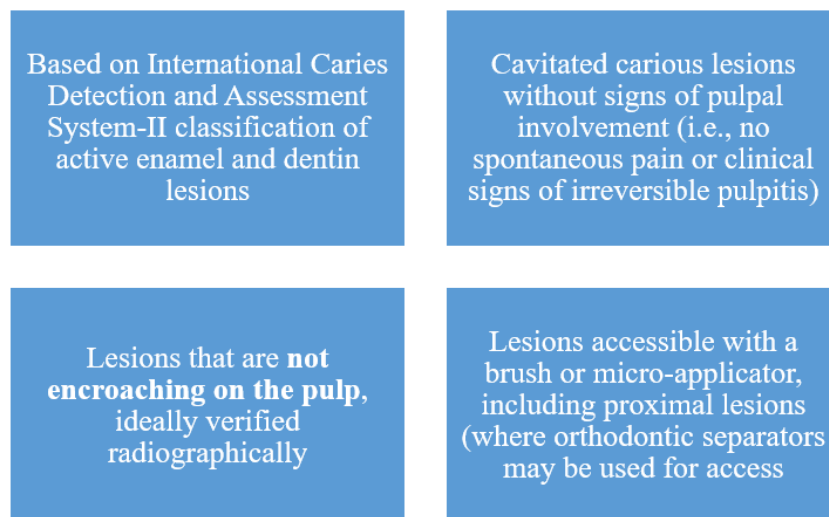


Figure 3: Tooth selection criteria

6. MODE OF DELIVERY

Silver diamine fluoride (SDF) can be delivered through various methods tailored to the clinical situation and clinician preference. The most common mode is direct application, where SDF is applied to the carious lesion using a microbrush or applicator tip until the surface is thoroughly wet, followed by removal of excess solution with a cotton pellet or suction. This straightforward technique is suitable for both primary and permanent teeth and is effective in arresting caries.

Another approach is the silver-modified atraumatic restorative treatment (SMART), a minimally invasive method combining SDF application with glass ionomer cement (GIC). After cleaning and drying the lesion, SDF is applied, excess removed, and then GIC is placed over the lesion, forming a protective barrier that helps prevent further decay. SMART is particularly useful for larger or deeper carious lesions where SDF alone may be insufficient.

Additionally, SDF can be used in combination with fluoride varnish to enhance protection, especially in high-risk patients. In this technique, fluoride varnish is first applied to the tooth surface, followed by SDF on the lesion, with the varnish reapplied afterward to cover the entire tooth. Ultimately, the choice of delivery depends on the clinical context and practitioner's judgment, with direct application being the most common and effective, while SMART and fluoride varnish combinations serve as valuable alternatives in specific cases.⁽¹²⁾

7. CLINICAL APPLICATION GUIDELINES OF SDF

Selection of the tooth should be done (Figure 3). Pre-application steps, Isolation and application procedure and post application steps should be followed as given in Figure 4. There are no dietary restrictions following application; patients can eat and drink immediately. Routine oral hygiene practices, including brushing with fluoridated toothpaste, may be resumed immediately after treatment. The caries arrest rate with a single application of 38% SDF ranges from 47% to 90%, depending on lesion characteristics and location. Anterior teeth demonstrate higher arrest rates compared to posterior teeth and effectiveness declines over time. For instance, 50% of lesions arrested at 6 months may revert to activity within 24 months. Biannual applications generally yield significantly higher arrest rates than annual application. The lesion should be evaluated within 2 to 4 weeks post-treatment, with reapplication as needed. Regular recall intervals (every 3, 4, or 6 months) should be based on the patient's individual caries risk assessment. For comprehensive caries management, SDF treatment should be incorporated into a broader caries management protocol, including dietary counselling, oral hygiene instruction, and behavioural modifications. The goal is not only arrest of existing lesions, but also prevention of new caries formation.⁽¹³⁻¹⁵⁾

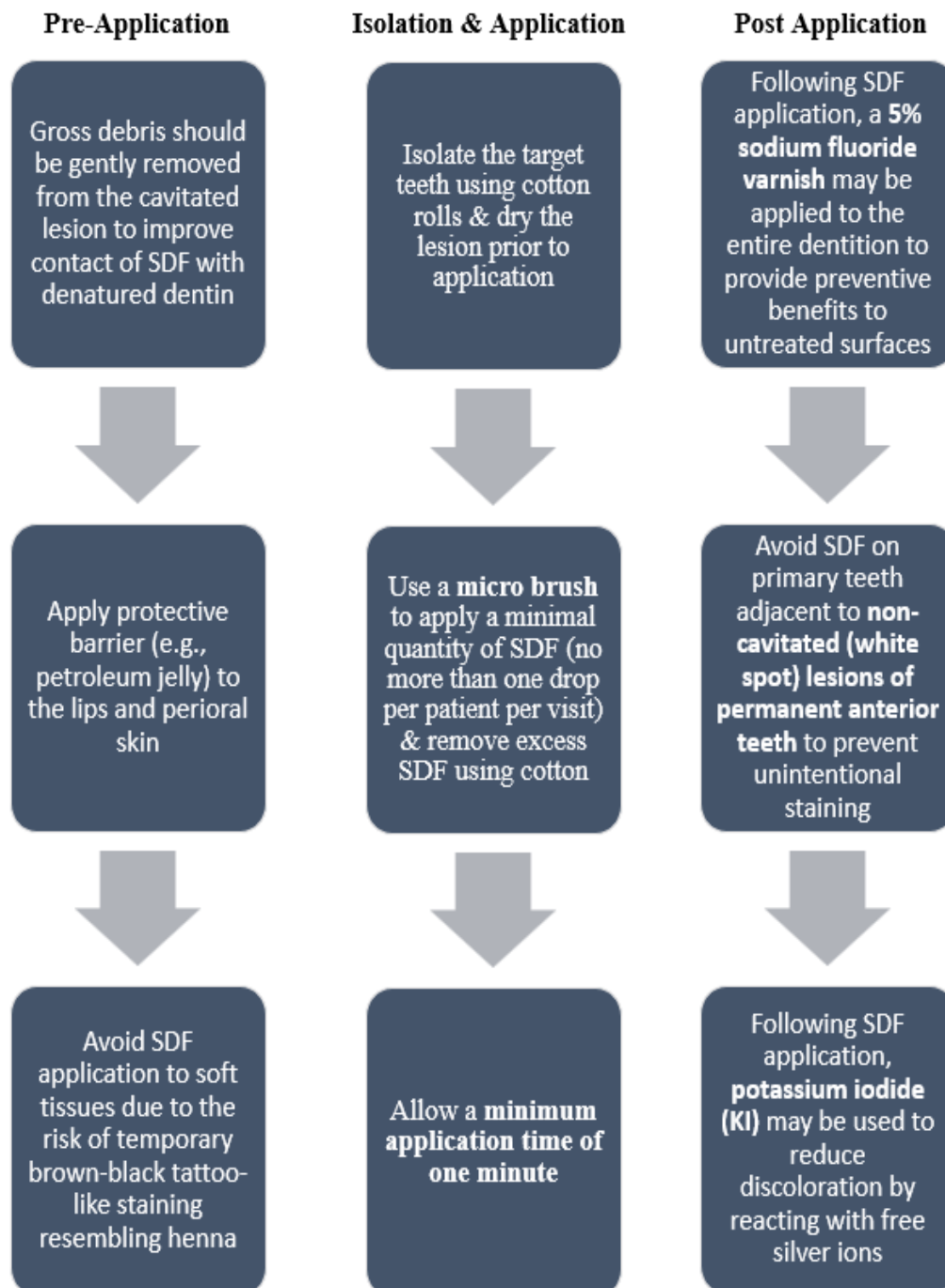


Figure 4: Steps in application of SDF

8. CLINICAL USES

Silver Diamine Fluoride (SDF) plays a pivotal role in contemporary pediatric caries management by effectively arresting cavitated carious lesions in primary teeth, particularly when conventional restorations are delayed or not feasible. It is especially valuable in underserved populations and among patients with limited access to routine dental care. As a preventive adjunct, SDF is beneficial for high-risk pediatric patients by reducing the need for invasive procedures, thereby minimizing reliance on general anaesthesia or sedation in uncooperative children. Its biannual application offers a reliable strategy for caries arrest on coronal surfaces while also serving as a non-aerosol-generating treatment option—ideal for use in infection-sensitive environments such as post-pandemic dental settings. Additionally, SDF can function as a foundation for subsequent restorative treatments using materials like glass ionomer cement, resin-modified glass ionomer, or glass hybrid restoratives. The effectiveness of SDF can be monitored visually through photographic documentation or written clinical records during baseline and follow-up evaluations.⁽¹⁶⁾ Various studies over years have validated SDF's efficacy in arresting caries. A literature review of past research work along with their key findings is given in Table 2.

Table 2: Summary table of key finding of various studies

Author(s)	Study Type	Focus	Key Findings
Yamaga M et al., 1993 ⁽¹⁷⁾	In vitro	Bond strength of GIC with tannin-fluoride and SDF on bovine dentin	SDF increased bond strength when combined with HY agent
C.H. Chu et al., 2002 ⁽¹⁸⁾	In vivo	Effectiveness of fluoride in arresting dentin caries in children	SDF more effective than NaF varnish; best outcomes with SDF
Knight G et al., 2005 ⁽¹⁹⁾	In vitro	Permeability of demineralized dentine to <i>S. mutans</i> after SDF/KI	SDF/KI reduced bacterial penetration compared to control
Chu CH et al., 2012 ⁽²⁰⁾	In vitro	SDF effects on biofilm and demineralized dentine	SDF showed anti-microbial and remineralization effect
Mei ML et al., 2013 ⁽²¹⁾	In vitro	Mechanism of SDF on dentine biofilms	SDF inhibits biofilm and protects collagen
Gluzman R et al., 2013 ⁽²²⁾	Review	Prevention of root caries in elderly	38% SDF best for primary prevention
Horst JA et al., 2016 ⁽²³⁾	Systematic Review	Clinical use and safety of SDF	SDF safe and effective across all age groups
Mei ML et al., 2017 ⁽²⁴⁾	In vitro	SDF's effect on hydroxyapatite formation	SDF forms fluorohydroxyapatite aiding caries arrest
Iovan A et al., 2023 ⁽²⁵⁾	In vitro	Protective effect of SDF+KI on demineralized root dentin under acid attack	SDF+KI increased microhardness and sealed dentin effectively
Almuqrin A et al., 2023 ⁽²⁶⁾	Literature Review	Improving SDF aesthetics using nanoparticles	SeNPs may reduce staining and enhance antimicrobial effect
Muntean A et al., 2024 ⁽²⁷⁾	Systematic Review	SDF in preventing and arresting dental caries in primary teeth among pediatric patients.	SDF is an effective, affordable, and non-invasive treatment for caries in children

Elshenawy EA et al., 2025 ⁽²⁸⁾	In vitro	SDF varnish against white spot lesions before orthodontic bracket bonding	SDF showed higher remineralization and bond strength
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9. DVERSE EFFECTS AND PARENTAL ACCEPTANCE

Although Silver Diamine Fluoride (SDF) is generally regarded as a safe and effective treatment for caries arrest, it is important to inform patients and caregivers about potential adverse effects. The most common side effect is permanent black or brown staining of the treated tooth surfaces, which can be more noticeable on anterior teeth and may raise aesthetic concerns. Use of potassium iodide (KI) following SDF application has been shown to minimize discoloration. Mild irritation or sensitivity of the gums and other oral soft tissues may also occur, though these symptoms typically resolve within a few days. Some patients may experience a temporary metallic taste during or shortly after application, which usually subsides quickly. Although rare, allergic reactions to SDF can occur and may present as itching, rash, swelling, or difficulty breathing, requiring immediate medical attention.⁽²⁹⁾

10. SAFEST CONCENTRATION OF SDF

The standardized and widely accepted concentration of Silver Diamine Fluoride (SDF) for clinical use is 38%, which has been approved by the American Dental Association (ADA) and the U.S. Food and Drug Administration (FDA) for the management of dental caries in both pediatric and adult populations. This concentration has demonstrated a favourable safety and efficacy profile in multiple clinical studies when applied according to established guidelines. While 38% SDF is considered safe for routine use, caution is advised in individuals with known hypersensitivity to silver or fluoride. Patients should be carefully monitored for any adverse reactions, including allergic responses or localized tissue irritation.⁽³⁰⁾

11. CONCLUSION

SDF represents a significant advancement in non-invasive dentistry. Its proven efficacy, ease of application, and low cost make it an ideal caries management tool, particularly in pediatric and underserved populations. Wider acceptance, combined with clinical training and public health awareness, can unlock its full potential.

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