Quest Journals
Journal of Medical and Dental Science Research
Volume 9~ Issue 12 (2022) pp: 80-87
ISSN(Online) : 2394-076X ISSN (Print):2394-0751
www.questjournals.org

Research Paper

Silver Diamine Fluoride in Pediatric Dentistry – A Review of Literature

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Abstract: *Though there are many advances in caries prevention, the global prevalence is still more which is related unavailability of treatment to various vulnerable groups and economic problems. SDF is aeconomical solution to prevent the caries progression. It was first approved for the management of hypersensitivity of teeth. Due to further studies and proper research, the various advantages of SDF. It is essential to search an efficient, affordable method of treating dental caries. This article reviews various advantages, disadvantages, indications & contraindications.*

Key words: *Dental caries, Silver Diamine Fluoride, Early childhood caries, Remineralization.*

R*eceived 10 Dec., 2022;* ***R****evised 23 Dec., 2022;* ***A****ccepted 25 Dec., 2022 © The author(s) 2022.*
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I. Introduction:

Early childhood caries is a public health emergency. It is 12th place on the list of 291 most common childhood diseases.[1] The traditional conservative treatment of dental caries involves an elaborate process which includes mechanical preparation by removing the dental caries followed by restoration. Uncooperative children can be treated using conscious sedation or general anaesthesia, but these are not available for all children.[2] There are many preventive interventions that can be used as an alternative to traditional restorative procedure, and one of them is the use of silver diamine fluoride.

History:

Common fluoride products and their concentration[3,6,11]

Fluoride concentration	ppm
Silver diamine fluoride	44,800 ppm
5% Fluoride Varnish	22,600 ppm
APF (In office)	12,300 ppm
NaF2	9000 ppm
Rinse	3,300 ppm
SnF2 w/ACP	3,300 ppm
CPP ACP with fluoride	900 ppm
OTC 0.05% NaF2 rinse	200 ppm

Table 1: Fluoride products and their concentrations

Though SDF was approved for use in Japan in 1969, it had renaissance only after approval by U.S Food and Drug Administration (FDA) in 2014.[3]

Composition:

SDF is a liquid substance used to help prevent caries from forming, going or spreading to other teeth. It is safe, painless alternative to traditional cavity drilling procedures.
-SDF is available in different concentrations like 12%, 30% & 38%.
-38% SDF is most commonly used which includes[4]:

Table 2: Composition of SDF

SILVER	25%
AMMONIA	8%
FLUORIDE	5%

Mechanism of Action of SDF:

-When applied to the tooth surface, SDF is proposed to read with hydroxyapatite to form silver phosphate and calcium fluoride which acts as a reservoir of fluoride and phosphate ions in aiding remineralization.

-The silver ions penetrate into the lesions and remain there to exert their influence.[4,7,15]

Table 3: MOA of SDF

Carious surface	**Arrested carious surface**
$Ca_{10}(PO_4)_6(OH)_2$ + **SDF** **Role of SDF** 1. Antimicrobial activity against cariogenic bacteria [MS]. 2. Aids in remineralization and inhibits demineralization 3. Reduce collagen matrix destruction.	**CaF_2:** Serves as a fluoride reservoir, exerting anticariogenic effects and can washout over time. **Ag_3PO_4:** Silver ion penetrates into the dentin surface and remains. Phosphate reservoir aids in remineralization. Silver compound stain lesion black. **NH_4OH:** It keeps pHelevated. Antimicrobial activity.

-The presence of silver compounds such as silver oxide and silver phosphate is the reason for the lesions turning black.

-Ammonium acts as a stabilizing agent.[4,6,8,9,18]

A. Silver:

1.	Anntimicrobial and inhibit biofilm formation	a. Breaks cell walls & membranes b. Denatures all proteins & deactivates c. Inhibits DNA replication
2.	Strengthens dentin	Silver – protein protective layer ⬇ Acid resistant ⬇ Resistant to enzymatic digestion
3.	**"ZOMBIES" EFFECT**	Killed bacteria acts as reservoir of silver ions present.

Table 4: Role of Silver in SDF

A. Fluoride[5]:

1. Fluorapatite = Hydroxyapatite + SDF
2. CaF_2 → Reservoir of fluoride 2-3 times more subsurface fluoride than other fluoridesolutions.
3. Remineralization
4. Increased surface microhardness.

B. **Ammonium:**

It acts as a stabilizing agent.[5]

Indications:[4,5,6,13,18,22]

1. High caries-risk patient with anterior & posterior caveated lesions.
2. Behavioural or medical management challenges.
3. Multiple cavitated lesions- that cannot be treated in one visit.
4. Patients without access to or with difficulty accessing dental care.
5. Active cavitated lesions with no clinical signs of pulp involvement.
6. SDF can be used as a potential substitute to $Ca(OH)_2$ for Indirect Pulp Capping.
7. For prevention of root caries in high-risk patients.
8. 3.8% solution for irrigation of root canal→ as a potent antimicrobial agent.
9. SDF is very effective in reducing bacterial load from canal wall &circumpulpal dentin.
10. It prevents the formation of S. mutans or Actinomyces naeslundi mono species biofilms.
11. Inhibits biofilm formation & MMP activities.
12. Increases microhardness of carious dentin.
13. Reduces Ca & P ions.
14. Lessens collagen damage.
15. To treat hypersensitivity.
16. To treat infected root canals (1:10 dilution).
17. Strengthen endodontically treated teeth [laser + SDF].
18. Treatment of MIH.
19. Treatment of recurrent caries [secondary caries].
20. Indirect pulp therapy.
21. Arresting caries to maintain the teeth nearing exfoliation.
22. As a substitute to sealants.

Contraindications:[3,4,11,15,1,19,23]

1. Silver allergy
2. Relative contraindications: Desquamative gingivitis or Mucositis.
3. Ulcerations or Stomatitis.

Advantages:[3,5,6,7,9,11]

1. Control of pain & infection
2. Affordable cost.
3. Simplicity of treatment.
4. Minimal equipment is required.
5. As the treatment is non-invasive, the risk of spreading the infection is very low.

Disadvantages:[3,4,12,15]

1. The inherent disadvantage of using SDF to arrest caries is that the lesions will be stained black.
2. Some children and their parents may not be pleased with the aesthetics of this treatment outcome.
3. Moreover, SDF can stain cloths and the skin of the body. In most cases, the affected tissue turns white and the change is transient. The white marks on the gingiva usually heal within 1 to 2 days.
4. SDF solution also has a metallic taste that is not too pleasant.
5. It is sensitive to light and hence it must be kept in dark / opaque container.
6. Its high fluoride concentration can be toxic when swallowed in large doses, hence precaution must be taken especially when it is used on very small children.

Tooth selection:[3,4,11,21]

1. Absence of clinical signs related to inflamed pulp or history of spontaneous pain.
2. Carious lesions that are not infringing on to the pulp – radiographs.
3. Carious lesions on any surface that are accessible with a brush during SDF application.

Penetration:[6,8,14,]

1. 25 microns into ENAMEL & 50-200 microns into DENTIN.
2. Arrested lesions are 150 microns thick.

Procedure:[2,5,7,8]

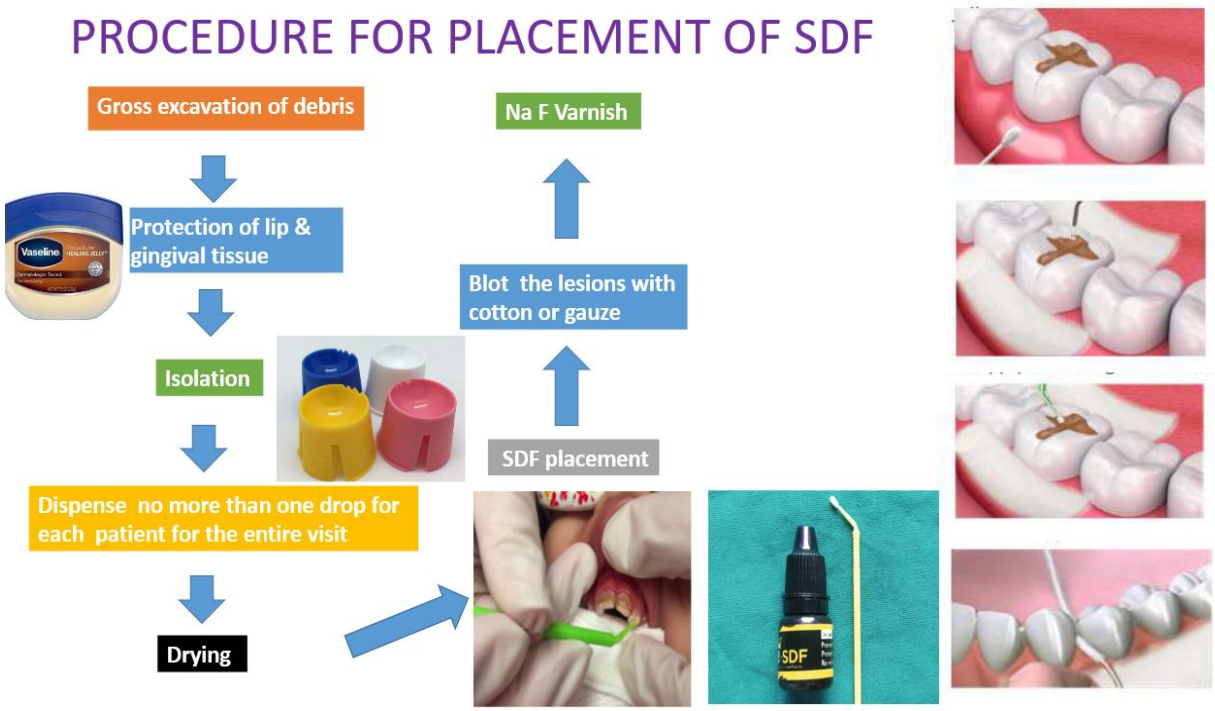

Figure 1: Procedure

Precautions:[7,8,9]

-Contact with soft tissue should be avoided since the material may produce **transient gingivitis or black discoloration.**

-Placement of rubber dam or cotton rolls.

-Coating the gingival tissue with petroleum jelly.

Frequency of application:[4,6,9]

-Biannual application increased the rate of caries lesion arrest compared to annual.

-3 months interval SDF application on the rest of the dentition at 3 months interval.

Dosage & Safety:[3,4,8]

-Average lethal dose by oral administration of SDF → 520 mg/kg.

-One drop (25microliters) → 9.5mg SDF

-For 10kg child, the dose would be 0.95mg/kg.

Masking of black discoloration:[6,8,9,14]

Alternatives to SDF	Reeducing agents	Resoration
1. Silver nano fluoride 2. Ammonium hexafluoro silicate	1. Potassium Iodide 2. Magnesium chloride 3. Tea 4. Glutathione	SMART Technique or Crowns

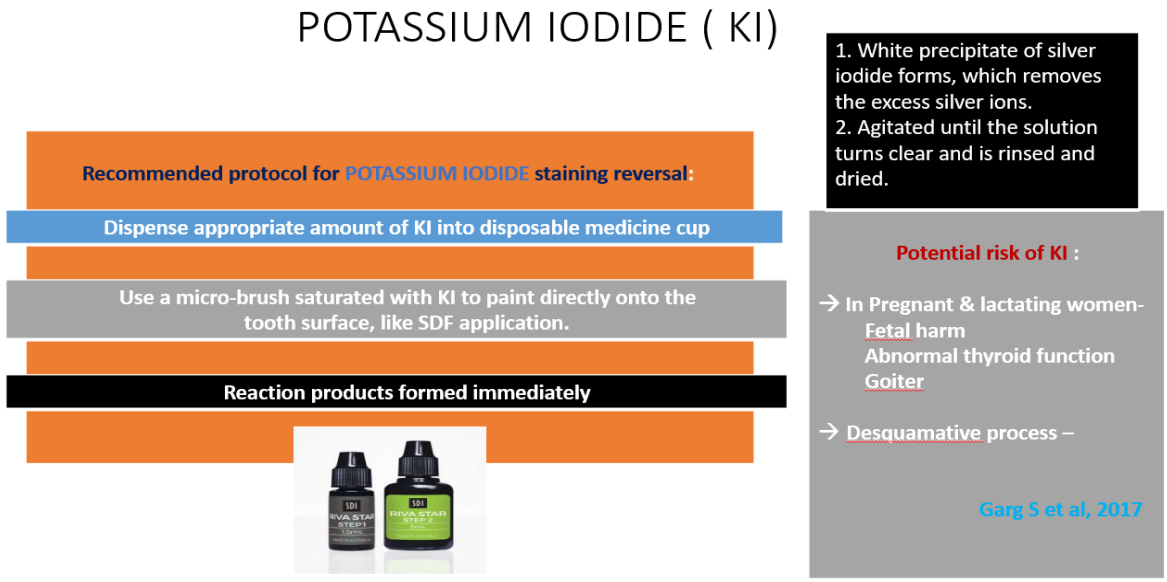

Figure 2: Potassium Iodide

Adverse Reaction:[8,9,10,23]

1. Metallic / bitter taste
2. Temporary staining to skin that resolves in 2-14 days.
3. Mucosal irritation/ lesions – resolves within 2 days.
4. Sensitivity to light – dark/opaque container.
5. High fluoride concentration (44,800 ppm) of 38% SDF.

⇓

Dental fluorosis

⇓

Large doses in young children

6. SDF is cytotoxic to fibroblasts → It increase pulp cell death hen the remaining dentin thickness is less.

Follow up:[4,8,12,16]

1. Evaluation of SDF treatment at 2-4 weeks after the initial application is recommended to determine if the lesions are arrested unless treating lesions with only superficial dentinal involvement.
2. Lesions that are not arrested can be retreated with SDF again at the recall visit.
3. If appropriate, the lesion can be restored at a later visit with a conventional restoration depending on behaviour of the child.
4. Biannual reapplications may be required for continued effectiveness.

Recommended protocol for POTASSIUM IODIDE (KI) staining reversal:[3,7,11]

1. Dispense appropriate amount of SDF into disposable medicine cup (one drop can be applied to at least five teeth with moderate size cavities.
2. Apply petroleum jelly or use rubber dam to protect soft tissue near affected areas.
3. Dry affected tooth surfaces as much as possible with air syringe or with cotton pellets.
4. Use a micro brush saturated with SDF to paint directly onto the tooth surface.
5. Avoid cavity margins or soft tissues.
6. Allow to absorb for one minute, then remove excess with cotton pellets.
7. Dispense appropriate amount of KI into disposable medicine cup.
8. Use a micro-brush saturated with KI to paint directly onto the tooth surface, like SDF application. Reaction products will be formed immediately.
9. Restore areas with resin – modified glass ionomer or composite restoration as indicated.

STUDIES OF SILVER DIAMINE FLUORIDE

S. No	TITLE & JOURNAL	AUTHOR, YEAR, PLACE	RESULT	STUDY RELATION
1.	Parental expressed concerns about SDF treatment.[13] JOURNAL OF CLINICAL PEDIATRIC DENTISTRY	Crystal Y O et al, 2019, NEWYORK	The parental acceptance for SDF treatment increased due to the risk of alternative treatments Location Visibility	PARENTAL ACCEPTANCE
2	SDF staining is acceptable for posterior primary teeth and is preferred over advanced pharmacologic behaviour management by many parents.[14] JOURNAL OF EVIDENCE BASED DENTAL PRACTICE	Gorden N B et al, 2018 USA	SDF application was esthetically acceptable Post: 67.5% Ant: 29.7 1/3rd of parents Other factors: AGE, INCOME EDUCATION& ETHINICITY	PARENTAL ACCEPTANCE
3	Effect and acceptance of SDF treatment on dental caries in primary teeth.[15] JOURNAL OF PUBLIC HEALTH DENTISTRY	Clemens J et al, 2017, USA (FLORIDA)	SDF was effective in arresting active carious lesions in primary teeth Well accepted by parents.	PARENTAL ACCEPTANCE
4	Potassium Iodide: The solution to SDF discoloration?[16] ADVANCES IN DENTISTRY & ORAL HEALTH	Nguyen V et al, 2017 USA (Florida)	SDF treatment along with saturated solution of KI markedly reduced staining compared to SDF alone, with or without common restorative materials.	STUDY ON POTASSIUM IODIDE FOR STAINING REVERSAL
5	Effect of SDF & KI treatment on secondary caries prevention and tooth discoloration in cervical GIC restorations.[17] INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES	Zhao I S et al, 2017 HONG KONG	Secondary caries- SDF + KI→ Secondary caries formation can be avoided. Staining is possible.	STUDY ON POTASSIUM IODIDE FOR STAINING REVERSAL
6	Effect of SDF on dentine carious lesions induced by S. mutans & A. naeslundii biofilms.[18] INTERNATIONAL JOURNAL OF PEDIATRIC DENTISTRY	Chu et al, 2012, HONG KONG	1. SDF poses an antimicrobial activity against cariogenic biofilm of SM & AN. 2. SDF slowed down demineralization in dentine	As an antibacterial/ antiplaque agent
7	Efficacy of SDF as an antibacterial as well as anti-plaque agent compared to Fluoride varnish and Acidulated phosphate fluoride gel.[19] INDIAN JOURNAL OF DENTAL RESEARCH	Shah et al, 2013, SANTEJ, GUJARAT, INDIA	1. Significant reduction was found in S. mutans counts irrespective of group division 2. No statistical diff. of plaque score 3. S. mutans reduction > G1	As an antibacterial/ antiplaque agent
8	Adverse effects of SDF treatment among preschool children.[20] (RCT) JOURNAL OF DENTAL RESEARCH	Duangthip O, 2017, HONG KONG	Blackening of caries lesion: G1: 36.7% G2: 49.5% G3: 65.5% G4: 76.3 % Prevalence of tooth/ gum pain – 6.6% Proportion of parents satisfied with children's dental appearance 67.6% 61.5% 70.8% 62.3% Tooth/ gum pain, gum swelling, gum bleaching– not significant and uncommon in all groups	Study on adverse effects of SDF

9	RCT of 12% and 38% SDF treatment.[21] JOURNAL OF DENTAL RESEARCH	Fung M H et al, 2018, USA	Caries arrest rate Group 1: 55.2% Group 2: 58.6% Group 3: 66.9% Group 4: 75.7% SDF 38% -- Semi-annually	DIFFERENT CONCENTRATIONS
10	Effect of SDF for caries reduction in primary teeth and 1st permanent molars of school children: 36-month clinical trial.[22] JOURNAL OF DENTAL RESEARCH	Llorda J C et al, 2005 SPAIN	Mean no. of new decayed surfaces Primary: Gp1 with SDF:0.29 Gp2 – control: 1.43 Permanent: Gp1: 0.37 Gp2: 1.06	DIFFERENT CONCENTRATIONS
11	Inhibitory effect of SDF on dentin demineralization & collagen degradation.[23] JOURNAL OF DENTISTRY	Mei M L et al, 2013, HONGKONG	The use of 38% SDF inhibited demineralization & preserved collagen from degradation in demineralized dentin.	Comparative studies
12	Effect of SDF & KI on residual bacteria in dentinal tubules.[24] AUSTRALIAN DENTAL JOURNAL	Hamama et al, 2015 EGYPT	45 Dentine discs from caries free maxillary premolars 9 groups Negative control Positive control SDF+ KI CHX CARISOLV PAPACARIE SDF + KI exhibited a potent antibacterial effect as represented by a significantly higher percentage of dead bacteria in comparison with carisolv&papacarie.	Comparative studies
13	Silver Diamine Fluoride: A Caries "Silver Fluoride Bullet".[25] JOURNAL OF DENTAL RESEARCH	Rosenbalt A, 2009 BOSTON, USA	Caries arrest: 97% Caries prevention: 70% Compared to Fluoride varnish: CA: 21% CP: 58%	Systematic review/ Meta analysis
14	SDF has efficacy in controlling caries progression in primary teeth: A systematic review & meta-analysis.[26] CARIES RESEARCH	Chibinski A C 2017 BRAZIL	SDF caries arrest was 66% higher than other materials and 154% higher than placebo.	Systematic review/ Meta analysis

II. Conclusion:

Application of SDF biannually is better than all other minimally invasive treatment choices. However, it is unclear what will happen if treatment is stopped after 2-3 years and further research is required. SDF is more effective as a primary preventive material than other restorative materials which are available, except dental sealants which are >10 times more costly and needs professional follow up.The black staining is potential disadvantage, but the parents favourably select SDF over invasive technique as it is painless and safe.

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