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SDF: Enhanced preventive, operative care: Call based on caries risk

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Abstract

Dental caries remains severe oral health problem, despite being the most preventable disease. The fact regarding this disease is that even though several efforts are made towards its total eradication, it is still prevalent. It was easier to work on the resultant effect of the disease rather than imagining the unseen pathological mechanism, which led to the resultant obvious effect. However, conventional management of carious lesion requires patient's cooperation, which is the most important consideration in pediatric dentistry, the lack of which leads to progression of disease and subsequent tooth loss. The possibility of detecting non-cavitated stage carious lesions and also the possibility to remineralize/arrest these lesions have noticeably reduced the clinical situations that necessitate restorations. Preventive interventions can be used as an alternative to traditional restorative procedures and one of them is Fluorides, which resulted in significant decrease in prevalence of dental caries. The perfect alternative treatment for dental caries for many circumstances is the application of Silver Diamine Fluoride. The use of SDF provided appropriate care for low income, socially vulnerable children and also in some unique clinical circumstances that may not permit traditional cavity preparation. This article highlights the change in perception of Pediatric dentists towards caries management, preventive care and the role of 'Magic bullet' SDF in arresting carious lesions thereby improving the quality of life of children.

Keywords: Silver ions, ECC, caries risk, primary dentition, staining

Introduction

Dental caries is a common biofilm mediated chronic disease. Due to changing trend in lifestyles and dietary habits, the burden of dental caries is more among children. The current term used for dental caries in pre-school children is "Early Childhood caries" (ECC) which implies a more complex disease, related to frequent consumption of sugars in environment of enamel adherent bacteria that is not necessarily related to bottle feeding. At the Bangkok Global Summit on ECC, the expert panel further defined dental caries as "a biofilm-mediated, sugar- driven, multifactorial, dynamic disease that results in the phasic demineralization and remineralization of dental hard tissues, determined by biological, behavioural and psychosocial factors linked to an individual's environment"^[1].

Dental caries if left untreated not only causes damage to the tooth but is also responsible for several morbid conditions of the oral cavity due to pain and suffering^[2]. These consequences like difficulty in eating and sleeping, frequent absenteeism, esthetic problems, financial impact and hospitalization decrease the child's quality of life and also has an impact on family, community and health care system. Hence, there is a need to consider how ECC impacts day-to-day life of children and their families- the physical, social and psychological consequences of ECC.

Behaviour of the child- A key for successful treatment

"Children are not miniature adults". Children are unique, don't exist in isolation and may not have enough knowledge to understand. Hence, it is important to take enough time to establish rapport with them. Behaviour of child in dental office is utmost important. At times child may become uncooperative due to dental fear or anxiety.

Behaviour guidance is a continuum of interaction that involves the dentist and dental team, the child and the parent.

If the child is extremely uncooperative, then the child should be treated under sedation (Conscious sedation or General anesthesia).

Assessment of child

Successful prevention and management of caries is primarily dependent on comprehensive assessment of child that includes patient history, clinical examination, caries risk assessment, parent/caregiver motivation and explaining them their responsibility in maintaining oral health of child. Although these are considered as discrete individual elements, most pediatric dentists assess them simultaneously to plan a personal care for prevention and management of carious lesions.

Fluorides-The Saviour of tooth

Fluorides have remineralizing capacity and increases the tooth's resistance to demineralization. Even after widespread systemic fluoridation, prevalence of caries increased raising queries on pre-eruptive effects of fluoride on enamel. Thus, post-eruptive effect of fluoride became the topic of interest due to this lacuna. Compared to concentration of bound fluoride in enamel, the presence of free fluoride ions in the biofilm and the oral fluid is now considered to be more important. Thus, the wide spread use of topical fluorides emerged, where free fluoride ions were made available at the tooth's vicinity in high concentration. For prolonging the action of fluorides, retention rate and sustained-release effect became important requisites instead of increasing the frequency of application. Gels and varnish provide better retention of fluoride over the enamel and highest level of evidence is available on their superior anti-caries effect. Due to the cariostatic effect of fluorides, they are considered 'Corner Stone' of preventive dentistry.

Novelty of SDF

Regular pediatric dental practice cannot be carried out either due to uncooperative/young child, children with special health care needs or in present situation like COVID-19. In such case, Silver Diamine Fluoride which has globally amplified attention by clinicians plays a major role due to its ability to halt caries process and simultaneously prevent formation of new caries^[3, 4]. This paved a logical route towards maximal preservation and minimal sacrifice of the natural tooth substance.

In terms of WHO Millenium development goals for health, need for SDF is to achieve goals like provision to basic oral health consisting of emergency care, prevention and cost-effective intervention.

History of silver products in dentistry

Silver was first used during 1000 BC or earlier. During this period water stored in silver vessels was considered portable and antimicrobial properties of silver are well documented^[5]. Stebbins and Howe stated that, arresting of carious lesions by silver compounds is due to antimicrobial action and the production of sclerotic protective layer of secondary dentin due to deposition of "black crust"^[6, 7]. SDF was accepted as therapeutic agent for management of dental caries in Japan, 1960. It was first studied by Nishino, as a part of PhD thesis in Japan in 1969 and stated that this formulation resulted in a precipitate that occluded dentinal tubules and reduced hypersensitivity^[8]. Craig *et al.* in 1970s reported the use of AgF solution in dentistry^[9]. In 2014, SDF was approved by

US Food and Drug administration as a treatment option for dentinal hypersensitivity and recognised it as "breakthrough therapy" to treat dental caries in 2016.

SDF was mentioned in literature since 1969 with various names, such as silver diamine fluoride, ammonical silver fluoride, ammoniated silver fluoride, silver fluoride diamine, diamine silver fluoride and diammine silver fluoride.

pH of SDF is alkaline (pH:8-9). It is more stable than AgF and doesn't require any reducing agent. SDF was first used in dentistry at 38% concentration. It is also available in low concentration of 12% but it is not as effective as former^[10].

Composition and Mechanism of action

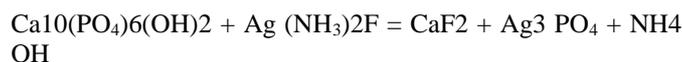
Silver diamine fluoride is a colourless liquid containing 25% silver, 8% ammonia, 5% fluoride and 62% water.

38% SDF contains 253,900 ppm silver (Ag) and 44,800 ppm fluoride (F).

SDF differs from other fluoride agents, as the combination of silver and fluoride in an alkaline solution of SDF has a synergistic effect in arresting dentine caries^[11].

SDF reacts with hydroxyapatite and releases

- i. Silver phosphate: Forms insoluble precipitates on tooth surface and
- ii. Calcium Fluoride: Acts as reservoir for formation of fluorapatite which is more resistant to demineralization than hydroxyapatite in oral environment.



Mechanism of action of SDF

a. Silver ions

- **Antibacterial property:** Binds with negatively charged peptidoglycans in bacteria cell wall, disrupts membrane transport function that leads to cellular distortions and loss of viability.
- Act as "Tiny silver bullets" - Interacts with sulfhydryl group of proteins and with DNA, altering hydrogen bonding, inhibiting respiratory process, DNA unwinding, cell wall synthesis, cell division and eventually leads to cell death. These killed bacteria acts as reservoir for silver ions and kills the nearby living bacteria in process called "Zombie effect".
- **Anti-enzymatic action:** Inhibition of enzyme actions and dextran induced agglutination of *S.mutans* cariogenic strains. Inhibits *S. mutans* at a concentration of 0.12 micromole/ml or more.
- **Strengthens dentin:** By inhibiting MMP and thus reducing degradation of organic collagen matrix

b. Diamine: Stabilizes high concentration solutions

c. Fluoride:

- ✓ Increased enamel resistance and surface energy- Formation of Fluorohydroxyapatite.
- ✓ Remineralization of lesions
- ✓ Interference with microorganisms and improved tooth morphology
- ✓ **Cariostatic action:** Fluoride increases the resistance of peri- and inter-tubular dentin to acid decalcification and as a result, retards the penetration of acid into deeper layers of the dentin.

Case selection^[12, 13]

Patient selection

- High risk children with active caries lesions

- Children with multiple carious lesions which cannot be managed in single visit
- Child with behavioural problems/ medically compromised/ with special health care needs. (Initially carious process is arrested or slowed down and future management of lesions will be done at later date when the child's ability to rationalise fear increases with age).
- Difficulty in access to dental care
- Arrest caries in teeth nearing exfoliation
- As a part of SMART- Silver modified atraumatic restorative technique
- Treatment of Molar incisor hypo mineralization/ dentinal hypersensitivity

Tooth selection

- No history of spontaneous pain
- No clinical signs of pulpal involvement
- Cavitated lesions not encroaching pulp. If possible, radiograph can be taken to access the lesion depth
- Cavitated carious lesions that are accessible for applying SDF with brush (To gain access to proximal lesions orthodontic separators may be used)

Contraindications

- Individuals with known silver allergy
- Cavitated lesions encroaching pulp/symptomatic
- If the parents/guardians have concerns regarding colour change
- Presence of ulcerative gingival conditions

Commercially available SDF products mentioned in Figure 1 and Table 1

Quality aims of SDF

- **Patient Centered:** Meets the instant needs of child in 1 treatment session
- **Safe:** Clinical trials on more than 3800 individuals reported no serious adverse effects
- **Equitable:** Cost effective; feasible option for low-income groups
- **Effective:** Approximately 80% of treated lesions are arrested
- **Efficient:** Can be applied with minimal preparation in less than 1 minute by health professionals
- **Timely:** As soon as problem is diagnosed, used as intervention agent

Clinical application protocol of SDF ^[14]: Figure 2

- For better contact of SDF with denatured dentin, gross debris is removed from cavitation.
- Carious dentin excavation is not necessary as it may reduce the proportion of arrested dentin.
- To prevent staining of lips and skin during the procedure due to accidental contact of SDF, protective petroleum jelly coating may be applied (Care should be taken not to coat the surface of carious lesion).
- Not more than one drop of SDF should be used for one appointment. The tooth surface is isolated with cotton rolls, gauze piece or compressed air and an application time of 1 minute is usually recommended.
- Micro sponge brush is bent and dipped in SDF. To remove excess liquid before application, the brush is dabbed on the side of plastic dappen dish. After application, excess SDF is removed with gauze or cotton

rolls to minimize systemic absorption. (Plastic dappen dish is used as SDF corrodes metal and glass).

- Gentle flow of compressed air is applied until medicament is dry. Isolation of operating site should be continued for 3 minutes after application.
- For proximal carious lesions, absorbent type of floss such as super floss has been proposed as a delivery method for SDF application.
- 5% NaF varnish may be applied to entire dentition after SDF treatment to prevent caries on teeth and sites not treated with SDF.

Post-operative instructions and Follow up

- No post-operative instructions were recommended by the manufacturers. However, 30 minutes to 1-hour restriction on consumption of food and drinks has been recommended in several studies on SDF.
- After initial treatment, follow up is advised at 2- 4 weeks to check arrest to treated carious lesions (Appear hard and dark).
- Based on colour and hardness of cavitated lesions or evidence of lesion progression, reapplication of SDF at recall appointments may be needed. ^[14]
- After treatment with SDF, lesions can be restored with resin modified glass ionomer or composites and is termed as "Smart".
On the basis of scientific evidence, RMGIC has advantages over the conventional GIC due to better bond strength, high early strength and less moisture sensitivity, thus resulting in low solubility and disintegration. ^[15]
- In case the lesions are not restored, biannual application of SDF is advised to increase the caries arrest rate.
- Following treatment, counselling of the child and parent regarding oral hygiene and diet plays a major role. This is because the application of SDF combined with the efforts of the child towards oral health maintenance will bring out positive outcome of treatment.

Adverse effects and disadvantages

- No deaths or systemic adverse effects have been reported in published clinical trials using topical silver diamine fluoride as per the manufacturer's recommendation.
- Maximum limit recommended is one drop per 10 kg of body weight per treatment visit at weekly intervals.
- Black discoloration, metallic taste, development of small white reversible lesions in the oral mucosa and gingivitis are the associated adverse effects with SDF.
- Adverse effects of SDF:
 - ✓ Pulpal damage is unlikely on application of silver diamine fluoride; however, it should not be placed on exposed pulp. Lesion close to pulp should be periodically monitored after application of SDF.
 - ✓ Silver phosphate precipitate is yellow when it is first formed, but readily turns black under sunlight or the influence of reducing agents and the discoloration is permanent until restored.
 - Knight *et al.*, 2006 ^[16] reported the addition of potassium iodide (KI) before application to the SDF could reduce the discoloration.
 - Sayed *et al.*, 2018 ^[17] reported that glutathione biomolecule reduces tooth discoloration after application of SDF, particularly on enamel and to a minor degree on dentin.
 - ✓ In majority of the cases, the affected gingival or mucosal

tissue turns white and the change is transient. The white marks (burning) on the gingiva usually resolve within 1-2 days.

- ✓ SDF can stain clothes and the skin of the body. Though it does not cause any pain or damage, an SDF stain on skin takes around 7-14 days for it (SDF doesn't penetrate dermis and desquamation takes 14 days) to disappear, and the stain on clothes is permanent.

of SDF based on the staining and found that staining on posterior teeth was more acceptable than on anterior teeth. Although staining on anterior teeth following treatment was perceived as undesirable, most parents preferred this option to avoid the use of advanced behavioural guidance techniques such as sedation or general anesthesia to deliver traditional restorative care. Once the disease is controlled, now arrested cavitated caries lesions can be restored to improve esthetics.

Parenteral preference-Esthetics Vs Caries arrest ^[18]

A recent study assessed parental perceptions and acceptance

Current evidences: Foundation for future research summarised in table 2.

Table 1: Original

Country	Product	SDF%	Major ingredients	Manufacturer	Package
Brazil	Cariostatic	10%	SDF	Inodon manufacturer	5 ml dropper bottle
	Cariestop	12%	Fluoridic acid, silver nitrate, ammonia	Biodinamica Quimica e Farmaceutica Ltda	5/10 ml dropper bottle
	Bioride	38%	SDF	Dentsply Industria e comercio Ltda	5 ml dropper bottle
Argentina	Fagamin	38%	SDF	Tedequim SRL	5 ml dropper bottle
	Fluorophat	38%	SDF	NAF Laboratories	5 ml dropper bottle
USA	Advantage arrest	38%	SDF	Elevate oral care	8 ml dropper bottle
Japan	Saforide	38%	SDF	Toyo Seiyaku Kasei Co.Ltd	5 ml dropper bottle
Australia	Riva Star	30-35%	Unit 1- Silver, Fluoride, ammonia Unit 2: Potassium, Iodine, Methacrylates	SDI Dental Limited	Unit 1- 0.05 ml Unit 2- 0.10 ml
India	e-SDF	38%	SDF	Kids-e- dental	5 ml dropper bottle

Table 2: Original

1	Burns J, Hollands K ^[19]	RCT	2015	Nano Silver Fluoride for preventing caries.
2	M.L. Mei <i>et al.</i> ^[20]	Invitro study	2015	Prevention of secondary caries by SDF
3	Gao SS <i>et al.</i> ^[21]	Systemic review	2016	Clinical trials of silver diamine fluoride in arresting caries among children: a systematic review. Proved that 38% SDF solution is more effective than lower concentrations.
4	Miller M.B, Lopez L.A, Quock R.L. ^[22]	Invitro study	2016	Silver diamine fluoride, potassium iodide, and esthetic perception: An <i>in vitro</i> pilot study.
5	Crystal YO <i>et al.</i> ^[14]	Systemic review	2017	Use of silver diamine fluoride for dental caries in children and adolescents, including those with special health care needs
6	Crystal YO, Janal MN, Hamilton DS, Niederman R. ^[18]	Cross-sectional study	2017	Parental perceptions and acceptance of silver diamine fluoride staining. Most parents preferred SDF to avoid the use of advanced behavioural guidance techniques such as sedation or general anesthesia to deliver traditional restorative care.
7	Chibinski AC <i>et al.</i> ^[23]	Systemic review and meta-analysis	2017	Silver diamine fluoride has efficacy in controlling caries progression in primary teeth: a systematic review and meta-analysis. Concluded that SDF (89% caries arrest) appears to prevent caries effectively in complete primary dentition.
8	Zhao I.S, Mei M.L, Burrow M.F, Lo, E.C., Chu C.H. ^[24]	Invitro study	2017	Effect of Silver Diamine Fluoride and Potassium Iodide Treatment on Secondary Caries Prevention and Tooth Discolouration in Cervical Glass Ionomer Cement Restoration. SDF + KI treatment inhibited development of secondary caries on GIC restorations, but was not as effective as SDF treatment alone. Moreover, SDF + KI treatment caused a perceptible staining at the restoration_margin, but the intensity was less than that with purely SDF treatment.
9	Zhao <i>et al.</i> ^[25]	Invitro study	2017	Prevention of secondary caries using silver diamine fluoride treatment and casein phosphopeptide-amorphous calcium phosphate modified glass-ionomer cement. SDF treatment and incorporation of CPP-ACP into GIC restorative material can prevent secondary root caries development.
10	Duangthip D <i>et al.</i> ^[26]	RCT	2018	Caries arrest by topical fluorides in pre-school children: 30-month results. Stated that over long periods (30 months), annual applications of SDF are more effective than 3 weekly applications at baseline and Anterior teeth have higher caries arrest rate than posterior teeth. He also reported that success of SDF does not seem to be time dependent, as application times ranging from 10 seconds to 3 minutes achieved various degree of success.
11	Fung MHT <i>et al.</i> ^[27]	RCT	2018	Randomized clinical trial of 12% and 38% silver diamine fluoride treatment. Proved that 38% SDF solution is more effective than lower concentrations, Biannual application of 38% SDF resulted in increased arrest of active dentin lesions than the annual application, Anterior teeth have higher caries arrest rate than posterior teeth. Reported that in children with poor oral hygiene, caries arrest rate can be improved by increasing the frequency of application from annual to semi-annual.
12	Oliveira BRA, Veitz-	Systemic	2018	The effect of silver diamine fluoride in preventing caries in the primary dentition: a

	Keenan A, Niederman R ^[28]	review and meta-analysis		systematic review and meta-analysis. Concluded that SDF (89% caries arrest) appears to prevent caries effectively in complete primary dentition.
13	Mahmoud Sayed <i>et al.</i> ^[17]	Invitro study	2018	Effect of Glutathione Bio-Molecule on Tooth Discoloration Associated with Silver Diammine Fluoride. Reported that glutathione biomolecule reduces tooth discoloration after application of SDF, particularly on enamel and to a minor degree on dentin.
14	Firouzmandi M <i>et al.</i> ^[29]	Invitro study	2019	Effect of Silver Diamine Fluoride and Proanthocyanidin on Mechanical Properties of Caries-Affected Dentin. Can be recommended to increase hardness and elastic modulus of caries-affected dentin.
15	Firouzmandi M <i>et al.</i> ^[30]	Invitro study	2020	Effect of silver diamine fluoride on the bond durability of normal (ND) and carious dentin (CAD). SDF treatment increased the bond strength to CAD but did not affect the bond strength to the ND. SDF hindered the decrease in the bond strength to the ND caused by aging. However, the effect of SDF on increasing the bond strength to CAD disappeared after aging.
16	Bao ying Liu <i>et al.</i> ^[31]	Invitro study	2020	Effect of silver diammine fluoride on microecology of plaque from extensive caries of deciduous teeth - <i>in vitro</i> study. Reported that most of the microbes present before the intervention were sensitive to SDF and the relative amounts decreased substantially.
17	Meng Jiang <i>et al.</i> ^[32]	Systemic review	2020	Effect of silver diamine fluoride solution application on the bond strength of dentine to adhesives and to glass ionomer cements: a systematic review



Fig 1: Original



A. Enamel and dentin caries lesions in primary anterior teeth of 18-month-old child
 B. Same lesions showing staining after SDF treatment

Fig 2: Original

Conclusion

SDF promisingly fulfils the criteria of providing cost-effective, biological management of caries based on caries risk. It paved a way towards redefining the goals of dental care to reduce burden on population as well as improving oral health related quality of life.

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