

SDF on Litmus Test for Caries Management: Review of Facts

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ABSTRACT

Background: WHO estimates oral diseases as the fourth most expensive disease to treat in most industrialized countries where, 5% -10% of health spending is on treating dental caries. Oral health is a basic human right. There arises a need of redefining goals of dental care to reduce burden on population¹ in developing countries which has to be implemented right from childhood especially during Covid pandemic which has forced the world into health and economic crisis. SDF can be considered as the need of the hour as it is cost effective and offers biological management of caries. It fulfills the criteria of promoting a positive dental experience in anxious pediatric patients reducing burnout in pediatric dentists as well as improving OHRQoL in children. This article highlights the resurgence of SDF as the Smart initiative in caries management and suggests a model of Medical – Dental interprofessional collaborative practice.

Keywords: ECC, silver ions, staining, caries arrest, fluoride, primary dentition.

INTRODUCTION

The ravages of oral disease on individual as well as society includes fear, anxiety, pain and discomfort with sleepless nights, time off from schools impacting educational attainment, loss of masticatory efficiency leading to malnutrition, growth retardation, functional limitations and treatment costs, all of which impact oral health quality of life, general health and wellbeing of child. A study on “Global burden of Disease” conducted by Marcenes et al, 2013 and Kassebaum et al, 2017, concluded that Oral health poses a major neglected area and presents a health challenge among the populations of the World.²

A study by Duangporn Duangthip et al, 2017 ECC prevalence, in ASIA in different countries is, Laos (96.1%), followed by Cambodia (93.1%), Myanmar (84.2%), Malaysia (76.2%), Thailand (75.6%), India (49.6%) and the least in Japan (24.4%). State wise prevalence of ECC from literature in Indian scenario showed a highest occurrence in Andhra Pradesh

with 63%, and least occurrence in Sikkim with 41.92%. There was no substantial data from 16 states.³ The above trends suggest a comprehensive approach for management of caries through Health education, Awareness programmes and community approaches. The suggestive treatment modalities include preventive and non-invasive measures.

Barriers to dental care most commonly include failure to recognize the importance of early dental visit, lack of finance, dental anxiety and not being advised by pediatrician to seek dental care at an early age. In the prevention of dental caries the vital four practices include plaque control, diet, fluoride and fissure sealing. The fluoride is paramount in the treatment of caries and can be used in a variety of ways. **Philosophy of pediatric dental care** - Children are future dental patients, the dental care they receive at an early age should promote positive dental experiences which in turn reinforce positive dental attitudes⁴. The adage of pediatric dentistry,

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sine qua non of successful practice is realization that children are **not miniature adult** with respect to their reaction to the treatment. SDF can be viewed as a reward to pediatric dentists in management of caries as it effectively balances anxiety of children and stress of pediatric dentists providing care.

Paradigms in Cariology:(Tab1)

SDF can be de-coded as the material that satisfies **WHO Millenium Development Goals and the US Institute of Medicine criteria for 21st century**, as it is safe, patient-centered, effective, efficient, timely and equitable(Wagstaff and Claeson, 2004).

HISTORY OF SDF:

Medicinal use of silver dates long back to 1000 BCE where water is stored in silver vessels (Russel and Hugo 1994) considering antimicrobial properties of silver⁵. Howe (1917) directly applied silver nitrate to caries lesions (Howe's solution) which generated secondary dentin⁶. In-vitro studies gave the following insight of Silver fluoride as a potential agent of caries prevention that inhibits *S.mutans* growth (Thibodeau et al ,1978; Ostela and Tenovuo ,1990), caries lesion depth progression (klein et al ,1999) and also metabolic activity of dental plaque (Oppermann and Rolla ,1980) ⁵.

In vivo in primary teeth - Lateral spread of caries is inhibited by silver fluoride (Nishino et al ,1969). Silver fluoride in combination with stannous fluoride and stomahensive inhibits occlusal and approximal caries (craig et al, 1981). Silver and stannous fluoride combination inhibits 95% caries progression (MC Donald and Sheiham, 1994)⁵.

In vivo in permanent teeth – Silver fluoride arrests development of caries lesions that have already been initiated (Green,1989) and inhibits approximal caries progression (Hyde 1973 using silver nitrate)⁵.

These early researches lead to the use of SDF in Australia (Gotjamanos,1997), Japan (Yamanga et al, 1969) and Mexico (Aron ,1995). Most of the available studies, demonstrated that SDF has a phenomenal effect in preventing caries, with the disadvantage of blacking the caries teeth. Ex vivo and in vivo studies on primary teeth with SDF

showed more effectiveness in arresting lesions than with fluoride varnish and APF gel.

SDF was first investigated in Japan as a PHD thesis (Nishino,1969)⁶. This formulation has a combined effect of high dose of fluoride and powerful antimicrobial properties of silver. In 1970, SDF is accepted in Japan for dental treatment by Central Council of Ministry of Health and Welfare as cariostatic agent and marketed as Saforide (Toyo Seiyaku Kasei Co. Ltd.,Japan). Aqueous SDF 38%, has been in use for decades in various countries for prevention and arresting of caries^{7,8}. In India, SDF is in use since 2004. In 2014, SDF got approval from USFDA as a Class II medical advice for dentinal hypersensitivity. In October 2016, SDF was awarded with the designation of “breakthrough therapy” by FDA.^{6,9}

New NOVEL Liquid

SDF differs from other fluorides agents, as the combination of silver and fluoride in an alkaline base, has a synergistic effect in arresting dental carious lesions.Evidence based clinical practice guidelines on non restorative treatment of carious primary teeth suggest, 38% SDF solution as a documented clinical pathway of management of cavitated occlusal, approximal as well as facial or lingual lesion¹⁰.SDF contains 25% silver particles, 8% ammonia, 5% fluoride and 62% water. It is a colourless liquid containing silver particles and 38% (44,800ppm) fluoride ion at a pH 10. This is referred to as 38% SDF.^{5,11,12}

Mechanism of action:

Silver:

It has an antimicrobial property which breaks cell walls and membranes, denatures all proteins, inhibits DNA replication, deactivates nearly any macro molecule. It also strengthens dentine, forms silver – protein protective layer which is acid resistant as well as resistant to enzymatic digestion (desensitize teeth with hypersensitivity)⁹.

Diamine:

Stabilizes high concentration of ions in solution.

Fluoride:

Increases enamel resistance, rate of maturation, surface energy. It interferes with micro-organisms and improves tooth morphology and plays an important role in remineralization of incipient lesions.

Consent for Silver Diamine Fluoride with Fluoride Varnish Therapy to Arrest Decay

The use of silver diamine fluoride in dentistry has been well documented for its safe and successful ability to control tooth decay. Its application is a conservative approach for the treatment of active decay.

The Procedure:

- Dry tooth
- Application of 38% Silver Diamine Fluoride (DFA approved product) to appropriate teeth with visible carious in very small amounts using a micro brush.
- Application of 10% Sodium Fluoride varnish (DFA approved product) used to seal Silver Diamine Fluoride into the treated tooth and to arrest the decay in the tooth.
- Silver Fluoride Therapy



Contra-indications:

- Silver Diamine Fluoride Allergy (very rare)

Possible Side Effects:

- A taste to the presence of Silver Diamine Fluoride will turn that part of the tooth dark. This is an indication that the decay in the tooth is arresting.
- If Silver Diamine Fluoride comes in contact with skin and/or gums, temporary discoloration will occur.
- If Silver Diamine Fluoride is placed on a tooth that has a tooth colored restoration on it, discoloration may occur.
- Silver Diamine Fluoride placed on demineralized enamel (white lesions) may cause discoloration.

The side effects listed above may not include all of the side effects reported by the drug's manufacturer. If you notice other effects not listed above, please contact us.

Treatment of tooth decay with Silver Diamine Fluoride does not necessarily prevent the need to place a regular filling in the affected tooth in the future in order to restore function and esthetics.

Be not out for one hour and do not brush your teeth for 24 hours after treatment.

The above treatment technique has been explained to me to my satisfaction and I understand it fully. I have read this form, understood the treatment, have had the risks, benefits, and alternative treatments explained, and have had the chance to ask questions. I understand that I may refuse treatment. I also understand that this treatment may not be covered by my insurance (if applicable) and any estimates of insurance coverage discussed by any staff member was provided to me as courtesy. It is my responsibility to contact my child's dental insurance company to discuss and understand my child's policy. I give my consent to administer Silver Diamine Fluoride on:

Patient Name: _____

No warranty or guarantee has been made as to the result or type. It has been explained to me and I understand the consequences which may affect my child's health if dental treatment is not performed.

Printed Name of Parent/Legal Guardian Date: _____

Signature of Parent/Legal Guardian Date: _____

Fig 1: Inform Consent.



Fig 2: Smart technique.

SDF targets both organic and inorganic components of caries lesion. SDF when applied locally, forms an insoluble layer of oxidized silver which increases remineralization, obturates dentinal tubules and inhibits breakdown of enzymes such as MMP's and

cathepsins.¹³ Thus, SDF highly increases resistance to acid dissolution and decreases sensitivity of tooth.¹⁴ SDF will interfere with biofilm formation, killing bacteria that causes oral local environmental imbalance¹⁵⁻¹⁸. Further, the dying bacteria releases tiny silver particles into oral environment thus, reactivating SDF to act on live bacteria (Zombie effect)^{19,20}.



Fig 3: Oral health model.

Table 1: Paradigms in cariology.

• Infectious (mono-infectious concept). • Fluorides create "enamel resistance". • Operative treatment. • DRILL AND FILL RESTORATION	• Dynamic process leading to mineral loss. • Fluoride inhibits demineralization and enhances remineralization. • Minimum intervention • SEAL AND HEAL OPERATION.
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Table 2: Commercially available products.

SDF (%)	Product brand	Manufacturer	Country	Ingredients	Package
10	Cariostatic	Inodon Laboratório	Brazil	SDF	5-mL dropper bottle
12 and 30	Cariestop	Biodinamica	Brazil	Fluoridic acid, silver nitrate, ammonia	5-mL or 10-mL dropper bottle
30	Bioride	Dentsply	Brazil	SDF	5-mL dropper bottle
38	Fluoroplat	NAF laboratório	Argentina	SDF	5-mL dropper bottle
38	Saforide	Toyo Seiyaku Kasei	Japan	SDF	5-mL dropper bottle
38	Advantage Arrest	Elevate Oral Care	United States	SDF	8-mL dropper bottle
38	e-SDF	Kids-e-dental, Mumbai	India	SDF	5-mL dropper bottle
38	FAGamin	Tedequim SRL	Argentina	SDF	5-mL dropper bottle
30-35	Riva Star	SDI Dental Ltd	Australia	Unit 1: silver, fluoride, ammonia; unit 2: potassium, iodine, methacrylates	Unit 1: 0.05 mL; unit 2: 0.10 mL

Fluoride and Silver ions penetrate to a depth of ~25 microns and 50-200 microns respectively into enamel,²¹ and dentin.²² SDF arrested lesions are 150 microns in thickness. Rosenblatt et al, 2009 extensively studied effects of SDF both on teeth (sound and decayed) and bacteria. Fluoride in healthy teeth reacts with hydroxyapatite crystals to form fluor-apatite which is less acid-soluble than hydroxyapatite, inhibiting decay process. Silver ions reacts with thiol groups of amino acid and nucleic acids of the bacteria. Silver amino and nucleic acids thus formed does not carry metabolic

and reproductive functions, leading to killing of bacteria. However, in decayed teeth SDF reacts with hydroxyapatite to form fluorapatite, forms calcium fluoride, ammonia monohydrate and precipitates as silver phosphate. Silver phosphate thus, formed subsequently reacts with bacterial amino and nucleic acid-thiol groups to form silver amino and nucleic acids^{5,21,22}.

Commercially available SDF products:(Tab:2)

Rivastar (SDI)²³: as a Masking discolouration of SDF

It is commercially available as SDF and KI agent, consisting of 30-35% Silver capsule and >60% ammonia solution and a saturated solution of KI. Rivastar is an effective biofilm inhibitor. It's a Silver fluoride with a two-step patented procedure which minimises risk of staining. By applying KI over silver fluoride solution, scavenging of free silver ions occur which prevent silver flocculation onto dentin and forms a silver iodide, a creamy white precipitate.

Indications for SDF

- Children with high risk of caries.
- Children unable to withstand traditional treatment due to medical or psychological reasons (behavioural problems).
- Multiple lesions which cannot be managed at a time.
- For caries lesions which are difficult to treat.
- In those children who have difficulty in access to dental care.
- SDF can be used where the prevention of disease is not possible in clinical situations such as special care dentistry, pre-cooperative child and current Covid situation.
- Treatment of molar incisor hypo-mineralization and dentinal hypersensitivity.
- Partially erupted anterior carious teeth.

Contraindication of SDF

- Individuals sensitive to silver and also cavitated lesions encroaching pulp or symptomatic teeth.
- Presence of mucositis and desquamative gingivitis that disrupt the protective barrier of stratified squamous epithelium.

- If parents / guardians have concern regarding black stain.
- If remaining dentin thickness is less (Fancher et al,2017).

Tooth selection

- No history of chronic pain.
- Caries lesions that do not involve pulp.
- Cavitated carious lesions that are accessible for applying SDF with brush.
- As a cariostatic means before placement of restoration.

Precautions to be taken before the treatment (Mei ML, Chu CH,2016)

- SDF produces transient gingivitis or blackish dis-colouration. Hence, direct contact should be avoided. Petroleum jelly or cocoa butter can be coated on gingival tissue.
- Rubber dam or cotton rolls should be used.

SDF – Inform consent (TO DO GOOD – TO DO NO HARM)

Inform consent (fig1) should particularly highlight the possible staining of treated lesions, blackening of skin, clothes with pictures and need for re-application of the treated lesions.

Protocol for Clinical application :^{24,25,26,27}

- The vicinity of carious teeth should be thoroughly cleansed for better contact of SDF with denatured dentin.
- Removal of caries dentin prior to application of SDF is unnecessary.
- In order to prevent blackening with SDF treatment, necessary precautionary measures in the form of application of petroleum jelly to lips and skin should be taken.
- Isolate the areas, that are in vicinity of caries teeth by means of cotton rolls or other isolation methods. Petroleum jelly should not be applied on caries surfaces that are to be treated.
- While applying SDF to carious primary teeth adjacent to non cavitated permanent teeth, care should be taken to avoid stain.
- To dry the lesion, compressed air should be blown very gently.

- The application of SDF on caries teeth should be carried out by a micro sponge brush after removing the excess fluid on the brush. To minimize systemic absorption of fluid by the child the excess fluid should be removed with gauze.
- Application of the SDF should last for a minimum of atleast 1 minute and should be allowed to air dry for a minimum of 3 minutes.
- In order to prevent caries in untreated teeth, 5%NaF varnish should be applied in entire dentition.

Follow up:

- Follow up of SDF treated lesion should be carried out within a period of 2-4 weeks.
- If the teeth are not stained and hardened, reapplication of SDF is necessitated.
- After SDF treatment, if the lesions are not restored, bi annual application and reapplication is advised.

Caries prevention- repetition is the key

Annual application of SDF resulted in better prevention of caries both in adults as well as children than with fluoride varnish applied 4 times in a year. A systematic review concluded that SDF application is better than NaF (Chu et al,2002; Lo et al, 2001; Duanghip et al, 2016;)^{20,28} in arresting caries. This is contrary to study done by Wong et al,2011; Wong et al, 2005). Current evidence on the efficacy of SDF (38%) for caries arrest in children (Gao et al,2016)²⁹ is 86% when tested after six months. It is ideal to apply SDF periodically, preferably every six months for arrest and prevention of caries.

Adverse effects:

- SDF tastes Metallic or bitter.
- Inadvertent contact with SDF is found to result in mucosal irritation and lesions that resolves itself after 48 hours.
- Temporary staining of skin is found with application of SDF, that resolves with in a period of 2-14 days.^{12,30}
- Permanent staining of clothes is also found.^{12,30}

Maximum Dosage and Safety margin

From the literature available, SDF gives a rare evidence of toxicity and adverse events (Lansdown, 2002b, 2006; Lansdown & Williams,2004).

Average lethal dose LD50 – by oral administration is 520mg/kg and 380mg/ kg by subcutaneous administration. One drop of SDF contains 9.5mg. Thus, recommended limit of SDF is set at 1 drop (25 µL) for a 10 kg bodyweight, for every visit at an interval of one week. This dose is in proportion with the EPA's allowable short-term exposure of 1.142 mg silver per litre of drinking water for 1-10 days (ATSDR, 1990).

Cumulative exposure from acute and chronic intake of silver at low level has no bearing in causing physiological disease, but bluing of skin in argyria should be avoided. The Environmental Protection Agency has set a lifetime exposure to silver conservatively, at 1 gram. The highest applied dose for 3 teeth measured in the pharmacokinetic study is 2.37 mg that would enable more than 400 applications. Additionally, research has shown that there is a **400-fold safety norm** in application of SDF with regard to normal pulpal response and with a very few minor adverse events like staining of gingiva and cloth.

Parent perspective:

The most frequently reported barrier for use of SDF is parental acceptance. Staining on posterior teeth is more acceptable to parents than anterior. Most parents accept SDF staining in anterior teeth to avoid treatment under sedation or general anaesthesia. Treatment with sedation or General anaesthesia in children under the age of 3 may affect the development of the brain. Hence, most parents prefer the SDF method. This suggests that many parents are open to compromise aesthetics in favour of less invasive approach, where child cooperation and age is a barrier for traditional restorative care³¹.

How to mask discolouration

Silver nano fluoride and ammonium hexa-fluorosilicate can also be used as alternatives to SDF. Reducing agents like potassium iodide, magnesium chloride, glutathione can be used along with SDF to mask the discoloration of teeth. **SMART** technique (fig2) and crowns can also be used to mask discoloration³².

Rivastar is a commercially available SDI (SDF + KI)^{33,34} which can be used to mask the decoloration of SDF. In a systemic review, Rivastar reported clinical effectiveness in arresting caries. They also concluded bond strength of dentine to adhesives and GIC is not effected by its application on tooth.

Smart technique involves application of GIC on SDF applied teeth. Studies on SDF application on the bond strength of dentine to GIC / RMGIC concluded that most common failure mode is adhesive failure when applied SDF, also a negligible decrease in bond strength noticed.

Effects on bonding

Studies have been carried out to find the effect of SDF on bonding of tooth by use of GIC and resin based restorative materials. In one of the studies, it is found that rinsing after application of SDF has decreased the bond strength between the tooth and restorative material by nearly 50% which contrasted with another study that showed increase in bond strength. Further studies by Selviraj et al (2016)^{33,35} and Quock et al (2012) indicated no decrease in bond strength. Decrease in shear bond strength is observed by Kucukyilmaz et al(2016), Soeno et al (2001) and Knight et al(2006)³³. Thus, it is recommended that for direct restoration, rinsing is obligatory and for cementing crown rinsing after application of SDF is un-necessary.

Clinical Utility

SDF as NRCC:

NRCC(Non Operative Caries Treatment) , is a novel method of treating dental carious lesions in children. The main objective of this treatment is to manage biofilm on the lesion surface. It is very effective in primary teeth treatment which presents with potentially cleansable and cleansable lesions. SDF treatment as NRCC is very safe, non-invasive, easy to perform and very economical method than other methods performed under NRCC³⁶.

Need for Sedation can be Avoided or Delayed in Treating Pediatric Patients: In the treatment of caries with SDF, sedation of the patient is not required. This itself is a major advantage for the treatment of caries in children. Treatment with sedation or General anesthesia in children under

the age of 3 may effect the development of the brain. Hence, most parents are preferring the SDF method.

Arrest of Caries in children in need of Special health care

As a pediatric dentist one can help children with special needs, such as Autism, sensory processing disorder, Down Syndrome by treating them with SDF. This treatment can be followed also in children who are immune-compromised, undergoing chemotherapy, salivary dysfunction or polypharmacy, and those suffering from chronic diseases. Laser treatment has an added benefit in promoting fluoride up take. A study concluded that among the 4 commercially available dental lasers CO2 and Er:YAG lasers³⁷ resulted in a increased fluoride uptake in the SDF-treated dentine . Hence lasers and SDF combination has synergistic affect in treating these children³⁸.

Caries Control in Patients with Extensive Treatment Needs

Pediatric patients who need extensive care in caries treatment may not be able to support financially for the restorative treatment. In such cases, SDF treatment will act as a stop-gap measure before they can afford for regular treatment.

Silver Modified Atraumatic Restorative Treatment (SMART)

SDF treatment prevents caries but does not restore form and function of the teeth. For efficient function of the teeth affected by caries, the treatment involves application of GIC restorative materials like HVGIC and Fuji EQUIA Forte (GC America) which is known as SMART approach³⁹.

Hypersensitivity

SDF also decreases dentinal hypersensitivity by occluding dentinal tubules and produces fluoro-hydroxyapatite which will increase mineral density and hardness. The method also does not stain healthy teeth structure and therefore is an excellent alternative for patients suffering from hypersensitivity^{10,26}.

Treatment of Molar Incisor Hypo-mineralization (MIH)

Molar Incisor Hypo-mineralization (MIH) is a clinically challenging situation involving 20-40% of permanent first molars. These MIH teeth are more vulnerable for developing caries involving a 10-fold risk. As, these teeth cannot be adequately anaesthetized SDF is a better option to desensitize these teeth.

Preventing caries recurrence at restorative margins

As restoration treatment of caries involves only a finite duration of longevity, SDF application prolongs the life of the existing restoration. It is a cost effective treatment that is beneficial to the patients.

Interproximal incipient caries

Interproximal Incipient lesions present a clinically challenging procedure for its treatment. SDF obstructs the growth of caries and present a suitable treatment for interproximal incipient lesions. The procedure involves application of SDF by using super- floss (Judy Bendit and Douglas Young,2017)

Treating infected root canals:

SDF due to its unique antibacterial effect is used as intracanal irrigant. Studies concluded that 10% SDF is effective and more efficient in treating E.Faecalis biofilm⁴⁰.

SDF – community prevention

It is always an effective method in treating dental problems involving the whole community rather than an individual approach. Treatment of oral problems with SDF is proved to be three-fold beneficiary involving the dentist, the child and the population. The method is most cost effective and provides inexpensive treatment for all the strata of society. The ease of SDF treatment is phenomenal, with no requirement of patients to visit regular dental clinics. The dentist by adapting the method has less burden in treating caries and oral health ailments. SDF application to children involves no painful procedures and by which the child willingly undergoes treatment⁴¹. Further, AAPD guidelines (2017), suggest that SDF as a brush on liquid, arrests 87.7% of dental caries lesions with success rate similar to restorations placed under general

anaesthesia. Hence, it can be advocated as school and community-based method for caries care. SDF treatment benefits should be made to publicise extensively among targeted population both by dental practitioners as well as **non-dental activists such as ASHA, Angalwadi and village volunteers etc and in school by teachers.**

Oral health Model (Fig:3) – Protecting and promoting oral care

It's time to break silo-effect between Medical – Dental fraternity and create a unified vision between Gynaecologists, Pediatricians and Pediatric Dentists to attain **“Healthy Mother- Smiling Child”**.

As medical professionals are influential due to their early access of children, we should encourage well baby visits and early first dental visit through collaboration. Covid -19 caries management model works on integrating knowledge about Home-care, noninvasive preventive measures such as risk assessment by 'lift the lip' procedure, dietary counselling oral hygiene training, biofilm control measures and role of fluoride varnishes, Sealants, SDF through digital platforms as CME - CDE.

CONCLUSION

Prevention is the corner stone of modern holistic dentistry. Individualised oral care is expensive but SDF can be used as affordable public health intervention thus, reducing economic burden of cost of caries treatment. It is most safe and effective alternative to conventional caries management across the age spectrums. Current Covid-19 pandemic has massively affected dental care and will need pediatric dentists and policy makers to adopt new practices and protocols which are health driven rather than treatment driven. **SDF** treatment efficacy, and clinical utility based on scientific evidence from literature represents a litmus test for SDF as a promising material of choice in achieving the Goal of **SAVE 20 IN 2020** and also in years to come.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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