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Review Article

Silver Diamine Fluoride – The Magic Bullet or myth: A Review

[1]Santoshni Samal, [2]Mayank Sachdeva, [3]Ratna Renu Baliarsingh, [4]Prayas Ray, [5]Anusuya Mishra

[1]Post graduate student, [3]Professor and Head of Department, [4]Associate Professor, [5]Post PG, Department of Pedodontics and Preventive Dentistry, SCB Dental College and Hospital, Cuttack, Odisha, Utkal University, India;
[2]Post graduate student, Department of Conservative and Endodontics, M.M College of Dental Science and Research, Mullana, Ambala, Haryana, India

ABSTRACT:
Silver diamine fluoride (SDF) is a topical fluoride which arrests dental caries and prevents its progression. It provides an alternative care path for those patients in whom traditional restorative treatment cannot be done for example children lacking cooperating ability. Although silver diamine fluoride had been used in past it had not become popular in the other part of the world. Now, many countries have recommended the use of 38% silver diamine fluoride solution for caries prevention as well as for caries arrest. It is non-invasive, simple to use, cost-effective and, can prevent dental caries progression by various mechanisms. The only disadvantage is staining which can be managed by various techniques.
Keywords: Adverse effect, caries, caries arrest, caries prevention, silver diamine fluoride

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Corresponding author: Santoshni Samal, Post graduate student, Department of Pedodontics and Preventive Dentistry, SCB Dental College and Hospital, Cuttack, Odisha, Utkal University, India

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INTRODUCTION

Dental caries is the most common chronic infectious disease of early childhood, caused by the interaction of bacteria, mainly Streptococcus Mutans, and carbohydrate-rich foods on tooth surfaces. These bacteria break down carbohydrate for energy, creates an acidic environment in the oral cavity and, results in demineralization of the enamel of the teeth, and then results in dental caries [1]. S. mutans can be derived from mother to baby during infancy and can cause MDSMD (Maternal derived Streptococcus mutans disease).ECC which begins early in childhood progresses rapidly in those who are at high risk, and mostly remains untreated [2].Early childhood caries (ECC) is a serious concern in both developing and developed countries [3]. Center for Disease Control and Prevention in "1994 workshop" suggested the term "Early childhood caries" in an attempt to focus attention on the multiple factors like socioeconomic, behavioral, and psycho-social) that contribute to caries at such an early age and not only on sole causation to inappropriate feeding methods[4].

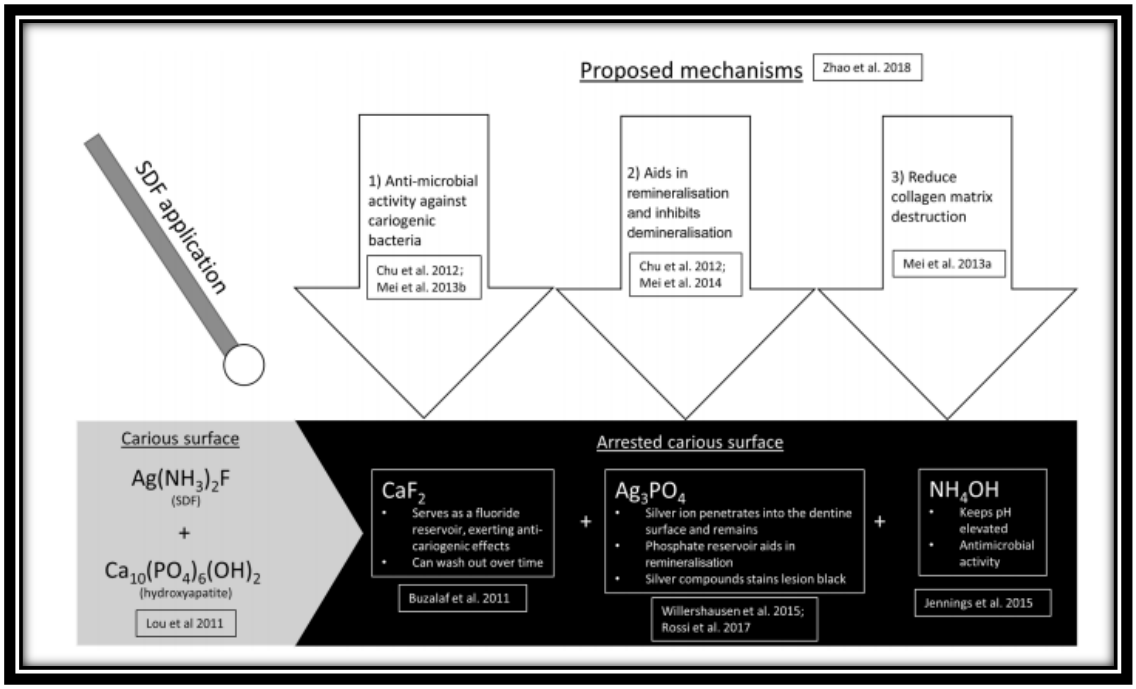
ECC is defined as "the presence of one or more decayed (non-cavitated or cavitated lesions), missing teeth (due to caries), or filled tooth surfaces in any primary tooth in a child 71 of months age or younger. In children younger than 3 years of age, any sign of smooth-surface caries is indicative of severe early childhood caries (S-ECC). S-ECC is one or more cavitated, missing teeth (due to caries), or filled smooth surfaces in primary maxillary anterior teeth, or decayed, missing, or filled score of ≥4 (age 3), ≥5 (age 4), or ≥6 (age 5) surfaces from age 3-5 years [5].Streptococcus mutans and Streptococcus sobrinus are the main cariogenic micro-organisms. These acid-producing pathogens cause damage by dissolving tooth structures in the presence of fermentable carbohydrates such as sucrose, fructose, and glucose in the oral cavity[6].

No restorative treatment is required in children who are at low risk. Restorations of the cavitated lesion should be done in children who are at moderate risk, white spot, and enamel proximal lesions should be treated by preventive techniques and should be monitored for progression. The earlier restorative intervention of enamel proximal lesions, as well as the intervention of progressing and cavitated lesions, should be done to reduce the progression of caries

development who are at high risk [7].Silver diamine fluoride (SDF) was developed in the late 1960s to combine the anti-bacterial properties of silver ions and the preventive effects of fluoride (Yamaga and Yokomizo 1969). Although silver nitrate was used extensively in the past (Zander 1941), but the side-effect of staining cavities black can be improved by using restorative materials and behavior management techniques such as dental treatment of children under general anesthesia (Roberts et al. 2010).

Silver diamine fluoride (SDF) is used worldwide since the 1970s in a concentration of 38% (44,800 ppm fluoride) because of its cariostatic properties (Yee et al. 2009). Calcium fluoride is formed when it is applied to the tooth, because the tooth surface reacts with hydroxyapatite forming, silver phosphate, and precipitated protein silver (Craig and Knight 2012; Chu et al. 2014).SDF also inhibits the growth of cariogenic biofilms, therefore used as an anti-hypersensitivity and anti-cariogenic agent. The current formulation on the market 38% SDF (44,800 ppm) has one of the highest fluoride ion concentrations of all topical applications as compared to 22,600 ppm in 5% sodium fluoride varnish (Crystal and Niederman 2016). The United States Food and Drug Administration approved SDF for clinical use in March 2015, as an alternative to caries management techniques among pediatric dentists (Nelson et al. 2016).

The Central Pharmaceutical Council of the Ministry of Health and Welfare of Japan has accepted 38% SDF as a therapeutic agent for more than half a century for dental treatment [8].Saforide (38% SDF) is one of the most widely used SDF products. Yee et al reported that a single SDF application was effective in arresting caries if the concentration was 38%, but not if it was 12%. 30% of SDF is also available in the market. There are no significant side effects of its use on children [9].Although neutral silver fluoride is much more soluble in water than other silver halides, it forms a colorless cubic crystal. SDF is a complex in which ammonia ions combine with silver ions to produce a complex ion called diamine silver ion [Ag (NH3)2]+. The formation of diamine silver ions is a reversible reaction. This complex is, however, very stable, with an equilibrium position that lies within the diamine silver ions [10].



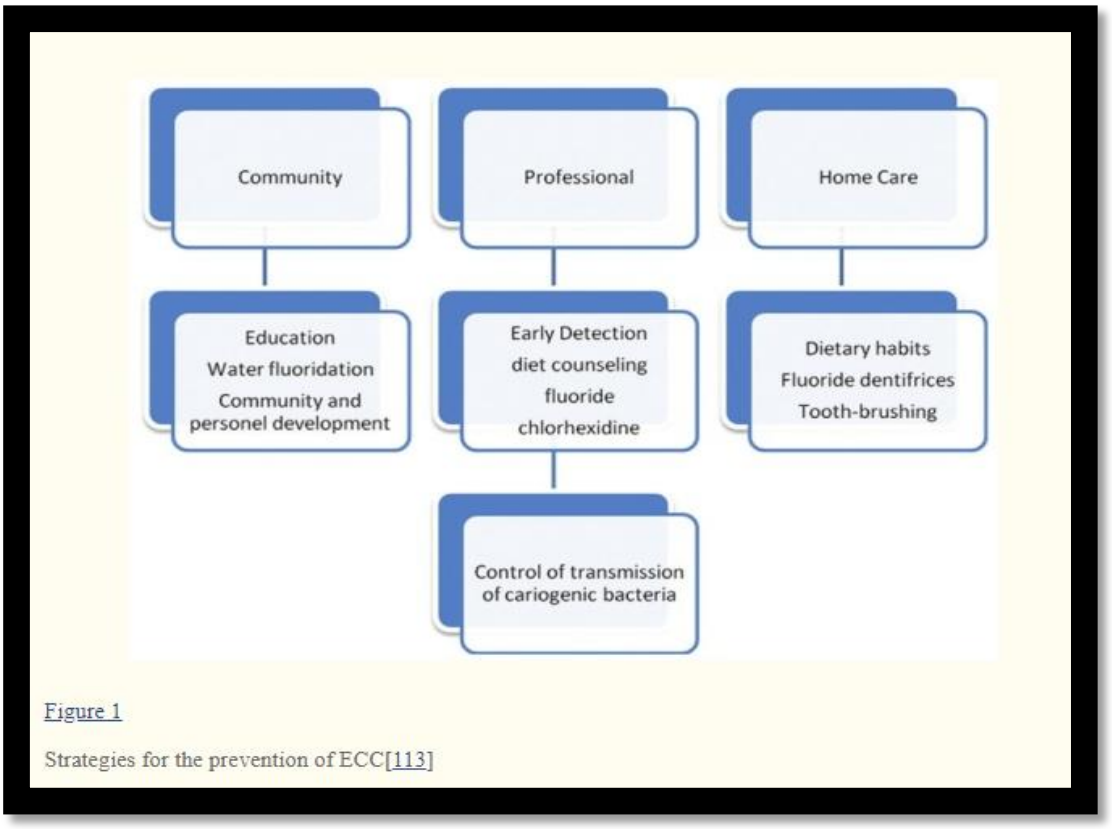


Figure 1

Strategies for the prevention of ECC[113]

MECHANISM OF ACTION OF SDF

When applied to the tooth surface, SDF reacts with hydroxyapatite to form silver phosphate and calcium fluoride which acts as a reservoir of fluoride and phosphate ions and helps in tooth remineralization (Buzalaf et al. 2011; Lou et al. 2011).

The silver ions penetrate in the lesions and stay there to exert their effect (Willershausen et al. 2015; Rossi et al. 2017). Silver compounds such as silver oxide and silver phosphate are responsible for the lesions turning into black (Lou et al. 2011).

The following mechanism of actions of SDF are:

(1) The bactericidal action of SDF on cariogenic bacteria such as Streptococcus mutans (Chu et al. 2012; Mei et al. 2013)
(2) The inhibition of demineralization of enamel and dentine and promotion of remineralization and (Chu et al. 2012; Mei et al. 2014),
(3) Collagenase inhibition (Mei et al. 2013) and the reduction of dentine collagen matrix destruction
(4) Inhibits adherence of S.mutans (Zhao et al)

Under the acidic environment, fluoride is absorbed onto the hydroxyapatite crystals on the tooth surface and inhibits demineralization. It also helps in the remineralization process by repairing damage caused by microbial action. The resulting mineral forms as fluorhydroxyapatite which is resistant to further acid dissolution. Also, some antimicrobial activity in vitro which may inhibit acid production in the dental plaque (Buzalaf et al. 2011).

PARENTAL AND PATIENT ACCEPTANCE

As a procedure, it was found to be acceptable, comfortable, and non-invasive for the children and parents (Clemens et al. 2018).

Advantages of the technique include local analgesia not required, minimal cooperation needed from patients, and potential reduction in cost compared to conventional dental treatment (AAPD 2017).However, when behavior management techniques were considered, parents were more accepting of anterior teeth staining (60%) as compared to dental treatment under general anesthesia (Crystal et al. 2017a). 61–71% of Hong Kong parents expressed an overall acceptance for their child's appearance after SDF application; although, posterior tooth staining is more acceptable than anterior teeth staining (Duangthip et al. 2018).

Silver diamine fluoride (SDF) is a cost-effective, and easy to apply cariostatic agent, which is suggested to be a suitable adjunctive modality to manage dental caries in high-risk groups [11]. The presence of a protective layer appearing as a black stain has been responsible for the clinical success of the SDF application which arrests the active carious lesion[12].Although black staining is considered to be the primary barrier and a frequent clinical observation following the SDF application. The application of potassium iodide (KI) following SDF has been suggested to reduce the staining potential. This is because KI can react with free silver ions to produce silver iodide, which is a creamy white reaction product [13]. The progression of dental caries in

young children can be arrested by the use of silver diamine fluoride (SDF) solution. The commonly adopted frequency of application for caries arrest is once a year or every 6 months [14].

38 % SDF contain 44,800 ppm fluoride. It contains the highest among the fluoride agents available in dentistry. Silver phosphate and calcium fluoride are formed during the chemical reaction between SDF and hydroxyapatite of teeth [15] which promotes the remineralization of hydroxyapatite in the tooth. Since its crystal structure is similar to that of hydroxyapatite the subsequent dissolution of fluoride and calcium facilitates the formation of insoluble fluorapatite, which is a possible reaction product of fluoride ions with hydroxyapatite. Calcium fluoride is less acid resistant than fluorapatite.

This pH-regulated slow-release reservoir of fluoride on the tooth surface is because of the calcium fluoride formed after the application of SDF. This calcium fluoride could be removed easily from a tooth surface by toothbrushing or mastication. The solubility of silver phosphate (6.4 9 103 g/100 ml) is higher than that of silver chloride (8.9 9 104 g/100 ml). Therefore, silver phosphate could react with alkali chlorides in remineralization solutions to form silver chloride. This explains why silver chloride was detected as the principal precipitate on the tooth surface after SDF treatment. Nanoscopic metallic silver particles attached to hydroxyapatite crystals are formed during the reaction between SDF and hydroxyapatite and the production of metallic silver was accelerated by exposure to light and high temperature [16].

SDF can also preserve collagen from degradation in demineralized dentin. In the past, bacterial collagenase was considered to be the causative factor for the destruction of the dentine organic matrix, while recent studies have suggested that collagen can be degraded by matrix metalloproteinase (MMPs). MMPs are present in saliva and the dentine matrix which can be activated in carious dentine where the acidic environment is present [17].Removal of caries is not necessary therefore dentists need not to remove caries from patient's teeth during treatment with SDF. SDF is a cost-effective, easy, and simple approach to arrest dental caries. However, the main disadvantage of using SDF is the staining of carious teeth, which leads to less acceptance & dissatisfaction [18].Some researchers have proposed using potassium iodide after topical application of SDF to reduce the staining effect by forming silver iodide. Since this silver iodide, is photosensitive and can turn dark with exposure to light. Ammonium hexafluorosilicate may also exclude silver and its staining effect, but it is less effective than SDF in arresting caries [19].

A recent study has used nano-silver fluoride, which did not result in black staining of the carious lesions and was found to be effective in arresting dentine caries. This new agent has antibiotic efficacy like that of SDF against S. mutans and has low toxicity to living cells[20].

SAFETY OF SDF

Additionally, silver ions are biologically active and can be absorbed in the human body and deposited in the skin and other organs. Moreover, there are known cases of silver allergy which will be a contra-indication for the use of SDF (Lansdown 2006).Although usage of SDF in children seems to be reasonably safe, it may be important to limit the amount of SDF used in a single visit due to the high concentration of fluoride which if ingested in large amounts may cause an issue.

INDICATION FOR CARIES MANAGEMENT WITH SDF

a. Multiple cavitated carious lesions (high caries-risk patients requiring multiple restorative visits).
b. Cavitated dental caries can extend to dentine and both anterior and posterior primary teeth
c. Patients with behavioral difficulties requiring dental treatment under general analgesia.
d. Limited accessibility to dental care.
e. Lesions on any surface (e.g. proximal) which is accessible with a brush for applying the SDF.

Contraindication for caries management with SDF

a. Spontaneous or elicited pain associated with the carious lesion
b. Carious lesion near to the dental pulp based on clinical and or radiographic findings.
c. Parental or patient objection to staining.
d. Silver allergy

SDF application is very simple and can be done in communities of limited access to dental care. However, it remains very important to obtain informed consent from the patient and parents for the staining of carious lesions resulting from the SDF application. Uncooperative patients (very young or special needs) may need restraint for SDF application due to the risk of soft tissue staining. If the isolation cannot be achieved even with restraint, there will be an increased risk of staining.

The least amount of SDF should be applied to the cavitated tooth surface to prevent contamination of adjacent surfaces and swallowing of the material. Careful application with a micro-brush should be adequate to prevent intraoral and extra-oral soft tissue exposure. This is important as contact with the lips or skin results in a rapid red-brown discoloration that may take several weeks to disappear as the stained cells are exfoliated and replaced. Additionally, staff should be educated on proper disposal because SDF can stain various surfaces which will be difficult to remove.

PROCEDURE FOR SDF APPLICATION

a. Gross excavation of debris may be required to allow better penetration of the SDF in the carious lesion.

b. Isolation with cotton rolls, rubber dam or any other appropriate method to limit contact with soft tissues.
c. Dispense no more than one drop for each patient for the entire visit.
d. The tooth is dried with compressed air and the SDF solution is placed directly on the carious lesions using a micro-brush for at least 1 min if possible.
e. At the end of the application, blot the lesions with a cotton pellet or gauze to remove any excess unreacted SDF.
f. Let it dry
g. After treating specific carious lesions with the SDF solution, the entire dentition is coated with a thin layer of 5% NaF varnish for primary prevention.

Fig. 2 **a** Set-up and procedure for SDF application. **b** Carious lesions arrested after SDF application showing black staining. **c** Restoration of stained and arrested lesions with composite strip crowns. **d** Glass ionomer cement interim restoration of SDF treated lesion

FOLLOW-UP

a. After the first application, evaluation of SDF treatment should be done at 2–4 weeks to find out if the lesions are arrested or not.
b. Recall the patient if the lesions are not arrested, it can retreat with SDF again
c. The lesion can be restored at a later visit with a conventional restoration depending on the behavior of the child.
d. Biannual (6 monthly) reapplication may be required for continued effectiveness.

Recently, an alternative restorative technique is regaining popularity known as silver modified atraumatic restorative technique (SMART) (Gotjamanos 1996) which involves the combination of SDF application and the atraumatic restorative technique of gross caries removal and placement of glass ionomer cement (Frencken et al. 1996). However, limitation of this technique as there are no long term studies on the effectiveness. Additionally, the SDF application resulted in decreased bond strength of glass ionomer cement to dentine (Knight et al. 2006). Moreover, the SMART restorations tended to stain black, probably due to contact with SDF, resulting in staining and less aesthetic restoration.

CONCLUSION

With advancement in Minimal invasive technique SDF has achieved a greater height in preventive restoration. It can be used in special health care need children and uncooperative children who are difficult to manage at dental clinic therefore it is not wrong to consider it as a magic bullet.

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