

Silver Diamine Fluoride- The New Black Magic.

Abstract:

Silver diamine fluoride combines the remineralizing effects of fluoride and the antibacterial effects of silver and thus provides an alternative care path for those patients in whom traditional restorative treatment cannot be done. Many countries have recommended the use of 38% SDF for caries prevention as well as for caries arrest. SDF is proved to be more efficient as caries preventive tool when compared to fluoride varnishes and APF Gel. Other dental benefits of SDF continue to be researched and discussed in the literature. However, SDF-related black staining is of prime concern while using it in aesthetic zone. No serious adverse effects of using SDF have been reported in dentistry. SDF is safe, effective, and cost-friendly agent. We can hope that it can meet both the AAPD and ISPPD vision and mission to advance optimal oral health for all children through prevention, involvement of the society and other necessary measures.

Keywords: Dental caries, anticariogenic agent, remineralization, fluoride.

Introduction:

Dental caries is a biofilm mediated, diet modulated, multifactorial, non-communicable, dynamic disease resulting in net mineral loss of dental hard tissues; [1] that affects a large percentage of the global population, regardless of age, gender, and ethnicity. With the better understanding of concept of caries as a dynamic and reversible process, it can be said that the carious process can be slowed down in most of the cases or even can be brought to a halt; with interception of its aetiological factors. With the usage of newer and advanced preventive approaches, the caries incidences have shown a declination in developed countries recently. Even after this decline, dental caries still is one of the most common chronic diseases in both industrial societies and low socio-economic countries. [2]

An array of fluoride-based agents have been marketed and used through ages for their caries inhibiting, arresting and remineralizing potential. Recently, silver diamine fluoride [Ag(NH₃)₂F] has been popularised to be a promising therapeutic anticariogenic agent and appears to be almost twice as effective than sodium fluoride. [3] It can be used for

managing caries lesions in young children, in high caries risk patients, those with special care needs, patients with limited cooperation and in cases where there is a barrier to access traditional restorative care.

Evolution of SDF:

Use of silver in dentistry was first reported earlier in 17th century. Since 1960s, SDF has been widely used in Japan for cosmetic purposes of blackening of teeth while it has only become available in the United States recently. Drs Nishino and Yamaga in Japan first introduced ammoniacal silver fluoride to arrest caries formation. Their development led to the approval of the first SDF product, Saforide in 1970. [4] In 2014, SDF was approved by the US Food and Drug

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Administration as a treatment for dentinal sensitivity.[5] In 2017, the SDF Panel of the American Association of Pediatric Dentistry (AAPD) issued a guideline supporting the use of 38% SDF for the arrest of cavitated lesions in primary teeth as part of an extensive caries management program. In 2017 the American Dental Association (ADA) approved it (code D1354) as an interim caries arresting medicament.[4,6]

Composition, Physical and chemical properties:

SDF is a colourless, alkaline (pH of 10) topical solution. There is 44,800ppm fluoride present in 38% SDF (44.8 F-ions mg/ml) solution and this concentration is highest among the available fluoridated agents for dental use.[5]

Composition	24%–27% silver
	7.5%–11.0% ammonia
	5%–6% fluoride (approximately 44,800 ppm)
	=62.5% deionized water
	<1% blue coloring

Mechanism of action:

The anti-cariogenic mechanism of SDF is mediated by either direct actions on bacteria or on tooth surfaces[7-9]:

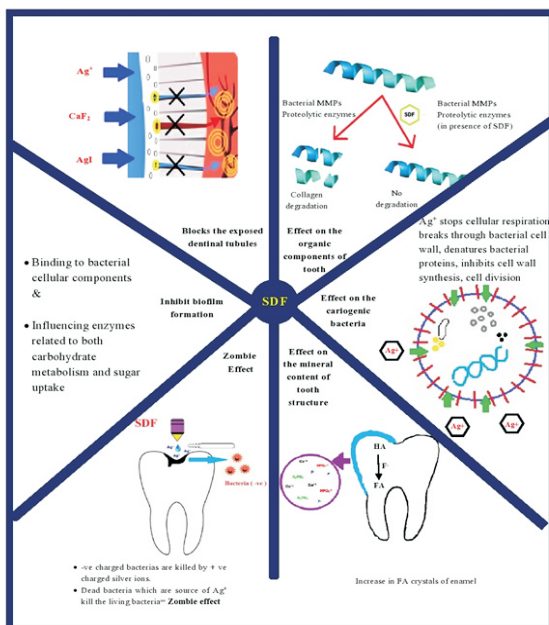


Figure 1. Diagrammatic representation summarising the main actions of SDF

Advantages in dental treatment:

SDF meets the US Institute of Medicine's 6 quality aims of being[10]:

- Safe- no serious adverse events have been reported in the available literature data of the clinical trials;
- Effective- arrests approximately 80% of treated lesions;
- Efficient- can be applied by professionals in various community or health sectors with basic preparations within 1 minute; and does not require expensive equipment or support infra-structure such as piped water and electricity.
- Timely- just after the caries is diagnosed, it can be applied as an intervention agent
- Patient centered- SDF is a painless minimally invasive treatment option which can satisfy the urgent requirements of the pediatric or adult patients in single session only; and the risk of spreading the infection is also very low.
- Equitable- its application is quite affordable and considered as a feasible treatment choice for lower income groups.

Disadvantages:

SDF treated lesions stain black immediately causing poor aesthetics. It can also stain skin, clothes and even dental instruments black. Thus, it must be handled with care by using protective gloves. SDF solution is also unpleasant to children because of its metallic taste. Use of SDF can cause gingival and mucosal irritation. In most cases, the affected tissue turns transient or white (Llodra et al, 2005).[11] SDF is sensitive to light, and hence it must be kept in dark/opaque container.

Indications:[12]

SDF is indicated in patients who have no access to dental care or unable to tolerate traditional dental procedures including children who are uncooperative, “pre-cooperative” or individuals with severe cognitive or physical disabilities or older adults. SDF when combined with strong oral hygiene maintenance is a proven game changer for the extreme caries risk patients suffering from xerostomia or severe ECC. Silver diamine fluoride arrests active carious lesions without

causing any pain. Hence, local anesthetic is not needed in SDF treatment and helpful in treating patients with needle phobia. SDF application does not produce aerosol droplets which can be contaminated with viruses. Thus in current scenario of COVID-19 outbreak, dentists are using SDF only to treat carious lesions; minimizing the chances of infection spread. The American Dental Association (ADA) and American academy of Pediatric Dentistry (AAPD) in collaboration with Centers for Disease Control and Prevention (CDC) are guiding them with standardized SDF protocols.[13]

Contraindications for use of SDF:

Silver allergy is the prime and absolute contradiction for SDF application. In patients with significant desquamative gingivitis or mucositis, contact to SDF during application can cause irritation to open wounds as the protective barrier formed by the stratified squamous epithelium is already disrupted. The most frequent side effect of SDF is discolouration of the affected site. Thus, it cannot be used in restorations or caries in the aesthetic zone. Presence of any clinical or radiographic signs or symptoms of periapical pathology is a complete contraindication for SDF.

Current evidences on the efficiency of silver diamine fluoride for caries arrest and prevention state-

1) Caries Prevention in Children:

Chu and coworkers[14] found that the caries preventive fraction for SDF was much higher than fluoride varnish group (>70% on primary teeth and >60% on permanent teeth). Similar result was obtained in a study by Llodra et al.[11] It was reported that annual application of SDF is more effective in caries prevention than fluoride varnish (4 times per year) in children.[14] In contrast to that, Liu et al.[15] concluded that annual application of SDF, placement of resin sealants, application of NaF varnish (semi-annual) are equally effective in preventing caries lesions in pit and fissures of permanent molars.

However, Monse et al.[16] in their study conducted on permanent 1st molars showed that one-time application of 38% SDF is not effective as compared to ART sealant in the prevention of caries. Oliveira and associates[17] found that

SDF decreased the development of dentinal caries lesions in both treated and untreated primary teeth with a preventive fraction of 77.5%. Hence, we can conclude that direct application of SDF to healthy tooth surfaces can also help in caries prevention in children.[14,15]

2) Caries arrest:

SDF treatment halts or slows down the caries progression and thus downplays the associated pain, discomfort and potential pulpal damage. Studies have quoted that the caries arresting efficiency of Silver diamine fluoride is much better than fluoridated varnish and is equivalent or better than GIC. Contreras et al.[18] in their review showed that applications of 30% and 38% SDF were more effective in arresting dental caries. Braga et al.[19] found SDF to be more efficient in arresting caries lesions than cross tooth-brushing and Fuji-III GIC on permanent 1st molars at the end of 3 and 6 months. Fung et al.[20] found that semi-annual application of 38% SDF is more competent than annual application of the same on primary teeth. Similar results were obtained in another study by Zhi et al.[21]

It was also found that the caries arresting efficacy of SDF declines over time.[22] A study by Yee et al.[23] reported that after a single application of 38% SDF, 50% of arrested lesions at 6 months reverted back to active state after 2 years. However, if SDF is re-applied at 12months post-treatment, its caries arresting potency increases significantly.[21-23] The effectiveness of its single application in arresting dental caries ranges between 47% to 90%, based on the its location within oral cavity, lesion size, tooth surface.[24] It was shown that posterior teeth have lesser rates of arrested lesions than the anterior ones.[20] Sinha et al.[25] in their clinical study discussed about the remineralizing, re-hardening, and antimicrobial potential of SDF.

SDF can be considered as a useful and alternative treatment choice when restorative treatment for primary teeth cannot be opted. For example; it can be used in young patients who are uncooperative and afraid of conventional rotary instrument or spoon excavator. Once the carious process is slowed down or halted, caries removal can be done at later stage when child is mature enough to justify his/her dental fear.

3) SDF as desensitizing agent:

On application over dentinal caries, Silver diamine fluoride forms a squamous layer and thereby blocks the dentinal tubules. Thus, SDF is often used in treating patients with dentinal hypersensitivity. Studies have shown that SDF was effective against irreversible pulpitis which is precipitated by mechanical and thermal sensation.[7]

Critical evaluation:

Various studies have established SDF as a potent anticariogenic agent for both caries prevention and arrest of its progression. Evidence-based literatures have also reported no acute side effects of SDF from its high level of fluoride or silver. However, minor side effects of SDF have been reported in some studies. In an experimental study on adults, signs of mild gingival erythema were seen after 24 hours of SDF application in a few participants but it healed within a week.[26] Another recent RCT quoted that the predominance of gingivitis and gum bleaching reported by parents was 2.8% and 4.7% respectively, 7 days after the treatment.[27] Though darkening of carious tissue is quite common with 38% SDF, Chu et al.[14] reported that for many parents the color change was a positive indication of effective treatment. A web-based survey concluded that parents who found SDF staining unaesthetic, a significant number amongst them would accept this treatment to avoid traditional treatment approaches under sedation or general anesthesia.[28] Thus, SDF promises to be the gold-standard therapy in caries management overcoming its aesthetic limitations. Recently, the WHO have recommended use of SDF as an alternative approach for caries prevention in tertiary level to curtail its negative impact by reinforce the loss of function and overcoming its complications and to improve the quality of life for children with ECC.[29]

Combined treatment options:

1) Silver modified atraumatic restorative technique (SMART):

The SMART technique combines the two powerful materials- SDF and glass ionomer cement. In this technique SDF is first applied over the caries surface and then immediately restored or sealed with conventional GIC on the same appointment. It is especially useful when, for whatever reason, the patient will not be able to return for subsequent dental treatment and it is

deemed advantageous to use a minimally invasive procedure rather than nothing at all. This technique also offers highly anxious children an interim alternative to traditional restorative techniques.[30]

The technique presented combines advantages of the following proven principles:

- The antibacterial and remineralizing effects of SDF causing caries arrest- without removal of additional tooth structure,
- Proper placement of a chemically sealed and bonded GIC restoration- mask the black stain caused by the SDF.

SDF treatment and placement of a glass ionomer cement (GIC) sealant/restoration during the same appointment limit bacterial access of fermentable carbohydrates and thus blocks their nutritional supply to enhance effectiveness of SDF in caries arrest. However, this SMART technique can be carried out after 2 applications of SDF solution (recommended biannually for caries arrest)[20] and then placement of the GIC over it. Studies have found that SDF does not adversely affect the bond strength between glass ionomer cement (GIC) and carious or non- carious dentin.[31-33]

1) SDF with Potassium Iodide treatment:

The only apparent drawback of SDF is when applied to carious lesions; it causes significant irreversible dark staining of tooth surfaces as well as restorative materials resulting in aesthetic problems especially in anterior region which is of particular concern for both patients and parents. To alleviate this undesired effect and increase patient acceptance, several studies have suggested applying supersaturated solutions of potassium iodide (KI) as a second step after SDF treatment. [34]

This combined approach has shown little to no darkening, compared to SDF alone or when used with restorative materials on both carious and sound teeth. It is reported that KI prevents SDF-staining by precipitating of excess silver ions as tripotassium phosphate (K_3PO_4), a white delinquent powder, and silver iodide (white powder).[35] As the silver ions are photosensitive, curing light can be used to ensure that the KI application over SDF has been successful.[34] Care

should be taken during KI application as it can initiate desquamation of the oral soft tissues, if not protected.

Zhao et al.[36] reported that KI treatment weakened the anti-cariogenic efficacy of SDF by reducing the number of silver ions. However, the number of SDF applications to the affected lesion enhances its caries arresting efficiency; thus reapplication of SDF+KI annually may be beneficial. So it can be concluded that the caries arresting efficacy of SDF is not affected, or minimally affected by this additive treatment. In-vitro study by Wang et al.[37] and Knight et al.[38] reported that SDF with KI treatment had no effect on bond strength of dentine to GIC as long as precipitate was washed and dried of. However, in another study, SDF-KI combination has shown least micro-leakage with a drastic increase in the bond strength of RM-GIC.[39] Greenwall- Cohen et al. [40] stated that bond strength to GIC with SDF after the application of KI resulted in reduced bond strengths than with SDF only.

It has also been reported that the SDF+KI pre-treatment showed reduced nano-leakage at the composite resin-dentin interface, without reducing the bond strength of it to dentin.[41] Another study has demonstrated that the specimens treated with SDF+KI and then restored with resin material with etch and rinse bonding agent showed increased micro-shear bond strength than that with self-etch bonding agent.[42] Regarding to SDF+KI and bond strength, further research is still required to find a conclusion. Conditioning agents or acid-etch can be applied after SDF+KI treatment to improve the bond strength. Surface abrasion may improve bond strength, though there is no clinical evidence to demonstrate this.

So SDF with KI treatment is a promising possibility that can be used in patients where aesthetic is the prime concern. However, more long-term studies comparing the properties of SDF+KI with SDF alone are needed to establish its universal usage over time.

2) SDF with Glutathione:

Glutathione (GSH) is an antioxidant found in fungi, some bacteria, plants, animals, and prokaryotes. Sayed et al.[43] evaluated the effect of Glutathione bio-molecule on the reduction of tooth discoloration after application of 38% silver diamine fluoride and compared its efficacy with

SDF+KI treatment. Results showed that SDF mixed with 20% Glutathione (GSH) was effective in minimizing the colour changes. Reduction in the colour changes was significant especially on enamel and to a lesser extent on dentin.

3) SDF+Laser:

In recent past, lasers have been studied extensively in the field of dentistry. There are four types of lasers used in modern dentistry: CO₂, Er:YAG, GaAlAs (gallium- aluminum-arsenide diode lasers), and Nd:YAG lasers. The heat produced by the laser can facilitate the deeper penetration of fluoride through hydroxyapatite crystals of enamel and thus serves as a fluoride reservoir to prevent demineralization of tooth. Mei et al.[44] studied the fluoride uptake of dentine by SDF treatment with laser irradiation. Authors found that CO₂ laser and Er:YAG laser irradiation caused higher fluoride uptake than Nd:YAG laser and diode laser irradiation. Luk et al.[45] also confirmed that the anticaries effect of SDF is further enhanced through CO₂ laser irradiation. The CO₂ laser wavelength has the best capability to aid absorption through hydroxyapatite crystals.[46]

Alternative options to SDF:

To overcome the only drawback of SDF, more materials have been tested in the literature which have efficacy as good as SDF with a supra-additive advantage of not causing stain. Alternative options to SDF like Nano-silver fluoride solution (NSF) and novel Nano-silver incorporated sodium fluoride (NSSF) varnish were proven to be efficient enough in preventing dental caries, without causing any stain. Silver nanoparticles inhibit the adhesion and growth of cariogenic bacteria leading to prevention of caries. They also impede the demineralization of enamel and dentine. NSF solution was found to be efficient in arresting and hardening dentine caries in primary teeth; similar to silver diamine fluoride when applied annually.[47] NSF had no metallic taste and can be recommended to children. In another study by Nanda et al.[48] showed that NSF pre-treatment increased the resistance of GIC and composite resin to dentine and thus capable of inhibiting secondary caries at tooth restoration interface.

Topical application of Propolis fluoride (PPF) solution also has the similar advantage of causing no black discoloration to the teeth. Darwita et al.[49] reported that PPF was effective in inhibiting dentinal caries till three months post-application. They stated that it should be repeated after 3 months to continue the preventive effect. The selection of natural PPF solution can be done based on the fact that the side effects of traditional natural agents are lesser than the chemical or synthetic formulations. Another study concluded that topical application of propolis

fluoride was effective in arresting the progression of active dentinal caries to become arrested caries, and also effective in inhibiting the dentinal caries activity.[50]

Tirupathi et al.[51] in their study compared the cariostatic efficacy of a novel Nano-silver fluoride varnish (NSSF) with 38% SDF varnish in preventing the progression of dentinal caries of primary molars. Authors concluded that annual application of 5% NSSF is better than or equal to 38% silver diamine fluoride in discontinuing dentinal caries progression. Compared to the SDF, this novel agent does not cause black staining of carious surface and thus the use of NSSF can be recommended in permanent dentition of children also. Further clinical comparative studies are needed to establish its use.

However, modified SDF solutions or SDF-alternatives are the promising possibilities that can be used on adult dentition where aesthetic outcome is the prime concern. More long-term studies focusing high-risk populations will help to confirm these findings over time.

Conclusion:

Silver diamine fluoride is simple, safe, quick to use and is an affordable therapeutic agent in developing countries with wide application in dentistry. SDF does not produce any pulpal damage, thus can be recommended in caries approaching pulp also. Bi-annual application of SDF outperforms all minimally invasive treatment choices including the atraumatic restorative technique- with which it is compatible but less expensive. Silver diamine fluoride is also proven to be a powerful primary preventive agent than

any other available material and particularly suited for those who suffer most from this disease. Clinical evidence supports application can be continued until the tooth is restored or exfoliates, and otherwise perhaps indefinitely. Though we know SDF has some minor disadvantages or contraindications, still it continues to be a magic alternative in treating uncooperative or special children without using any sedation or general anaesthesia. However, more extensive studies are needed to prove silver diamine fluoride treatment as the best caries preventive approach overcoming its limitation.

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