

Silver Diamine Fluoride in Preventing Caries: A Review of Current Trends

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ABSTRACT

Aim and objective: To evaluate whether silver diamine fluoride (SDF) is effective in the management of dental caries.

Background: Dental caries is most common chronic disease and conventional treatment method could not tackle the problem completely. The use of silver compounds in dentistry is over a 100 years. Silver diamine fluoride has become a newer trend in handling the caries especially in young and apprehensive children. It is a noninvasive method of arresting caries which is painless, safe, and cost effective. This article describes the trends in silver diamine fluoride in arresting caries. The combined effects of remineralizing and antibacterial property make SDF an effective cariostatic agent.

Review results: Articles were searched in electronic data bases for literature. *In vivo* studies, *in vitro* studies, systematic reviews and case reports were included.

Conclusion: Silver diamine fluoride is effective in the management of caries in primary dentition. There is a little effect of silver diamine fluoride in permanent molars.

Clinical importance: In the current scenario of raising importance of minimal invasive dentistry and preventive dentistry, silver diamine fluoride is an efficient tool in the management of caries.

Keywords: Silver diamine fluoride, Caries, Primary dentition, Minimal invasive dentistry.

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INTRODUCTION

Dental caries is a biofilm-mediated, sugar-driven, multifactorial, dynamic disease that results in the phasic demineralization and remineralization of dental hard tissues.¹ In past 25 years, caries is affected by half of the Indian children and increase in caries burden is seen in children.² The worse socioeconomic status are often associated with greater risk of severity of caries.³ Child cooperation to the treatment is another challenging aspect of caries to the dentist. So, in order to reduce the burden of caries and to avoid possible sequel associated with it, an alternative method which is cost-effective and effective in treating patients with high-risk to dental caries and with limited access to dental caries is required.⁴ Silver compounds are used in treating dental caries from century and they are the simple and low cost method in caries management techniques.⁵ Silver diamine fluoride (SDF) is composed of fluoride ion and diamine-silver ion. Introduction of SDF has led to a noninvasive, easy to apply, and invasive management of dental caries. It primarily consists of fluoride ion and diamine-silver ion.⁶ This review discuss in detail of various aspects of silver diamine fluoride in the management of dental caries.

Search Strategy

A strategy for search was developed for articles in three electronic databases, Pubmed, Science direct, and Google scholar from the year 1990 to 2020. Keywords given were "silver diamine fluoride," "silver fluoride," "diamine silver fluoride," and "arresting dental caries." Inclusion criteria were all *in vivo* and *in vitro* studies and reviews of SDF. Case reports, letter to editor, and non-English publications were excluded. The selected articles were reviewed for full text.

Composition of Silver Diamine Fluoride⁷

It is an alkaline solution and the constituents are given in Table 1.

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Indications

- Dental caries in young children
- Dental caries in medically compromised children
- Caries management in uncooperative children
- To arrest root caries
- To prevent pit and fissure caries
- To prevent recurrent caries
- In desensitization of teeth
- Infected root canals
- To prevent fracture of pulpally treated teeth

Mode of Action of Silver Diamine Fluoride

Silver is a potent antibacterial agent before the introduction of antibiotics. It has been used in the medical field about six millennia. It has placed a immense role in wound healing and the field of radiology.⁸ Silver ions kill the microorganism by blocking the

respiratory enzymes without causing harm to human cell.⁹ Silver ions also may cause condensation of DNA in microorganism and result in the loss of their replication abilities. Ions can also interact with thiol group and inhibit the bacterial enzymes.¹⁰

There are five possible mechanism on the action of SDF on dental caries.¹¹

- 1. Obturation of Dentinal Tubules:** Caries can be prevented by obturation of dentinal tubules since caries invasion is mainly through the tubules. Silver and its compounds occlude the tubules and prevent the invasion and acid diffusion. The microorganism in dentin are killed by oligomeric action of the silver. It is effective in reducing *S. mutans* in dentinal tubules.¹²
- 2. Reaction Products of SDF and Mineral Content of the Tooth:** Fluoride increased the resistance of dentin to decalcification and reduced the acid penetration into the deeper layers of dentin. Fluoride ion in SDF penetrated to a depth 50–100 microns in dentin. Calcium fluoride and insoluble silver phosphate are produced as a result of interaction of SDF with the hydroxyapatite crystals. Calcium phosphate acts as a reservoir for fluorapatite.
- 3. Anticollagenic Actions of the Reaction Products:** Inhibition of enzymes and dextran induced agglutination is responsible for the antimicrobial property. Dentin treated with SDF resulted in increased resistance to collagenase and trypsin.
- 4. Inhibition of Matrix Metalloproteinases:** MMPs breaks down extracellular components and it was suggested that MMPs in saliva and dentin plays an important role in dentin carious process. About 38% SDF has shown inhibitor effect on MMP-2, MMP-8, and MMP-9 and help in arresting dentinal carious process.¹³
- 5. Formation of Fluorhydroxyapatite:** SDF reacts with calcium and phosphates in the saliva and forms fluorhydroxyapatite. Alkaline property of SDF aids to it.¹⁴

Silver diamine fluoride has significant antibacterial effect on *streptococcus* and *actinomyces* and also gets precipitated in the biofilm. Microhardness of the carious dentin significantly increases on application of SDF.^{15,16} A highly mineralized dense layer forms on application of SDF and it is around 150 microns thick and also mineral content is more when compared to affected dentin which attributes to increased microhardness.¹⁷ It significantly reduces *streptococcus mutans* in saliva¹⁸ and also it possess antifungal activity against candida.¹⁹ Fluoride inhibits enolase and proton translocating ATPase thereby inhibits the metabolic activity of bacteria and silver also reduces metabolic activity binding to the bacterial proteins. Both silver and fluoride has synergistic effects.²⁰ Application of 38% SDF considerably arrested dental caries in preschool age children and the effect is safe and rapid. The microbial resistance to SDF is low.²¹ Mechanism of silver diamine fluoride is summarized in [Flowchart 1](#).

Zombie Effect of Silver

Main characteristic of biocidal metals like copper and silver is its prolonged activity which slowly releases cations that is toxic to microbes. Bacteria killed by silver particles showed biocidal action against living microorganism of same. After killing the bacteria metal ion is not deactivated and it kills the bacteria repeatedly. The dead bacteria act as a reservoir and promote sustained release of cations.²²

SDF on Dental Caries

SDF is available in various concentrations. A study conducted by Fung et al. found that 38% of SDF is more effective in arresting

dental caries on biannual application.²³ Zhi et al. in his study found that with increased frequency of SDF application the proportion of arrested dentin also increased and it follows the general recommendation that the children with high-risk need more fluoride application. On annual application SDF and glass ionomer cement has similar results in arresting the caries.²⁴ In 12 months study, it was found that in lower caries risk group, SDF has arrested 84% of interproximal carious lesions and can be considered as an effective tool in management of carious in primary dentition, when the lesion is confined to dentino enamel junction.²⁵ Some of the studies and the results^{26–28} are given in [Table 2](#).

A systematic review by Yasmi and Richard summarized following points:

- About 38% SDF is more effective
- Biannual is more effective than yearly application
- Success rates seem to be independent of time application
- Is more effective in anterior teeth than posterior teeth
- Use is not recommended in suspected pulpal involvement

SDF is equally effective in treating dental caries of initial (ICDAS 1 and 2), noncavitated (ICDAS 3 and 4), and cavitated (5 and 6).²⁹ SDF has more effect on primary tooth than in permanent molars in arresting the caries.³⁰ There is high quality of evidence of SDF arresting caries in primary teeth but not enough evidence for permanent molars.³¹

SDF on *Streptococcus Mutans*

Post application of SDF, *streptococcus mutans* levels reduced about 95% in 24 hours in saliva. Highest reduction of about 99.95% was observed after 30 days. The reason can be hardening of the tooth surface and/or inhibition of bacterial adherence. There is a significant rise in counts after 90 days in saliva, but still it is less than the baseline value.³²

SDF and Hydroxyapatite

Initially a globule containing calcium and fluoride is formed which can be calcium fluoride. High fluoride in SDF and calcium from hydroxyapatite resulted in the formation of calcium fluoride like globules. The reaction also resulted in the formation of nanoscopic silver particles seen attached to hydroxyapatite crystals.³³

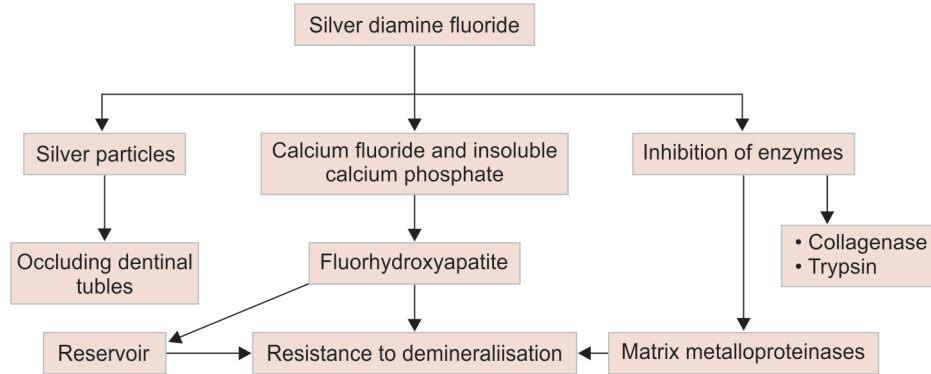
Table 1: Constituents of silver diamine fluoride

Silver	24–27%
Ammonia	7.5–11%
Fluoride	5–6% (approx 44,800)
Blue coloring	<1%
Deionized water	<62.5%

Table 2: Studies and results from the studies

Study	Conclusion
Caroline et al. ²⁶	89.3% arrest of caries and increased quality of life
Llodra et al. ²⁷	38% SDF effective in controlling caries in deciduous teeth and permanent molars
Chu et al. ²⁸	38% SDF more effective in hardening and arresting caries in primary maxillary teeth than 5% NaF

Flowchart 1: Mechanism of action of silver diamine fluoride



Histologic Findings of Dentin on SDF Application

Silver penetration into dentinal tubules can vary from 50–200 microns to maximum of 1 mm. No bacteria were found in the tubules. SDF can facilitate tertiary dental formation and minimal pulpal inflammation.³⁴ The edge of the lesions are hypermineralized and areas of hypomineralization can be found in intertubular dentin. Silver absorption is highest within the lesion decreasing when we approach the edge.³⁵ Silver precipitation is seen in pellicle, within the rod sheaths, extending to demineralized rods, and dentinal tubules. Silver enriched diffusion barriers is formed around the carious lesions.³⁶

Adverse Effects of SDF

No serious adverse effects or systemic illness is associated on application of SDF. Oral pain, gum bleaching, and transient gum swelling can be seen in some children. Black staining is frequently found and it is directly proportional to concentration and frequency of application.³⁷ Black staining is formed as result of formation silver phosphate and silver sulfide, which are the reactionary products. Clinically detectable staining occurs 2 minutes after application and large visual change occurs in 5 minutes. Staining is more in areas with surface irregularities.³⁸

Parental Acceptance of SDF

Staining of posterior teeth is accepted by parents than anterior teeth. But the parents are ready to compromise esthetics than going for a more invasive procedure.³⁹ In another study the acceptance of SDF is high (79.5%) in children with early childhood caries and high dmft/DMFT.⁴⁰ In a study by Kyoontan et al. most of the parents accepted SDF in treating early childhood caries as it is a noninvasive and painless.⁴¹

SDF and Bond Strength

In a study by Markham et al. SDF application on tooth surface reduced bond stability of composite for both enamel and dentin when used with universal adhesives. Most of the failures are due to adhesive failure. Decrease in bond strength can be as a result of surface contamination by SDF. So, SDF should not be applied on entire bonding surface of the tooth⁴² but Siqueiraa et al. reported application of diamine products increased the microtensile bond strength.⁴³ Firouzmandi et al. concluded through his study that SDF increased the bond strength of caries affected dentin but does not have any effect on normal dentin.⁴⁴

SDF and Potassium Iodide

SDF reacts with potassium iodide (KI) to form silver iodide (AgI) and tripotassium phosphate (K³PO₄). Tripotassium phosphate is a white powder which masks the black stain.

Recommendation for the use of potassium iodide

- Petroleum jelly is applied to gingival and rubber dam is placed
- Tooth is dried
- SDF is applied with a microbrush
- Wait for 1 minute and remove excess with cotton
- Apply KI with microbrush on SDF treated tooth
- Restore the teeth with glass ionomer cement or resin modified composite⁴⁵

Zhao et al. reported that potassium iodide reduces discoloration by SDF and does not affect the bonding of GIC to dentin⁴⁶ but systematic review by Roberts et al. concluded that there poor level evidence for potassium iodide reducing discoloration caused by SDF.⁴⁷

Silver Modified Atraumatic Restorative Technique

In this technique, SDF is applied on tooth surface and immediately it is filled with GIC. The technique has combined advantages of three principles:

- Remineralizing and antibacterial effect of SDF in arresting caries.
- Partial or incomplete caries removal in case of deep carious lesion not exposing the pulp.
- Chemical adhesion of GIC without an effect on bond strength.⁴⁸

Jiang et al. conducted a randomized control trial on SDF in atraumatic restorative treatment in primary tooth and found that application of SDF does not affect the success rate of atraumatic restorative treatment, but considerably reduces the chair time in placing the restoration.⁴⁹

CONCLUSION

SDF is the best alternative method to arrest caries in primary dentition especially in case of early childhood caries. Its effect on permanent molars has poor level of evidence and need further investigation. The black staining is potential disadvantage, but the parents favorably select SDF over invasive technique as it is painless and safe. Silver diamine fluoride has also have consider bond strength with composite which aids in masking the black stains.

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