

Silver Diamine Fluoride: A Review and its Utilization in Dentistry

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Abstract

This review article aims to see in detail about the uses and application of silver diamine fluoride (SDF) in dentistry. SDF is used for preventing and arresting caries. SDF is a bactericidal agent which inhibits demineralization of enamel and dentine and promotes remineralization. It is mainly used in young children and children with special needs, since its application is simple and painless. This intervention can be applied as soon as the caries is detected.

Keywords: Silver diamine fluoride, Dental caries, Remineralization

INTRODUCTION

Dental caries is the highly prevalent infectious and chronic oral disease.^[1] Dental caries when left untreated leads to risk of infecting the other deciduous teeth and underlying permanent teeth. The pain also affects the child's activities and overall well-being. The caries can also spread into a space infection which requires high-priced emergency treatments and general anesthesia.^[2]

The conventional management of the carious lesion follows the removal of carious tissue and restoration of the cavity with a suitable restorative material. These conventional methods require excessive removal of tooth structure, which are then replaced by minimal invasive dentistry that needs only less tooth preparation and protects the sound tooth structure.

To prevent caries at community level, various preventive interventions were used.^[3] One of the effective preventive methods is the use of silver diamine fluoride (SDF). Although SDF has been used as a preventive material for caries earlier in the 20th century in Japan, it gained its popularity among clinicians most recently. The SDF is recommended by the American Academy of Pediatric dentistry in 2017 for the caries treatment. SDF was cleared by the Food and Drug Administration (FDA) for dental use.^[4] The effectiveness of SDF is based on various clinical trials, scientific evidence, and reports. SDF is one of the preventive interventions which can halt the caries progression and prevent new lesion development.^[5] It is a colorless, odorless liquid composed

of silver, ammonium, and fluoride ions at a pH of 10.4 or 13.^[6] SDF often called as silver diamine fluoride which is a misnomer, as SDF contains two ammine (NH₃) groups, not amine (NH₂) groups.^[7,8]

History of the use of silver compound

The usage of silver in medicine dates back to 1000 BC or earlier. Silver vessels were used by the Greeks and Romans to store water in the early days, to keep the water fresh and disinfected. Silver nitrate was used in the past to reduce eye infections in newborn babies. The use of silver for burns has also been documented.^[9,10]

In dentistry, the use of silver nitrate was reported for its use in arresting the dental caries as early as the 1891s. About 1000 years ago, there was a custom among ladies in Japan to color their teeth black for expressing that they are married. They used silver nitrate as the tooth cosmetic which later conceived to prevent and arrest dental caries. In 1891, Stebbins^[11] used silver amalgam and nitric acid on decayed teeth and found that there was inhibition of caries progression. Then, Howe's solution was applied directly to the carious lesion,^[12] which is an ammoniacal silver nitrate, for caries

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inhibition in 1917. In the 1970s, silver fluoride (AgF) 40% was used in West Australia.^[13]

SDF was first developed by the Japanese scientists, Yamaga and Nishino to prevent and treat dental caries in 1969. They combined the antibacterial properties of silver with the anticariogenic properties of fluoride,^[14] which resulted in a formulation that blocked the dentinal tubules and minimized hypersensitivity. The Central Pharmaceutical Council of the Ministry of Health and Welfare of Japan allowed the use of SDF for dental purposes.^[13] In 2014, the FDA of the United States approved the use of SDF for tooth hypersensitivity.^[15,16] It was popular in China in schoolchildren from the 21st century.^[17] From 2005 to 2009 in Australia, a series of *in vitro* studies were conducted and the effect of SDF on *Streptococcus mutans* and dental biofilm as an antimicrobial and caries arresting agent, respectively, was proved.^[18]

Composition of SDF

SDF is a colorless liquid, generally composed of silver, ammonia, and fluoride.^[19] SDF is widely available as 38% solution with a pH of 10. The lower concentration of 12% and 10% is also available in some countries like Argentina but they are not much effective as 38% solution.^[20] The 38% solution is usually comprised of 24.4–28.8% of silver, 5.0–5.9% of fluoride (44 and 800 ppm),

7.5–11.0% of ammonia, and approximately 62.5% of deionized water. While silver and fluoride ions are used for their antimicrobial properties, ammonia is used to minimize the oxidative potential of silver and to increase its stability.^[6] The ammonia ions combined with silver ions generate a very stable diamine-silver ion ($\text{Ag}(\text{NH}_3)_2\text{F}$). In the United States, SDF is available under the brand, Arrest Advantage (38% w/v $\text{Ag}(\text{NH}_3)_2\text{F}$, 30% w/w) by Elevate Oral Care, LLC, West Palm Beach, Florida.^[4] Another popular formulation is from Japan called Saforide (Toyo Seiyaku Kasei Ltd., Osaka, Japan) which is again a 38% solution. In India, it is available as a 38% solution under the name e-SDF (Kids-e-dental, LLP, India).

MECHANISM OF ACTION

There are multiple modes of actions that have been proposed for silver. Even though there were many clinical reports and studies that documented the effectiveness of SDF, its mechanism of action is still unclear. However, based on the reviews, the modes of the action of SDF can be, its antibacterial properties on caries causing bacteria, its remineralization effect on the inorganic content, and its protection against the degradation of the organic matrix.^[21-23]

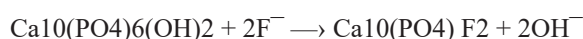
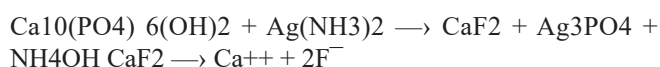
ANTIMICROBIAL PROPERTIES OF SDF

Silver ions in SDF can inhibit the formation of cariogenic biofilm. In a study by Suzuki *et al.*, they demonstrated that the SDF considerably reduced the important caries causing bacteria, the *Streptococcus mutans* and the *Lactobacillus*. Fluoride is also known for its antimicrobial properties.^[14] Fluoride also

hinders the biofilm formation in its higher concentrations, thus reducing the caries formation.^[24]

REMINERALIZATION OF INORGANIC CONTENT

SDF is also known for its remineralization effect on dentine caries. SDF reacts with the hydroxyapatite of teeth and results in the formation of silver phosphate and calcium fluoride, which are responsible for the prevention of dental caries by elevating the pH and formation of fluoride reservoirs. The fluoride and calcium subsequently undergo dissolution and result in the formation highly insoluble fluorapatite. The reaction between SDF and hydroxyapatite also results in the development of nanoscopic silver particles that are attached to the hydroxyapatite crystals, which inhibits the future caries in the arrested lesion. The chemical reaction is shown below,



INHIBITORY EFFECT ON DEGRADATION OF ORGANIC MATRIX

SDF also has inhibitory effect on matrix metalloproteinase and cysteine cathepsins, which are the proteolytic enzymes that cause collagen degradation and development of dental caries. Hence, the inactivation of these enzymes helps in the prevention of dental caries.

EFFECT OF SDF IN HYPERSENSITIVITY

SDF is also commonly used in the treatment of hypersensitivity. The mechanism of action behind this can be explained as the aqueous silver and fluoride solution produce a squamous layer on the dentinal tubules that are exposed. The obturation of dentinal tubules which are the main invasion road of dental caries also helps in the prevention of caries.

CLINICAL INDICATIONS OF SDF^[25,26]

1. SDF is indicated in the management of patients with extreme caries risk such as xerostomia, usually secondary to cancer treatment, aging, and severe early childhood caries
2. SDF is used to prevent caries in very young children and children with behavioral problems
3. In the management of patients who cannot tolerate standard restorative treatment for medical or psychological reasons, which includes those with severe cognitive and physical disabilities and dental phobias
4. To prevent caries progression in pit and fissure caries
5. SDF is used to prevent lesions that are difficult to access and treat caries such as caries at crown margin, caries in the furcation area, and occlusal surface of partially erupted third molar

6. Annual application of SDF is found to be more effective in treating and arresting the root caries
7. SDF is very useful in preventing dental caries in patients with no access to dental care and who cannot afford costlier restorative procedures
8. SDF is indicated in the management of dentinal hypersensitivity due to its ability to occlude the dentinal tubules
9. It is also used as an endodontic irrigant to disinfect the root canals.
10. Only one drop of SDF is sufficient to treat five to six tooth surfaces
11. Bend the microbrush, dip the brush into SDF, and pat against the side of the dappen dish to reduce the extra liquid before the application on the lesion
12. Apply the SDF only on the affected area and allow it to absorb for at least 1 min
13. After the application time of at least 1 min, a gentle flow of compressed air has to be applied until the SDF is dry
14. The excess SDF has to be removed with cotton
15. The treated area should be isolated for at least 3 min
16. It is optional to apply a varnish like fluoride varnish on top of SDF to prevent saliva from diluting the SDF
17. Application frequency: The SDF is recommended to be applied twice a year for better results. The studies that had 3 times a year applications showed sustained and higher arrest rates.

CONTRAINDICATIONS OF SDF

1. SDF is totally contraindicated in patients with the history of silver allergy
2. The prevalence of individuals with silver allergy is believed to be rare. Individuals who have been previously sensitized to silver either from medical or industrial exposure are at high risk^[4]
3. SDF is not recommended in people with open ulcers and sores. When these open ulcers, in case of desquamative gingivitis and other soft-tissue lesions, are exposed to SDF, there will be increased absorption since the protective barrier has been disrupted. It results in further irritation in the soft tissues and causes pain
4. It is also not indicated in teeth that require pulpal therapy, since application of SDF cannot treat the pulpal pathology. Those teeth will require additional restorative treatments
5. The main disadvantage of SDF is the discoloration that is formed after its application. It can be overcome by the application of potassium iodide on the surface, which is contraindicated in pregnant and breastfeeding women^[10]
6. Since SDF can cause some staining, application of the same on teeth in the esthetic zone is a major concern.

CLINICAL APPLICATION PROCEDURE OF SDF^[10,25-27]

1. The procedure and the possible outcomes with the application of SDF have to be explained to the patient and the written consent has to be obtained
2. Use of protective gears (PPE) for the patient (protective eye wear, bib, etc.) and the operator (protective eye wear, gloves, mask, gown, etc.) is recommended
3. SDF should be dispensed into a plastic dappen dish and should be recapped immediately
4. A protective layer of Vaseline or petroleum jelly should be applied extraorally to prevent the temporary staining, if SDF comes in contact with the skin and lips
5. Removal of plaque and debris should be done in the cavitated lesion
6. Removal of caries is not necessary before the application of SDF
7. Proper isolation methods has to be used (cotton rolls, gauze, etc.) to prevent unwanted staining
8. Dry the area to be treated with gentle flow of compressed air and gauze
9. SDF should be applied with a microbrush to prevent intraoral and extraoral soft-tissue exposure

DRAWBACKS OF SDF

The most intrinsic disadvantage of using SDF in caries prevention is that the treated areas have the tendency to stain black. Because of this drawback, some children and their parents who are concerned with the esthetics may not find it satisfying.^[27,28] The black stain is due to the silver phosphate which is formed when SDF reacts with carious dentin. It will be yellow initially and turns black when exposed to sunlight. To deal with this constraint, Knight *et al.*^[18] suggested the use of potassium iodide after the application of SDF so that the free silver ions will react with KI to form silver iodide which will be creamy white in color. The another disadvantage is that when SDF is exposed to skin or lip accidentally, it may result in a temporary tattoo like stain which will disappear in 2–14 days. The SDF spills in the dental clinic can also cause stains which should be removed immediately with lot of water or bleach. The another downside in SDF is that its taste which will be metallic.^[9] Hence, the very young children will find it unpleasant.

CONCLUSION

In this new era of minimal intervention dentistry, the modern non-restorative management of dental caries effectively substitutes the conventional restorative techniques. The most integral part of minimally invasive dentistry is the prevention of dental caries which is most efficiently done with the help of SDF.

This successful, effective, easy, safe, and affordable method of dental treatment is undoubtedly a boon to pediatric dentistry. Not only in pediatric dentistry, SDF has a broad spectrum of applications in general dentistry as well. To conclude, SDF is a powerful pre-emptive measure for dental caries, which acts by reducing the cariogenic bacteria, promoting remineralization of enamel and dentine, and protecting the collagen matrix.

REFERENCES

- Pitts N, Amaechi B, Niederman R, Acevedo AM, Vianna R, Ganss C, *et al.* Global oral health inequalities: Dental caries task group-research agenda. *Adv Dent Res* 2011;23:211-20.
- Marcenes W, Kassebaum NJ, Bernabé E, Flaxman A, Naghavi M, Lopez A, *et al.* Global burden of oral conditions in 1990-2010: A systematic analysis. *J Dent Res* 2013;92:592-7.
- Roberson TM, Heymann HO, Swift EJ. *Sturdevant's Art and Science of Operative Dentistry*. Mosby: St. Louis; 2002.
- Horst JA, Ellenikiotis H, Milgrom PL. UCSF protocol for caries arrest using silver diamine fluoride: Rationale, indications, and consent. *J Calif Dent Assoc* 2016;44:16-28.
- Duangthip D, Jiang M, Chu CH, Lo EC. Non-surgical treatment of dentin caries in preschool children-systematic review. *BMC Oral Health* 2015;15:44.
- Mei ML, Lo EC, Chu CH. Clinical use of silver diamine fluoride in dental treatment. *Compend Contin Educ Dent* 2016;37:93-8.
- Chu CH, Lo EC, Lin H. Effectiveness of silver diamine fluoride and sodium fluoride varnish in arresting dentin caries in Chinese pre-school children. *J Dent Res* 2002;81:767-70.
- Nishino M, Ono S, Kita Y, Tsuchitani Y. Caries prevention in pits and fissures with diammine silver fluoride solution and fissure sealant. Sealing properties of pits and fissures and adhesive characteristics to enamel. *J Osaka Univ Dent Sch* 1974;14:1-7.
- Yamaga R, Nishino M, Yoshida S, Yokomizo I. Diamine silver fluoride and its clinical application. *J Osaka Univ Dent Sch* 1972;12:1-20.
- Russell AD, Hugo WB. Anti microbiological activity and action of silver. *Prog Med Chem* 1994;31:351-70.
- Stebbins EA. What value has argenti nitras as a therapeutic agent in dentistry? *Int Dent J* 1891;12:661-70.
- Howe PR. A method of sterilizing and at the same time impregnating with a metal affected dentinal tissue. *Dent Cosmos* 1917;59:891-904.
- Yamaga R, Yokomizo I. Arrestment of caries of deciduous teeth with diamine silver fluoride. *Dent Outlook* 1969;33:1007-13.
- Rosenblatt A, Stamford T, Niederman R. Silver diamine fluoride: A caries "silverfluoride bullet". *J Dent Res* 2009;88:116-25.
- Duperon DF. Early childhood caries: A continuing dilemma. *J Calif Dent Assoc* 1995;23:15-25.
- Rosenblatt A, Stamford TCM, Niederman R. Silver diamine fluoride: A caries "silver fluoride bullet". *J Dent Res* 2009;88:116-25.
- Chu CH, Lo EC, Lin HC. Effectiveness of silver diamine fluoride and sodium fluoride varnish in arresting dentin caries in Chinese preschool children. *J Dent Res* 2002;81:767-70.
- Knight GM, McIntyre JM, Craig GG, Mulyani, Zilm PS, Gully NJ. An *in vitro* model to measure the effect of a silver fluoride and potassium iodide treatment on the permeability of demineralized dentine to *Streptococcus mutans*. *Aust Dent J* 2005;50:242-5.
- Burgess JO, Vaghela PM. Silver diamine fluoride: A successful anticariogenic solution with limits. *Adv Dent Res* 2018;29:131-4.
- Yee R, Holmgren C, Mulder J, Lama D, Walker D, van Palenstein Helderman W. Efficacy of silver diamine fluoride for arresting caries treatment. *J Dent Res* 2009;88:644-7.
- Lansdown AB. Silver I: Its antibacterial properties and mechanism of action. *J Wound Care* 2002a;11:125-30.
- Lansdown AB. Silver in health care: Antimicrobial effects and safety in use. *Curr Probl Dermatol* 2006;33:17-34.
- Shimizu A, Kawagoe M. A clinical study of diamine silver fluoride on recurrent caries. *J Osaka Univ Dent Sch* 1976;16:103-9.
- Suzuki T, Sobue S, Suganaka H. Mechanism of antiplaque action of diamine silver fluoride. *J Osaka Univ Dent Sch* 1976;16:87-95.
- Burgette JM, Weintraub JA, Birken SA, Lewis TA, White BA. Development of a silver diamine fluoride protocol in safety net dental settings. *J Dent Child (Chic)* 2019;86:32-9.
- Chibinski AC, Wambier LM, Feltrin J, Loguercio AD., Wambier DS, Reis A. Silver diamine fluoride has efficacy in controlling caries progression in primary teeth: A systematic review and meta-analysis. *Caries Res* 2017;51:527-41.
- Crystal YO, Marghalani AA, Ureles SD, Wright JT, Sulyanto R, Divaris K, *et al.* Use of silver diamine fluoride for dental caries management in children and adolescents, including those with special health care needs. *Pediatr Dent* 2017;39:135-45.
- Halsted WS. The operative treatment of hernia. *Am J Med Sci* 1895;110:13-7.