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Original Research

Unlocking The Silver Lining: How Silver Diamine Fluoride Is Revolutionizing Dental Health

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ABSTRACT:
Silver diamine fluoride (SDF) has gained prominence as an effective agent in the management of dental caries, renowned for its ability to arrest caries and prevent further decay. This comprehensive review synthesizes current knowledge on the efficacy, safety, and application of SDF in dental practice. The chemical composition and mechanism of action of SDF are examined, along with its clinical effectiveness in both primary and permanent teeth and its role in public health, particularly for underserved populations. Aesthetic considerations, patient acceptance, and potential side effects associated with SDF treatment are also addressed. Additionally, the review compares SDF with other caries management strategies, providing a holistic view of its advantages and limitations. Future research directions and implications for clinical practice are discussed to guide dental professionals in optimizing caries management protocols.
Keywords: Dental caries, silver diamine fluoride, aesthetic considerations, dental treatment.

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INTRODUCTION

A smile is an inexpensive way to change your looks' – **Charles Gordy**. Attractive smile is the best way to familiarize with people. It is an important social asset that builds confidence in children so that they can interact within their surroundings. Children with decayed or broken teeth avoid smiling as they find themselves unattractive. The common cause of decayed teeth is Dental caries.

Dental cariesbeing one the most frequentencountered diseaseworldwide.[1]It is characterised as irreversible microbial disease leading to the demineralisation of inorganic and destruction of organic portion of tooth.[2]Regardless of being the most preventable disease, it still remains a common oral health problem in children.[3]Dental caries occurs as a result of dynamic interaction between cariogenic bacteria and fermentable carbohydrates. The extent of decay is strongly influenced bythe socio-economic status, oral hygiene& diet of the child.[4]For management of caries, both surgical and medical models are used.The surgical model involves the cutting and drilling of teeth with cavities & replacing them with adequate restorative material like amalgam, glass-ionomer cement and composite resin.[5]On the other hand, medical model involves the prevention of caries and also to stop the progression of dental caries. Despite of preferring these conventional drilling procedures, dentists should opt for a non-invasive& painlessprocedures for managing carious lesion in paediatric patients.Silver Diamine fluoride (SDF) is a fluoridated agent which is used to halt the progression of carious lesion in paediatric patients and prevent the formation of new caries.[6] It is a non-invasive method of arresting caries, allows easy application in minimal time&capable of controlling pain and infection through bacteriostatic and bactericidal action. This review will delve into the important aspects of SDF (Silver diamine fluoride)& aims to explain its various applications and benefits.

WHAT IS SDF?

Silver diamine fluoride(SDF) is a colorless metal ion based topical fluoride solution which combines the antibacterial effect of silver & remineralizing effect of fluoride. The combination of silver and fluoride ions in alkaline solution has a synergistic effect in arresting dentine caries, which makes SDF different from other fluoride agents.[7] SDF has a pH value ranging from 9-10.[8] It is mainly composed of silver, ammonia and fluoride, each playing a crucial role in its mechanism of action. The composition of SDF at 38% concentration is shown in table 1[9].

Table 1: Composition of Silver Diamine Fluoride at 38% concentration

Constituent	Concentration	Ppm	Properties
Silver	24-27%	255,000	Helps to kill bacteria (Antimicrobial action)
Fluoride	5-6%	44,800	Helps to rebuild the tooth material mainly referred as REMINERALIZATION & Anticariogenic
Ammonia	7.5-11%		Reduces the oxidative potential of SDF and maintains the concentration of solution so that it remains effective for a longer period of time.
Water	<62.5%		Acts as a base for mixture

HISTORY OF EVOLUTION OF SDF

Around 1000 BC, silver was used as medicine. They were stored in water vessels, which had antibacterial properties. In 1891, Stebbins observeda significant reduction in caries with silver nitrate and was attributed as antimicrobial agent. It resulted in the formation of black crust as a protective layer over secondary dentin, reducing the intensity of dentinal hypersensitivity. In the following years, silver nitrate was popularly known as "Howe's solutions". From 1960 -1970,it was used in Japan where they pioneered the silver diamine fluoride with high fluoride concentration.In 1970, The Central Pharmaceutical Council of Japan Ministry of Health and Welfare authorized "silver diamine fluoride" as a cariostatic agent and it became accessible to all the dentists in Japan. In further years, its usage became unpopular in Japan due to the low prevalence of ECC in children.[9]

At the beginning of 21st century, China started using SDF as caries arresting agent in school children. In 2014, FDA cleared SDF to be used asdesensitising agent for dentinal hypersensitivity. The Dental Procedures and Nomenclature (CDT) Code Maintenance Commission authorized a new code D1354 for "interim caries arresting medicament application" in 2016.[10]

MECHANISM OF ACTION

Silver is a potent antibacterial agent& effective against strains of*Streptococcus mutans, Antinomies naeslundii & Lactobacillus acidophilus.*

SDF penetrates the SDF the enamel of about25 μand dentin of about 16-200μ.[11] SDF when applied on tooth surface reacts with hydroxyapatite crystals $[Ca_{10}(PO_4)_6(OH)_2]$forming calcium fluoride (CaF_2) and silver phosphate(Ag_3PO_4) as major reaction products in alkaline environment.Sufficient fluoride is provided byCaF_2 for the formation of fluoroapatite $[Ca_{10}(PO_4)_6F_2]$, which is less soluble than hydroxyl apatite in an acidic environment.[12]

The reaction can be summarized as –

$$\mathbf{Ca_{10}(PO_4)_6(OH)_2 + Ag(NH_3)_2 = CaF_2 + Ag_3PO_4 + NH_4OH}$$

The mechanism of action can be explained by three possible mechanisms –

1. In the caries process, bacterial invasion initially involves streptococci, actinomycetes & lactobacilli. Concentrations of antibacterial agent's for inhibiting biofilms are more than 100 times higher than that for planktonic bacteria. As anti-microbial SDF has the ability to inhibit the formation of cariogenic biofilms. High concentration fluorides can inhibit biofilm formation because fluorides can bind to bacterial cellular components and influence enzymes. Silver ions at a concentration of 20 ppm can inhibit the growth of *streptococcus mutans* by destruction of the cell wall structure of bacteria, inhibition of enzyme influencing the metabolic processes and also inhibits the DNA replication of bacteria. [13]
2. Second mechanism of action is promotion of remineralisation & inhibition of demineralisation of enamel & dentine. SDF reacts with hydroxyapatite to release calcium fluoride and silver phosphate which are responsible for the prevention of the dental caries.[14] An insoluble protective layer of silver phosphate that precipitates on the tooth surface decreases the calcium & phosphorus loss from demineralised enamel & dentine. Calcium fluoride provides a reservoir of fluoride for the formation of fluoroapatite, which is more resistant to acid attack than HA. It also promotes the calcification, restores the lattice imperfection & improves the crystallinity of hydroxyapatite.[15]
3. Third mechanism of action is the reduction of dentine collagen matrix through collagenase inhibition. In dentine, type I collagen is 90% of the organic component and the residual part is composed of non-collagenous proteins. Type I collagen acts as a scaffold for the deposition of mineral crystals & also inhibits demineralisation. Matrix metalloproteinase (MMPs) plays an important role in the enzymatic degradation of collagen. SDF has an inhibitory effect on the

proteolytic activities of MMP-2, MMP-8 & MMP-9 & it also inhibit the activities of cysteine cathepsins, which are proteolytic enzymes that contributes in dentine collagen degradation. Therefore, the inhibition of MMPs &cysteine cathepsins activities may preserve collagen from degradation & contribute to the arrest of the caries process. Silver ions may contribute more than fluoride to the SDF inhibition effect on cysteine cathepsins.[16]The figure 1[11] depicts the mechanism of action of SDF.

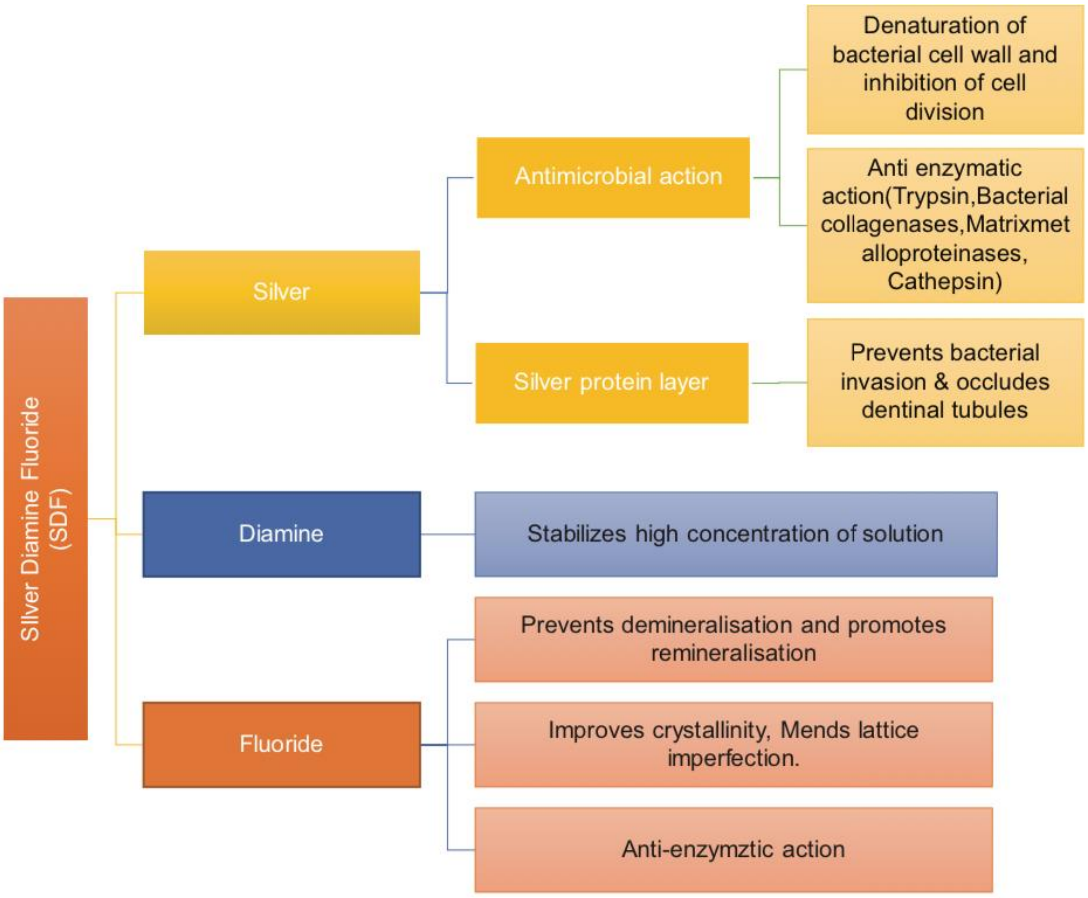

Figure 1: Mechanism OfAction SDF

INDICATIONS[17]

- High risk carious prevalence in patients with xerostomia, cancer therapy, salivary dysfunction etc.
- Carious lesion in both young children and special healthcare need children
- To prevent root caries
- To treat dentinal hypersensitivity
- Tooth with no signs & symptoms of pulpitis
- To prevent the occurrence of secondary caries (recurrent caries)
- To prevent pit & fissure caries

CONTRAINDICATIONS[9]

- Patients allergic to silver
- Patients with soft tissue ulcerations for example recurrent aphthous stomatitis, desquamative gingivitis, ulcerative gingivitis etc.
- When parents don't give consent to use SDF because they are concerned about the color changes
- Tooth is associated with periapical lesion
- Signs & symptoms of irreversible pulpitis
- If isolation of respective tooth is not possible
- Pregnancy [18]
- Breastfeeding [18]
- Caries in aesthetic zone [18]

CLINICAL APPLICATION TECHNIQUE

Step 1- The tooth which needs to be treated should be isolated properly to avoid direct contact with soft tissue.

Step 2- Once the tooth is isolated Vaseline or petroleum jelly can be applied on nearby soft tissue to prevent staining.

Step 3- The affected tooth with decayed material needs to be dried completely so that it not hamper the effectiveness of silver diamine fluoride.

Step 4 –Take one drop of SDF(25 µL) not more than one drop should be used in each appointment. One drop can be sufficiently used to treat five teeth.
Step 4- Application should be done using microbrush as depicted in figure 2.[18]

Step 5- After applying the SDF wait for 60 seconds before removing the unwanted material with cotton gauge.[19]
Step 6- Wash the tooth with water.
Step 7 –The procedure should be carried out once in 6 months (Biannual application)is recommended for arresting the carious lesion.

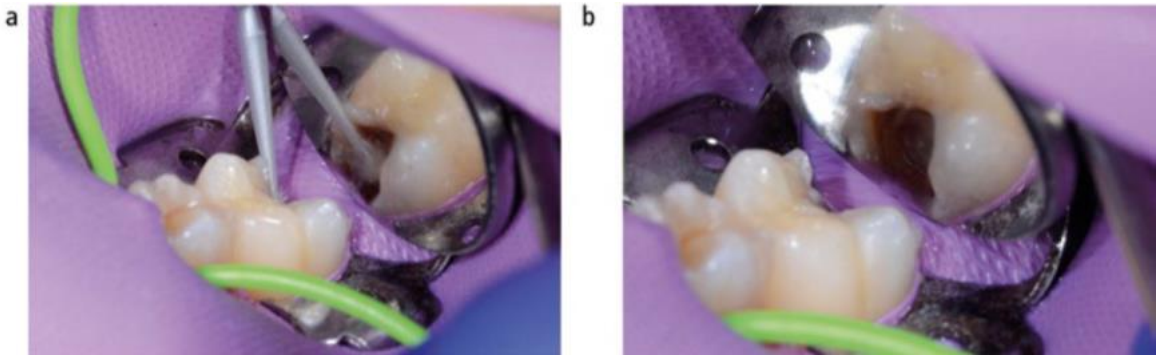

Figure 2: A Clinical Photograph Depicting Sdf Application To A Significant Carious Lesion On Tooth 46 Resulting In Darkening Of The Lesion.

ADVANTAGES

- Cost-effective
- Easy application
- No instruments required
- Non- invasive
- Less technique sensitive
- Decreases the risk of spreading infection
- Capable of controlling pain

DISADVANTAGES

- Metallic/ Bitter taste can be inconvenient for children.
- Can stain surfaces, and clothes.
- Can stain skin like henna but due exfoliation of epithelial cells, it resolves on its own within 2-14 days.[11]

USES OF SDF

- **Caries Control**

Pit & Fissure caries - SDF can be effectively used as a caries-arresting agent for pit and fissure caries, root caries, and secondary caries. Pits and fissures are the first sites approached by bacterial agents due to their morphological differences. Identifying pits and fissures as incipient lesions can be a challenging task for dental professionals.

Secondary caries-Most restorative materials adhere to the tooth structure, but some restorative materials are incapable of this chemical bond. This results in gap formation between the wall of the prepared cavity and the restorative material, allowing bacteria, saliva, and food debris to penetrate, which eventually leads to secondary caries. Some studies have proven that the application of SDF prior to any restoration can prevent secondary caries.

Root caries – Root surfaces are more prone to carious activity because of their high critical pH, i.e., 6.7-6.8. As the chances of developing periodontal disease increases with age, the incidence of root caries also increases with age. To prevent its progression, SDF can be effectively applied annually to limit its extent.

- **Management of Dentinal Hypersensitivity**

Dentinal hypersensitivity occurs as result of exposed dentinal surface. It is characterized as acute, sharp shooting painwhich is exaggerated when exposed dentin comes in contact to thermal, evaporative, tactile, chemical,or osmotic stimuli.SDF was first used as a desensitising agent in Japan. The clinical procedure for its application is similar to asit was for caries. Prior studies, found that SDF along with KI is found to be effective as it could further reduce the dentin permeability when applied after fluoride treatment.[20]

- **Disinfection of Root Canal during endodontic treatment**

For a successful endodontic treatment it is essential to completely eliminate the microorganisms from the root canal system.[21]Incomplete disinfection of the root canalwill result in persistent infection. Ultimately, affecting the success of the treatment. Several root canal irrigants were used for disinfection& found to be resistant to Enterococcus faecalis.[20] A laboratory study conducted by Law A et al. [22] showed that 38% SDF solution, is capable of reducing the Enterococcus faecalis by 100% after 60 minutes of exposure.

SAFETY & ADVERSE EFFECTS

The average lethal dose of SDF differs with route of administration, if administered though oral route lethal dose is 520 mg/kg& through subcutaneous route of administration it will be 380 mg/kg.The concentration of 38% of SDF is found to be effective for arresting caries and preventing formation of new

carious lesion. Since minimal amount of SDF is applied semi-annually or annually to the hard tissue,chances of developing silver toxicity is less. According to previousstudies, 90% of deep carious lesion treated with SDF showed positive pulpal response.[12] Some of the adverse effects are mild gingival irritation, small white lesion in the oral mucosa can be observed, but it usually resolves on its own within 2 days. Moreover, its spillage should be avoided onclothes or over skin, as it may result in formation of tattoo. A study conducted by Selvaraj et al. [23] statedthat SDF is known to cause black staining of tooth structure as shown in figure 3[6]. Heevidentlyproved that this staining can be eliminated by application of KI following SDF. Fluoride in SDF The presence of 44,800 ppm fluoride in SDF increases the risk of dental fluorosis but till date no such cases have been reported.

Figure 3: Black staining after SDF application

CONCLUSION

Silver diamine fluoride (SDF) stands out as a versatile, cost-effective & patient friendly option in dental care. It is known for its simple, quick and efficient mode of action.It's readily availability& painless procedure makes it an invaluable tool for dentists, particularly for treatingpaediatric& special need patients. SDF provides wide range of applications like managing carious lesion, treating dentinal hypersensitivity, & treating root caries. In addition, it can also be used to disinfect root canals.Clinical studies have proved that 38% of SDF is capable of arresting dental caries. By embracing SDF in dentistry, compassionate care can be provided to the patients for better oral health outcomes.

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