



Silver Diamine Fluoride Applications in Dentistry: Review Article

Zainab I. Alkhatat *, Reem R. Ali

Department of Pediatric Orthodontic and Preventive Dentistry, College of Dentistry, University of Mosul

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***Correspondence:**

E-mail:

Zainabalkhatat87@uomosul.edu.iq

Abstract

The worth of using Silver Diamine Fluoride (SDF) during COVID-19 pandemic has highly increased due to its low invasiveness and non-aerosolizing technique. The blend of silver and fluoride in an alkaline solution has a great action in arresting active enamel and dentin carious lesions, also acting as a desensitizer to lessen dentine hypersensitivity in adults, this review article was conducted to highlight the SDF mechanism of action, clinical applications, and its main indications and contraindications.

الخلاصة

لقد ازدادت أهمية الفضة ثنائي أمين الفلورايد كأداة طفيفة التوغل وغير منتجة للرداذ أثناء جائحة كورونا فايروس . حيث أن مزيج الفضة والفلورايد في محلول قلوي له تأثير قوي في القبض على الأفات النشطة للمينا وعاج السن، كما يعمل كمزيل للحساسية لتقليل فرط حساسية عاج السن عند البالغين، وقد أجريت هذه المقالة لأبراز آلية عمل الفضة ثنائي أمين الفلورايد والتطبيقات السريرية والمؤشرات الرئيسية وموانع الاستعمال.

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INTRODUCTION

Dental caries (DC) is a chronic site-specific bacterial-driven multifactorial disease that arises as soon as cariogenic microorganisms of the oral cavity are fueled by repeated consumption of fermentable sugar and carbohydrates, which allows the proliferation of acidouric and acidogenic bacteria. International data confirmed that DC remains a significant disease and about 530 million children are suffering from it each year ⁽¹⁾. *Streptococcus mutans*, *Streptococcus sobrinus*, *Lactobacillus acidophilus*, and *Veillonella parvula* are well-known species that are connected directly to DC, when their prevalence increases they cause demineralization of enamel crystals owing to a high concentration of organic acids which drops the PH and causes a disproportion in the balance between the tooth mineral content and oral plaque ⁽²⁾, with time persistent loss of tooth surface minerals leads to cavity formation in tooth enamel and dentin which if not treated will advance rapidly to pulpal tissues causing infection, pain, and ultimately tooth loss ^(3,4). The traditional treatment of DC demands great skill of the clinician, good patient cooperation besides the cost of expensive materials, different restorative equipment, and instrumentation ⁽⁵⁾. The prevalent approaches implemented in developed countries for the treatment and

prevention of DC are neither available nor affordable in developing countries where there are insufficient health providers, financial supplies, and modern facilities however, these traditional approaches have changed over time and replaced by minimally invasive non-restorative intervention to prevent and control DC ⁽⁶⁾.

The requisite for a simple, functioning, and low-cost way to arrest carious lesions in deciduous and permanent teeth have made dental manpower and oral health stakeholders look for new alternative materials to maximize caries prevention and treatment ^(7,8), mainly for children with special health care needs, low-income and those with difficulty getting into dental care clinics ⁽⁹⁾.

Silver Diamine Fluoride (SDF) has attracted attention because of its valuable properties including being minimally invasive, non-aerosol simple procedure, portable and inexpensive, SDF 38% is a colorless alkaline liquid with a PH of 10, contains about 5% to 5.9% fluoride and 24.4% to 28.8% silver ⁽¹⁰⁾.

Within the spread of the SARS-CoV-2 virus (COVID19), SDF has been suggested as a proper, non-aerosolizing, less invasive surgically and active caries arresting agent that fulfills with direction from public health officials and specialized associations to reduce the exposure to airborne pathogens, SDF has

also been recently recommended by the Illinois Department of Public Health in Springfield, United States to be used as interim management of caries during the acute stages of COVID outbreak ^(11,12,13).

- **Indications**

According to (14, 15 and 16) the indications of SDF are:

- 1- Stabilize uncontrolled caries in people with high caries risk.
- 2- Treat patients with no access to conventional dental restorative care or with limited access, SDF can be used for individuals with limited financial resources for traditional care (patients in developing countries, rural areas).
- 3- Treat patients who are unable to cooperate with routine restorative therapy (special care needs) owing to physical, medical, or behavioral complications. These patients have a higher risk of systemic infection arising from untreated dental caries.
- 4- People with caries that are difficult to treat (caries in partially erupted teeth, root surface caries, and caries in a furcation area or at the margin of a fixed bridge).
- 5- Treatment of very young “pre cooperative” children.

- **Contraindications**

- 1- The SDF comprises people with sensitivity to silver, fluoride, or other heavy metal ions, large amounts of silver can be absorbed through dentinal and pulp tissues, mucous membranes in

the mouth, the nasal cavity and accumulate in the body ⁽¹⁷⁾.

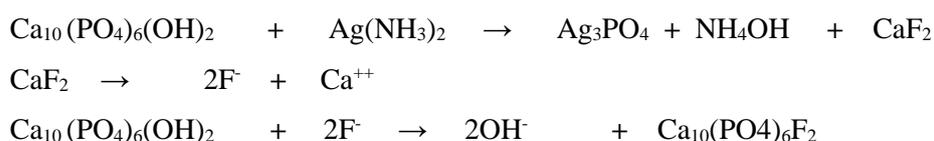
- 2- The SDF solution should be avoided in patients with stomatitis or ulcerative gingivitis or if SDF contacts these inflamed tissues it will result in pain and delay healing ⁽¹⁸⁾.
- 3- The patients showing abnormal skin sensitization or who had full mouth gingivectomies are recommended for exclusion ⁽¹⁹⁾.
- 4- Carious lesions that have symptoms and/or signs of acute pulpitis, periapical abscess, infection, or current active lesions should be excluded because of SDF ammonia content and high pH, resulting in adverse pulpal reaction ^(18,15).
- 5- SDF should not be used in pregnant or breastfeeding patients, especially when adding the potassium iodide (KI) following the use of SDF to prevent discoloration (during the first six months) due to concern of overloading the developing thyroid with iodide ⁽¹⁹⁾.

- **Mechanism of action of SDF**

The exact mechanism for SDF action is still unknown however, there are three proposed theories suggesting that the ions of fluoride act mostly on the tooth structure for remineralization, while the antimicrobial action comes from the silver ions like other heavy metals ⁽²⁰⁾.

- **The first proposed theory for the SDF mechanism**

Is the obturation of dentinal tubules:
 The dentinal tubules are the chief penetration path of caries in dentin, Shimizu and Shah (1974), found that the dentinal area treated with SDF reduced in dye permeability and augmented in electrical resistance because they confirmed the existence of silver ions in the dentinal tubules ⁽²¹⁾. These silver compounds in the dentinal tubules will obliterate them and inhibit the invasion and/or the growth of cariogenic microorganisms by the oligodynamic effect of silver ⁽²²⁾. When the dentinal tubules become obturated, the dentinal surface area will decrease and the silver particles will cover the peritubular zone which is the part of dentin that demineralized easily and ends the dentine collagen degradation, this mechanism was enhanced by Zhao *et al.* ⁽²³⁾. The topical application of SDF on exposed dentine leads to the creation of deposits that to some extent plug dentinal tubules, and this



could be the reason for using SDF as a desensitizing agent for hypersensitive dentine ⁽²⁴⁾.

-The second proposed theory for the SDF mechanism is the cariostatic action that results from the reaction between tooth mineral component and SDF products:

After SDF is applied to carious lesion in dentin, the free calcium ions in the hydroxyapatite interact with fluoride ions from SDF to form calcium fluoride and fluorapatite ($\text{Ca}_{10}(\text{PO}_4)_6\text{OH}_2\text{-xFx}$) at the same time, silver ions interact with the free phosphate to form a deposit of silver phosphate (Ag_3PO_4), these deposits have also been detected in deeper layers of the dentinal tubules ⁽²⁵⁾. The treated tooth surface that has been fluoridated is more acid-resistant than the normal tooth structure, thus the augmented hardness and mineral density will remarkably affect the lesion depth and lessen it ⁽²⁶⁾.

- **The third proposed theory for the SDF mechanism is the ant-enzymatic actions resulting from the reaction between the organic component of the tooth and $\text{Ag}(\text{NH}_3)_2\text{F}$:**

The ionic silver can switch off almost all macromolecule within its atmosphere, the bactericidal effect of silver can inhibit the enzyme actions and dextran prompted clumping of cariogenic strains of *Streptococcus mutans* ⁽²⁷⁾. In general, the anti-caries effect of SDF may be owing to its antimicrobial action plus its chemical interaction with the tooth surface, and this interaction is more important than the antimicrobial effect because SDF cannot decrease lactate production even though it had significantly decreased the cariogenic microorganism ⁽²⁸⁾.

-Clinical Applications of SDF

-For High Caries Prevalence of Young Children

To treat DC in young patients, the conventional way involves removing the infected dentin either by rotary dental handpiece or sharp spoon excavator, the yielded pressure from using these instruments can trigger anxiety and fear for young patients, while when using SDF as a cariostatic agent, the dental caries progression is arrested or decelerated, and carious lesions removal will be postponed at another date as the child's capability to explain fear is increased with time ⁽²⁹⁾. In Japan, SDF has ~80% efficacy in arresting carious lesions in enamel and dentin ⁽³⁰⁾. The American Association of Pediatric Dentists and the American Dental Association have recommended the use of SDF for arresting

cavitated carious lesions in primary teeth ⁽³¹⁾. Recently SDF has been used as Silver modified atraumatic restorative treatment (SMART), the technique treated carious lesions first with SDF and then restored with a glass ionomer, this method can efficiently arrest caries without further removal of tooth structure, which is a promising treatment approach in early childhood caries and root caries in elderly patients, SMART has a part to play in the secondary and tertiary prevention of caries and should be executed in community dentistry programs globally ⁽¹⁾.

-Arrest Dental Caries in Anterior Deciduous Teeth of Children, Early Childhood Caries (ECC)

In preschool kids have what is called ECC as numerous primary teeth are attacked by caries, ECC may be delineated as the incidence of one or more decayed, missing (due to caries), or filled tooth surfaces in the primary teeth of a child about 5-6 years of age or below ⁽³²⁾. Primary teeth are very important teeth not only show the main part in the normal growth and eruption of the permanent teeth but are also critical for jaws and the face bones growth and development, the damaging effects for young children as a result of this disease consist of: compromised communication, nutrition, learning and other activities vital for proper development ⁽³³⁾. Data collected by Crall *et al* in 2005 from the NHANES study recognized nearly 60% of children overall will have dental caries in their deciduous baby teeth by age of five, before, the treatment methodology for ECC, was to remove possible carious dentin then place provisional

restorative materials like zinc oxide eugenol, today SDF can offer a better, low cost and simple alternative⁽³⁴⁾.

-Enhance the Effectiveness of Fissure Sealant and avoid Pit and Fissure Caries

Pits and fissures areas are difficult to be cleaned with a toothbrush and are considered excellent stagnation spots therefore, DC occurs at higher rates in these areas than the smooth tooth surfaces. Fissure sealant (FS) was established as a preventive caries measure by establishing a physical barrier that avoids plaque and food accumulation, SDF can be effectively used for the avoidance of pits and fissures caries of the first permanent molar teeth, whereas the application of topical fluoride is shown to be more effective on smooth tooth surfaces than that of the pit and fissure areas⁽³⁵⁾. Sato *et al.*⁽²⁹⁾ and Nishino and Massler⁽³⁶⁾ have found that the caries score of the teeth treated with SDF was noticeably lesser than the fissures treated with 8% SnF₂ or Ag(NO)₃ however, the success of Fissure Sealant is technique sensitive and hangs on Fissure Sealant ability to deliver a tight sealing to the pits and fissures areas, inadequate sealing will lead to marginal leakage and caries progression.

-Inhibit Secondary Caries

Secondary or recurrent caries usually occur at the margins of an existing restoration, it is one of the main causes for the restoration of teeth in the long term⁽³⁷⁾. About 25% of restoration replacements of resin composite and amalgam were attributed to secondary caries, although most restorative materials used

in general dentistry are completely insoluble in oral fluids and truly adhere to the tooth structure, saliva, food debris, and bacteria can penetrate through the space between the restorative materials and the cavity walls, the cariogenic microorganisms of the secondary and primary caries are identical, especially *Streptococci*, *Lactobacilli* and *Actinomyces naeslundii*⁽³⁸⁾. Studies have revealed that SDF has a powerful antibacterial action on cariogenic microorganisms and can inhibit the development of different cariogenic biofilms on tooth enamel surfaces⁽³⁹⁾. The cavity wall resistance to caries must be augmented to reduce recurrent caries and SDF can promote this enhancement, Shimizu confirmed no secondary caries on amalgam restorations of deciduous teeth that were previously treated with SDF after 2 years⁽²¹⁾, while Zhao *et al.* found that using SDF + potassium iodide (KI) treatment on GIC restorations inhibited the development of secondary caries⁽⁴⁰⁾.

-Arrest Root Caries

The occurrence of root caries increases with age and this was improved by different epidemiological studies, for the reason of age-linked changes to the enamel, dentin, pulp chamber, and periodontal ligaments, conventional restoration is more difficult in this group of people than in younger people, the majority of older adults' cavities take place at the boundary of unsuccessful restorations and crowns, the gum contour and on root surfaces subsequently to gum recession, these restored lesions often fail and are difficult to be restored with conventional surgical management⁽⁴¹⁾. An annual application of 5%

sodium fluoride varnish or 38% SDF solution is capable to decrease the initiation of carious root lesions by 64% and 71% correspondingly⁽⁴²⁾, Tan *et al.* and Zhang *et al.* stated that once a year treatment of SDF is reasonably effective in arresting dental caries on root surfaces^(43, 44). A systematic review by Gao *et al.*, revealed that 38% of SDF was able of arresting active DC by 81%, and similarly⁽³⁰⁾, another systematic review by Hendre *et al.*, found that the three years prevented a fraction of root caries with SDF was 71% greater than with the placebo⁽⁴⁵⁾. Annual professional applications of 38% SDF for middle-aged and older adults were valuable in reducing carious lesions on roots in several clinical trials⁽⁴⁶⁾.

-Desensitize Sensitive Teeth

Dentin hypersensitivity is categorized by varying grades of pain which is usually started with thermal, tactile, chemical, evaporative, or osmotic stimuli, and takes place on an exposed dentin surface⁽⁴⁷⁾. SDF can be used to treat dentin hypersensitivity and the clinical process involves isolating the hypersensitive teeth with cotton rolls then gently drying out the area to be treated, with a disposable micro-brush SDF is applied, Knight and co-workers in their study suggested applying KI instantly after SDF application, their justification for this addition was that KI further reduces dentin permeability was when applied after SDF⁽⁴⁸⁾. Gottlieb found that there is a mutual factor concerning the mechanism of desensitizing hypersensitive dentin and arresting DC⁽⁴⁹⁾, also it might possible to measure the SDF caries arresting action in relation to the

desensitizing action since the SDF can occlude the dentinal tubules and gives promising results in treating patients with dentin hypersensitivity⁽¹²⁾.

-Treat Contaminated Root Canals

The eradication of microorganisms from the root canal spaces is a vital step for an effective endodontic therapy, Okamoto *et al.*, (1971) observed a significant reduction in the number of endodontic treatment visits required after the application of the SDF solution⁽⁵⁰⁾. Hiraishi *et al.*, revealed that 3.8% SDF can be used as an effective intra-canal antimicrobial irrigant or be used for inter-appointment dressing, particularly in sites where possible darkening of dentin by metallic silver is not an issue, besides it can penetrate up to 40 μm into the dentinal tubules and to block tubular openings even after elimination of the smear layer, the presence of silver deposits from SDF can diminish microbial biofilms formed inside the dentinal tubules and the silver salts that are formed earlier in the dentinal tubules prevent the reinfection of these tubules because of their low solubility⁽⁵¹⁾. Mathew *et al.*⁽⁵²⁾ found that SDF can successfully eliminate the microorganisms that exist in the canal and circumpulpal dentin when using it as an endodontic irrigant. Recently a ten folds dilution of SDF solution with a concentration of 3.8% has been developed for intracanal irrigation and is being used with a remarkable clinical success rate⁽⁵³⁾.

-Limitations of SDF

The use of SDF is still limited even with its high efficacy, for of its potential to black

staining the carious tooth structure, owing to the formation of insoluble silver phosphate (Ag_3PO_4), which is brown in color, but quickly turns to black in the existence of reducing agents, or the sunlight exposure⁽⁵⁴⁾. Even though this black staining is a sign of the successful anti-carries effect of the SDF, it also presents an aesthetic worry for many parents of patients, particularly when used in anterior teeth⁽¹⁸⁾. The main limitation of using SDF solution on carious lesions of the enamel and dentine is the permanent dark black stain that can also stain the skin when contact with it creating a Henna-like appearance⁽⁹⁾. Fathers and mothers have an essential role in making decisions for dental treatment with SDF, numerous studies have been made to weigh parental perception and approval just before SDF treatment, and though the results were wide-ranging, the majority of these parents favored the application of SDF in comparison to other aggressive managements such as general anesthesia and/or nitrous oxide sedation, Crystal *et al.*⁽⁵⁵⁾, revealed in a survey that only 29.7% of parents found SDF mediated tooth staining to be acceptable in the anterior teeth, while Gordon *et al.*⁽⁵⁶⁾, stated the acceptability of SDF staining was higher when applied on the less visible (posterior) teeth in the mouth.

Several techniques have been employed to reduce the staining effect of the SDF on teeth, Knight *et al.*⁽⁴⁸⁾, applied potassium iodide (KI) after SDF to overcome the discoloration (black staining) opportunity, the silver ions in SDF solution reacts with KI and results in deposition of a white creamy mixture of silver

iodide (AgI) that counterbalances the teeth staining. However, other studies have shown that the SDF black staining of the teeth still occurred far ahead, so the application of KI following SDF is thus an effective but temporary solution⁽⁵⁷⁾. Recently, the incorporation of glutathione biomolecule (GSH) into SDF has shown favorable results in a reduction of SDF staining, GSH is an intracellular, non-protein thiol that performs as an antioxidant and is also a metal ion chelator⁽⁵⁸⁾. Sayed *et al.*⁽⁵⁷⁾ combined 20% GSH with SDF to overcome the staining potential and stated that it minimized the color changes associated with SDF application efficiently, due to the coating effect of the thiol groups in the cysteine moieties of GSH on the silver particles, in this manner preventing them from developing the silver compounds and clusters that cause tooth staining. A new study has used Nano-silver fluoride and declared that this product has the ability to arrest carious lesions on dentine, have a low toxic effect on human living cells, has good antibiotic efficiency against *S. mutans*, and finally the absence of the black unpleasant discoloration associated with the conventional SDF solution^(54,59).

CONCLUSIONS

COVID-19 viral transmission worry imposes the implementation of specific protocols to lessen the risk and spread of infection from patient to dentist or medical tools and equipments. The use of low-aerosol generating procedures has been powerfully advocated one of these methods including the SDF. The global research concerning the SDF

has been increasingly recommended using SDF in the past three years. SDF is a valuable option for arresting or preventing ECC that can improve child and population oral health level and fulfils with immediate and long-term dental service delivery.

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