

## EXPANDING HORIZON IN CARIES PREVENTION WITH SILVER DIAMINE FLUORIDE- A REVIEW

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### Abstract

Dental caries is the most common pandemic on the globe, affecting various age bars in all countries with varying degree of severity. Silver diamine fluoride provides an alternative care path for those patients in whom traditional restorative treatment cannot be done. Application of SDF to arrest dental caries is a non-invasive procedure that is quick and simple to use. Reports of available studies found no severe pulpal damage after SDF application. However, it has drawbacks like black discoloration of the carious teeth and an unpleasant metallic taste. But, the low cost of SDF and its simplicity in application suggest that SDF is an appropriate therapeutic agent for use in community dental health projects.

**Keywords:** Silver diamine fluoride; Dental caries; Caries arrest

### Introduction

Dental caries is the most common pandemic on the globe, affecting various age bars in all countries with varying degree of severity. It is estimated that around 2.5 billion (35%) people on the planet have untreated caries in their permanent dentition. Between 60% and 90% of children are affected, but the majority of dental decay remains untreated due to inappropriate, unaffordable, or unavailable oral care services [1]. The traditional conservative treatment of dental caries involves mechanical cavity preparation and restoration with suitable material. However, this kind of treatment requires clinical skills, expensive instruments, materials, and patient's cooperation. In young children, lack of cooperation often complicate the traditional restorative treatment of carious tooth and often leads to progression of disease and subsequent loss of tooth [2]. Moreover, in many developing countries due to barrier of accessing dental care, low socioeconomic populations go through life with untreated dental caries, suggesting the need for new or alternate approaches to control dental caries. There are many preventive interventions that can be used as an alternative to traditional restorative procedure, and one of them is the use of silver diamine fluoride.

#### Silver Diamine Fluoride

SDF 38% is a colorless liquid that at pH 10 is 24.4% to 28.8% (weight volume) silver and 5% to 5.9% fluoride [3]. It is manufactured in different concentrations such as 38%, 30% and 12%. SDF has been widely used in Japan for prevention and arresting caries in children since 1960s. At the beginning of 21st century, its use started in China as caries arresting agent in school children. Silver diamine fluoride is an effective caries arresting agent which can be

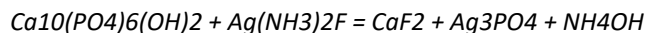
used for those patients who have difficulties in accessing proper dental care. It is also very useful in high caries risk patients with active carious lesions in both anterior and posterior teeth and also for medically and emotionally challenged children. From 2005 to 2009 Knight *et al.* in Australia did a series of *in vitro* studies and proved its effect as a caries arresting and antimicrobial agent. In 2009 Braga *et al.* in US and Yee *et al.* in Nepal used SDF as caries arresting agent successfully [4].

#### Mode of Action of Silver Diamine Fluoride

Multiple modes of action have been proposed for SDF on arrested caries.

The first mechanism is by forming a product which is more resistant to bacterial challenge and increase the resistance of peri-tubular and inter-tubular dentin to acid decalcification and as a result retard the penetration of acid into deeper layers of the dentin [5]. Studies have indicated that silver interacts with sulfhydryl groups of proteins and with deoxyribonucleic acid (DNA), altering hydrogen bonding and inhibiting respiratory processes, DNA unwinding, cell-wall synthesis, and cell division. It has also been demonstrated that silver diamine fluoride can inhibit biofilm formation and this inhibition is quite prominent in the first 7 days after application [2]. Silver diamine fluoride has also shown to have an inhibitory effect on matrix metalloproteinase and thus reduces the degradation of organic collagen matrix. Shimooka pointed out that F<sup>-</sup> ion of SDF applied to dentin under *in vivo* conditions penetrated to a depth of 50–100 μ [6]. It has been reported that SDF (Ag(NH<sub>3</sub>)<sub>2</sub>F) reacts with the tooth mineral hydroxyapatite (HA)(Ca<sub>10</sub>(PO<sub>4</sub>)<sub>6</sub>(OH)<sub>2</sub>) to release calcium fluoride (CaF<sub>2</sub>) and silver phosphate (Ag<sub>3</sub>PO<sub>4</sub>), which are responsible for the prevention and hardening of dental caries.

A simplified chemical reaction was suggested as



The  $\text{Ag}_3\text{PO}_4$  precipitates on tooth surface are insoluble and the  $\text{CaF}_2$  acts as reservoir of fluoride for the formation of fluorapatite, which is more resistant to dissolution. In addition, it is known that  $\text{F}^-$  promotes calcification, and also restores lattice imperfection, and improves the crystallinity of HA [7].

The second mechanism is by obturation of dental tubules. Gottlieb described that caries would be prevented by obturation of the organic invasion road. The main invasion road of caries in dentin is dentinal tubules. According to Shimizu, dentin treated with SDF decreased in dye permeability and increased in electric resistance. Successively, he confirmed that silver and its compounds were present in the dentinal tubules [4]. Therefore acid and cariogenic microorganisms can't invade through this, thus arresting the caries process. Even if microorganisms invade dentinal tubules, their growth will be inhibited by oligodynamic action of silver [8]. Those factors in association with the obturation of dentinal tubules must contribute to increase in resistance to recurrent caries. Mei *et al.* (2013) proved that the use of 38% SDF inhibited demineralization and preserved collagen from degradation in demineralized dentin [9].

The third mechanism may be the antienzymatic actions of the reaction products between  $\text{Ag}(\text{NH}_3)_2\text{F}$  and organic component of the tooth, which disrupt the metabolic process causing death of the cariogenic bacteria and reducing their colonization. Its antibacterial properties arise from inhibition of the enzyme activities and dextran-induced agglutination of cariogenic strains of *Streptococcus mutans* [4]. Chu *et al.* reported that SDF possesses an antimicrobial activity against cariogenic biofilm of *S. mutans* or *A. naeslundii* formed on dentin surface. Also, they showed that SDF slowed demineralization of dentin. Sunada *et al.* found that dentin, which had been treated with  $\text{Ag}(\text{NH}_3)_2\text{OH}$  by iontophoresis increased in resistance to trypsin. They stated that it might be owing to reaction of Ag and organic component of dentin [10]. Yanagida *et al.* showed that dentin protein treated with  $\text{Ag}(\text{NH}_3)_2\text{F}$  had increased in resistance to collagenase and trypsin.

### Clinical Applications of Silver Diamine Fluoride

#### SDF to Arrest and Prevent Dental Caries

Many clinical trials have found that 38% SDF solution is effective in preventing new coronal caries in primary and permanent teeth. Gupta *et al.* found the highest zone of bacterial inhibition with silver diamine fluoride. SDF had been used off-label for caries arrest; however, it was recently approved (code D1354) as an interim caries

arresting medicament [11]. SDF has been shown to lower caries risk of the adjacent tooth surface when applied to carious lesion due to fluoride content. Sinha *et al.* mentioned the remineralizing, rehardening, and antimicrobial abilities of silver diamine fluoride in *in vivo* study. Hihara *et al.* (1994) in Japan, McDonald and Sheiham (1994) in London, Llodra *et al.* (2005) in Cuba, Braga *et al.* (2009) in Brazil and Yee *et al.* (2009) in Nepal found that SDF is significantly effective in arresting the cavitated as well as incipient carious lesions[4].

#### Early Childhood Caries and Silver Diamine Fluoride

Early childhood caries (ECC) is the presence of 1 or more decayed, missing, or filled tooth surfaces (dmfs) in any primary tooth in a preschool-aged child, it has been recognized by the American Dental Association as an important public health issue. Conventional treatment of early childhood caries in young children involves many difficulties like behavioral issue and lack of cooperation, so a majority of the patients are left untreated, which ultimately result in loss of teeth. Loss of deciduous teeth mainly upper anteriors may cause psychological trauma to the patient or phonation problems. Deciduous teeth not only play an important role in the normal eruption and growth of the permanent teeth, but also are essential for the growth of the jaw bone. From such point of view by the application of silver diamine fluoride, caries can be arrested. Chu, Lo and Lin (2002) found that SDF was effective in arresting dentin caries in primary anterior teeth in pre-school children in a Community-based Caries Control Program [12]. Nishino *et al.* (1969) and Moritani *et al.* (1970) found less caries increment in children receiving SDF compared with those without SDF therapy [13,14].

#### Silver Diamine Fluoride to treat Dentin Hypersensitivity

Silver diamine fluoride forms squamous layer when applied on dentinal surface and thereby occludes dentinal tubules. Many studies reported the reduction of dentin hypersensitivity by employment of SDF in the affected area. SDF seems to be appropriate to reduce pain caused by dentin hypersensitivity by obliteration of exposed dentinal tubules. In a lesion like erosion or abrasion where dentinal hypersensitivity is precipitated by mechanical and thermal sensation, application of silver diamine fluoride can be an effective alternative treatment. Hatsuyama *et al.* (1967), Murase *et al.* (1969) and Kimura *et al.* (1971) have shown that  $\text{Ag}(\text{NH}_3)_2\text{F}$  was the most effective against erosion and abrasion followed hypersensitive dentin to mechanical, cold, and heat sensation [4]. It was also suggested that 4 times repeated application was the most appropriate and no further desensitizing effect could be obtained. In a randomized controlled study carried out on 126 adults with at least one tooth sensitive to compressed air were randomly assigned to either SDF or sterile water. The study tested application of SDF in a single visit and

pain was assessed at 24 hours and then again 7 days after the visit. The findings indicated that SDF reduced pain significantly in response to air in 24 hours and were maintained at 7 days[15].

#### Silver Diamine Fluoride to treat infected root canals

When used as 3.8% solution for irrigation of root canal silver diamine fluoride has shown potent antimicrobial effect. Because of its inhibitory effects on bacterial cell wall synthesis, DNA unwinding, and cell division, it can effectively reduce microbial load within a root canal. Okamoto *et al.* found that application of the SDF solution considerably reduced the number of treatments required. Mathew *et al.* found that silver diamine fluoride is very effective in reducing bacterial load from canal wall and circumpulpal dentin[16]. Hiraishi *et al.* (2010) concluded that 3.8% SDF has potential to be used as an antimicrobial root canal irrigant or interappointment dressing, especially in locations in which potential blackening of dentin by metallic silver is not a major concern [17].

#### Safety and adverse effect of silver diamine fluoride

There is approximately 24%–28% (w/v) silver and 5%–6% (w/v) fluoride present in silver diamine fluoride[3]. Studies that were carried out using SDF found that there were no reported cases about acute toxicity or significant adverse effects. Also, for more than 60 years of SDF use in Japan, no single adverse event has been reported. Other study reported that there were no adverse effects observed or complaints from either parents or children concerning the SDF treatment. Gotjamanos showed a favorable pulpal response when SDF was applied to deep caries in primary teeth of children. It was found in that it induced the presence of abundant reparative dentin and a wide odontoblast. Silver diamine fluoride has been shown to be safe to the pulp when placed on exposed dentin, but should not be placed on exposed pulps [18]. Nishino *et al.*, Okuyama in Japan investigating pulpal response to SDF applications found transient gingival irritation, but there was no severe pulpal damage and no severe reaction reported [19]. Also, no report is found in the literature, which suggests that SDF will cause severe reactions such as contact dermatitis of the skin or stomatitis of the oral mucosa. Some concerns have been raised over dental fluorosis, and accidental toxic overdose from the use of 40% SDF for arresting dental caries although these concerns have been refuted [20]. Vasquez *et al.* found that serum concentrations of fluoride and silver after topical application of SDF should pose little or no toxicity risk when used in adults[21]. The disadvantage of SDF is black discoloration of the carious lesions, the color change is a positive indication that the treatment was effective. This staining may be decreased by the application of potassium iodide immediately following SDF treatment. The only

cases where SDF should not be used are if the patient has an allergy to silver.

#### Discussion

Dental caries is the most common childhood chronic disease worldwide. International data on caries epidemiology confirm that dental caries remains a significant disease of childhood that is found in a subset of at-risk children in both developing and developed countries. The traditional treatment for a cavitated tooth involves mechanical excavation of infected, irreversibly demineralized tooth structure and replacement with a restorative material which can be challenging and require advanced clinician skill. A fluoridated agent silver diamine fluoride's (SDF) hypothesized ability to halt the caries process and simultaneously prevent the formation of new caries. Reports of the available studies suggest that 38% SDF may be an effective agent in arresting caries in the primary teeth. When SDF is used to arrest caries lesions in primary teeth it also provides an anticaries effect for the entire dentition; that is, 38% SDF applications decrease by 77% the development of new caries in treated children in comparison to non treated children [22]. It reduces the growth of cariogenic bacteria, hampers degradation of collagen in dentin, inhibits demineralization and promotes remineralization of both enamel and dentin [Zhao et al., 2018]. The application of SDF to dental surfaces is simple and inexpensive [Mei et al., 2016] and complies with the concept of minimally invasive dentistry [Ericson et al., 2003]. Thus, treating caries lesions with SDF seems especially suitable for younger, less cooperative and more socially vulnerable children [Crystal and Niederman, 2016]. SDF at a concentration of 38% contains 44,800 p.p.m. fluoride which is highest among the fluoride agents available for dental use. Fluoride promotes the remineralisation of hydroxyapatite in enamel and dentine. Furthermore, SDF is simple and quick to use and is an affordable therapeutic agent in developing countries. Still, more studies required in this direction to prove silver diamine fluoride as a material of choice in the 21st century.

#### Conclusion

38% silver diamine fluoride is effective in caries prevention. It halts the caries progression. SDF can also remineralise both enamel and dentine caries. The possible mode of action of SDF for arresting caries may be attributed to its inhibition of mineral demineralisation, promotion of mineral remineralisation and protection of the collagen matrix from degradation. It is simple to use, cost-effective and complies with the concept of minimally invasive dentistry. It is very useful for the management of caries in young children. Still more studies required on silver diamine fluoride to prove it as an ideal caries preventive measure.

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