



Review Article

Silver diamine fluoride - Magic alternative in caries management: A review

Pallavi Anand^{1,*}, Pulkit Jhingan¹, Manvi Malik¹, Shivani Mathur¹, Vinod Sachdev¹¹Dept. of Pediatric and Preventive Dentistry, ITS-CDSR, Muradnagar, Ghaziabad, Uttar Pradesh, India

ARTICLE INFO

Article history:

Received 10-06-2020

Accepted 10-09-2020

Available online 21-07-2021

Keywords:

SDF

Early childhood caries

Parental consent

Oral health

COVID 19

ABSTRACT

Silver diamine fluoride (SDF) is a clear and odorless liquid used for dentinal hypersensitivity and arresting caries unless there's no pulpal involvement for all age groups across all countries. Discoveries let us change old paradigms with the new ones. SDF being cleared for commercial use now can help in achieving the all-time goal of caries prevention. Various studies have established that options like potassium iodide and different restorations can help mask the staining problem of SDF. This can restore form and function as well for the teeth. With the unimaginable COVID 19 situation, dentistry has realized the importance of minimally invasive interventions than ever before. SDF is a blessing in such challenging times and it may be the magical alternative to caries management in the future.

© This is an open access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>) which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

1. Background

“Aside from fluoridated water, silver diamine fluoride may be the single greatest innovation in pediatric dental health in the last century.”

- Dr. James Nickman

For decades, dentists worldwide have been promoting oral health with more fluoridation and less sugar consumption. Even with these efforts, dental caries is most prevalent yet preventable chronic diseases in the world. Over the years a change in caries management has been observed. Newer caries-risk assessment based options are being explored rather than focusing on the traditional approaches alone. Minimally invasive alternatives to the “drill and fill” approach have been advocated in the past decades.¹ With the introduction of Silver Diamine Fluoride (SDF), paradigm shift to non-invasive, inexpensive, easy to apply, interim intervention has occurred. It is used to treat and prevent dental caries and relieve dentinal hypersensitivity, especially in underprivileged populations lacking timely access to restorative dental services.

SDF is commonly known to be a “silver fluoride bullet” to caries. Well known expression ‘silver bullet’ or ‘magic bullet’ originates from a mythical age belief that actual silver bullets were the only option to kill werewolves or other supernatural beings.

The current literature search focuses on the greatest innovation of all times which has now become a tool in every dentist’s armamentarium.

2. History

The more you know about the past, the better prepared you are for the future.

-Theodore Roosevelt

Silver compounds were used in dentistry since around 1000 AD in Japan. SDF was first investigated in Japan (Osaka University) in 1969. Research on SDF as an alternative dental treatment emerged was reported from the developing world, where access to dental care was extremely limited.² By August 2014, SDF was approved by the Food and Drug Administration (FDA) as a Class II medical device for managing dentinal hypersensitivity. In October 2016, the FDA awarded SDF the designation of “breakthrough therapy” due to its ability to arrest dental decay across all

* Corresponding author.

E-mail address: pallavianand_mds18_21@its.edu.in (P. Anand).

age groups, a first for oral health therapy.³

First evidence-based dentistry (EBD) guideline was published by the American Academy of Pediatric Dentistry (AAPD) on the use of 38% SDF in September 2017. Presently, SDF is covered under the Current Dental Terminology code D1354 as set forth by the American Dental Association (ADA). This is designated for a caries-arresting medicament to topically treat an existing asymptomatic carious lesion without removal of tooth structure by oral health care professionals.

2.1. Composition and mechanism

SDF is a colorless, odorless liquid of a pH around 10 comprising of:

1. 25% Silver: active antimicrobial ingredient.
2. 8% Ammonia: solvent which made it possible for SDF to be a stable solution.
3. 5% Fluoride (44,800 ppm): The remineralizing agent.

This is referred to as 38% SDF which was found to be the most effective in various clinical trials. AAPD has hypothesized that it is the fluoride ions that mainly act on the tooth structure, whereas silver ions are antimicrobial. When SDF and hydroxyapatite reacts the resultant compounds are silver phosphate and calcium fluoride (CaF₂). Fluorapatite is formed from the fluoride in CaF₂ which is less soluble than hydroxyapatite in an acidic environment.

Some widely used brands that are available commercially in different countries are as follows:

1. USA: 38% SDF solution, Advantage Arrest
2. India: 38% SDF solution, e-SDF
3. Japan: 38% SDF solution, Saforide
4. Argentina: 38% SDF solution, Fluoroplat

2.2. How to apply?

Following the manufacturer's directions for use of SDF is the most accepted method of application. e-SDF is a pre-filled bottle containing 5ml 38% Silver diamine fluoride liquid. They advise keeping in mind the precautions for use and handling before starting the treatment. Due to the ability of SDF to stain surfaces/clothing permanently; it is optimal to use standard Personal Protective Equipment (PPE) for both dentist and patient.

Directions for Use

1. Excavate gross debris from the lesion
2. Maintain proper isolation and coat vaseline on the surrounding soft tissues
3. Drying of cavity with a soft flow of air
4. Dispense 1 drop SDF in a plastic dappen dish
5. The dispensed liquid is coated on the cavity using a microbrush. Superfloss is soaked in for 1-3 minutes for interproximal decay.

6. Excess is removed with a cotton pellet
7. To reduce blackening, polish along the margins of the discoloration or cover with restoration
8. For enhanced results, repeat once every 6 months

2.3. The zombie effect

Something coming back from the dead almost always is considered bad news but not for this magic bullet. The silver killed bacteria by SDF have been known to cause the "zombies effect".⁴ This metal-induced biocidal action by SDF can be explained as follows:

1. Even after the bacterial death, the silver ions can continue with their biocidal action
2. The killed bacteria act as an efficient reservoir of lethal metallic cations that are continuously released to act against on the other live bacteria.

2.4. Frequency of application

The key factor in SDF is repeated application over multiple years. To evaluate the caries arrest following application of SDF, a follow up after 2-4 weeks has been suggested by the AAPD. Reapplication is advised if the lesion does not appear dark and hard on probing. Unless a restoration has been done for esthetics, a biannual SDF application has been recommended by the AAPD as it has shown a higher percentage of caries arrest than in an annual application⁵.

2.5. When is SDF used?

2.5.1. COVID-19 Pandemic Era

In a time like COVID-19 where aerosol-generating procedures (AGPs) are avoided to control the risk of cross-infection, SDF can be used as a provisional therapy for caries management across all age groups. The new norm in dentistry is all about the non-AGPs which exponentially increases the value of SDF.

2.5.2. Delay In treatment under sedation by parents

In 2016 U.S. FDA reported the side effects of prolonged use of general anesthetic and sedation drugs used during procedures on the development of children's brains younger than 3 years of age. Following this warning, parents have found a need to explore minimally invasive treatment options like SDF till the time their children are older or cooperative for traditional dental treatment.

2.5.3. Caries arrest for those with special health care needs (SHCN) and medically frail patients

Traditional approaches in oral health care rehabilitation may not be as simple for patients with special needs or complicated medical problems such as chemotherapy, salivary dysfunction or, an immunocompromised state. SDF can be successfully used in such cases as well.

2.5.4. Caries control in patients with early childhood caries (ECC)

Patients with a high risk of caries development such as in ECC, conventionally more sittings are required thus increasing the financial burden. SDF can be a suitable alternative for such cases, by preventing the worsening of the condition due to monetary issues.

2.5.5. Silver modified atraumatic restorative treatment (SMART)

SDF can only arrest caries development; however, the esthetics and function of the tooth can be gained later by a method known as SMART. This approach uses High Viscosity Glass Ionomer Cement which is a self-curing bulk-fill restorative material.

2.5.6. Geriatric population

Older adults face multifactorial challenges ranging from alteration in salivary flow due to age and medication and recession leading to exposure of root surfaces to limited finances and restricted mobility. These challenges in return may lead to untreated dental caries. SDF's role in managing caries in the elderly has been researched widely through a systematic review that recommended SDF as an economical method of dental caries treatment in older adults.⁶

2.5.7. Hypersensitivity

SDF blocks dentinal tubules and forms fluorhydroxyapatite. This not only combats dentinal hypersensitivity but also increases the mineral density and hardness of the tooth.

2.5.8. Molar Incisor Hypomineralization (MIH)

It is a common developmental condition causing defective mineralization which is responsible for increased caries risk and extreme hypersensitivity. This is a clinically challenging situation especially in young patients. It requires invasive, expensive, and multiple dental appointments making it taxing for the patient as well as the dentist. SDF application for teeth desensitization followed by a SMART restoration has been a game-changer in MIH cases.

2.5.9. Secondary caries

Caries is a chronic disease with no cure and restorations with finite longevity which can often result in recurring caries surrounding the restorative margins. The life expectancy of an existing restoration can be improved by a simple and cost-effective application of SDF.

2.5.10. Incipient Interproximal Lesions

Due to the challenging anatomical location of interproximal lesions, a sizeable amount of tooth surface is lost in cavity preparation. To conserve a healthy natural tooth structure and postpone or prevent the need for further intervention,

SDF is applied using a puffy floss to arrest the incipient cavity.

2.5.11. Disinfection of root canals

3.8% SDF has shown root canal disinfection in infected teeth. A study supported this by indicating that a 3.8% SDF solution showed a 100% reduction of *Enterococcus faecalis* after 60 minutes of exposure.⁷

2.5.12. Community level

Patients without access to dental care can also benefit from the SDF application.

SDF treatment offers versatility which can be used in any clinical setting due to its low cost, minimal equipment, and low technique sensitivity among its other advantages.

2.6. When to not use SDF?

1. Teeth that require pulpal therapy,
2. Individuals at risk of or having silver allergy and
3. Patients with existing mouth sores (herpetic gingival stomatitis)

3. Safety

Innovation is the ability to see change as an opportunity, not a threat.Steve Jobs

The US FDA consulted the dose limit, based on all shreds of evidence from their various clinical trials. They concluded that one drop (25 μ L) contains 9.5 mg SDF and can treat up to 5 teeth. SDF offers a 400-fold safety margin. The relative safety margin for one drop on a 10kg child is: 380 mg/kg Lethal Dose (LD50) / 0.95 mg / kg dose.⁸

3.1. Unfavorable effects

In the published literature on the clinical dental use of SDF among all age groups, exposure to recommended amounts of SDF has not resulted in any reported deaths or systemic adverse effects.⁸ The disadvantages of the magic bullet include:

1. Staining of teeth: SDF permanently blackens enamel and dentinal caries lesions irreversibly due to the formation of silver oxide leading to poor esthetics.
2. Temporary tattoo: On skin contact, SDF creates a harmless silver nitrate stain. However, the skin stain is temporary owing to failure of dermal penetration by the silver and 2-14 days desquamation of skin occurs.
3. White lesion on mucosa: Gingival responses are minimal if SDF contacts the mucosa. Some studies have reported a transient mucosal white lesion with mild pain which healed in 48 hours without any intervention.
4. Stained surfaces: SDF can permanently stain most surfaces such as tables, clothing if it comes in

contact. These stains from the spill can be removed immediately before it dries up either copious water or ethanol. High pH solvents such as ammonia are more successful.

The undesirable effects of SDF are outweighed by its desirable properties in most cases. The permanent staining of carious teeth can be reversed by the use of Potassium Iodide (KI).

3.2. Reversing the silver stain

Dark staining of decayed teeth by SDF can be reversed through instantaneous coat of Saturated Solution of Potassium Iodide (SSKI). Iodide and silver ions then react to make silver iodide which is responsible for masking the staining. The use of SSKI with SDF has not only shown reduced staining but also inhibited the development of secondary caries.⁹ Riva star is such a commercially available mixture improving esthetics that can enhance the prospect of SDF's comprehensive use.

SSKI use is not advised in expecting mothers and during the first six months of breastfeeding as it can overload the developing thyroid with iodide.

3.3. Effect on bonding

According to the published studies if a conventional bonding system is used there is no effect on composite bonding to non-cavitated dentin.¹⁰ For carious teeth, simply rinsing after the SDF application will suffice for direct restorations. To facilitate normal form and function of compromised primary teeth, stainless steel crown can be a useful restorative option once the caries are arrested by SDF, until the succedaneous permanent teeth are not erupted.

3.4. Consent

Silver Diamine Fluoride's off label use as a medical device to prevent and treat dental caries makes it even more important to take consent from the parents/guardians. Plenty recognized bodies have a special consent form for SDF application which explains the benefits and the risks of the treatment. Some parents consider this treatment unacceptable which is why informed consent should have pictures of the staining, especially when treating anterior teeth to avoid any legal complications. This can be correlated to the famous proverb "Better safe than sorry".

3.5. Acceptance of SDF

Acceptance of SDF is generally seen in parents when their dental care provider after exhausting all other options of care, suggests treatment under general anesthesia. It is quite fascinating that at least for young children, the color change is being perceived by the parents as a positive indication for effective treatment. Although a survey concluded that

parental acceptance of SDF staining especially in the anterior teeth region was the biggest barrier in its use.¹¹ Evidence-based dental treatments such as SDF are to be counseled well among the increasing caregiver and patient niche for its appropriate acceptance.

3.6. SDF vs fluoride varnish

The topical application of fluoride has been proven to be the most important method in combating carious lesions. 5% Sodium fluoride (NaF) varnish containing as high concentration as 22,600ppm F have been clinically proven to arrest caries. In infants, both SDF and NaF have been indicated and used due to their easy application and safety. However, research suggests superiority of SDF in both arresting and preventing caries.¹²

3.7. SDF and laser

These two new-age tools of dentistry used together have proven to be a boon. For superior caries prevention, SDF with LASER irradiation may be used to strengthen dentin. LASER irradiation of any topical fluoride increases its uptake on dentin enhancing its action. The limited literature on this topic has explained the possible mechanism for the combined effect of SDF and LASER irradiation as the alteration in the composition of recrystallized hydroxyapatite, resulting in decreased solubility; enhanced uptake of fluoride to make fluorapatite; and micropores created within the mineral structure, providing sites for precipitation of calcium, phosphate, and fluoride.¹³ This can contribute to the fact that a 38% SDF solution followed by LASER irradiation can reduce the risk of tooth fracture of endodontically treated teeth.

4. Role of Pediatrician

Coming together is a beginning; keeping together is progress; working together is success.

-Henry Ford

Early childhood caries can be disastrous for young children if not treated vigilantly. American Academy of Pediatrics (AAP) encourages pediatricians to identify and refer patients to a dental home by the age of 1 where they could benefit from SDF therapy. Patients and their families should be questioned when black teeth are noted on oral inspection in regular pediatric appointments to determine if SDF is being used. Providers should stress follow up appointments within the dental home at least every six months to promote optimal outcomes.

5. Conclusion

1. SDF has a significant potential to change the conventional surgical dental paradigm of oral healthcare in our country till the community level.

2. Biannual application of SDF is 20 times less expensive and outplays all minimally invasive options including the Atraumatic restorative techniques. Many parents are in favor of less invasive caries management techniques when their child's cooperation is a barrier to the traditional dental treatment.
3. SDF not only aiding in the management of early childhood caries but also helps in dentinal hypersensitivity.

Lastly, in difficult times like COVID19 more and more options like SDF where AGP is not required are the need of the hour.

6. Source of Funding

No financial support was received for the work within this manuscript.

7. Conflicts of Interest

There are no conflicts of interest.

References

1. Kidd E. The implications of the new paradigm of dental caries. *J Dent.* 2011;39:3-8.
2. Contreras V, Toro MJ, Elías-Boneta AR, Encarnación-Burgos A. Effectiveness of silver diamine fluoride in caries prevention and arrest: a systematic literature review. *Gen Dent.* 2017;65(3):22-9.
3. Crystal YO, Niederman R. Evidence-Based Dentistry Update on Silver Diamine Fluoride. *Dent Clin North Am.* 2019;63(1):45-68. doi:10.1016/j.cden.2018.08.011.
4. Wakshlak RBK, Pedahzur R, Aynir D. Antibacterial activity of silver-killed bacteria: the "zombies" effect. *Sci Rep.* 2015;5(1):9555. doi:10.1038/srep09555.
5. Fung MHT, Duangthip D, Wong MCM, Lo ECM, Chu CH. Arresting Dentine Caries with Different Concentration and Periodicity of Silver Diamine Fluoride. *JDR Clin Transl Res.* 2016;1(2):143-52. doi:10.1177/2380084416649150.
6. Subbiah GK, Gopinathan NM. Is silver diamine fluoride effective in preventing and arresting caries in elderly adults? A systematic

- review. *J Int Soc Prev Community Dent.* 2018;8(3):191-9. doi:10.4103/jispcd.jispcd_99_18.
7. Mathew VB, Madhusudhana K, Sivakumar N, Venugopal T, Reddy RK. Anti-microbial efficiency of silver diamine fluoride as an endodontic medicament - An ex vivo study. *Contemp Clin Dent.* 2012;3(3):262-4. doi:10.4103/0976-237x.103615.
8. Horst JA, Ellenikiotis H, Milgrom PL. UCSF Protocol for Caries Arrest Using Silver Diamine Fluoride: Rationale, Indications and Consent. *J Calif Dent Assoc.* 2016;44(1):16-28.
9. Zhao I, Mei M, Burrow M, Lo E, Chu CH. Effect of Silver Diamine Fluoride and Potassium Iodide Treatment on Secondary Caries Prevention and Tooth Discolouration in Cervical Glass Ionomer Cement Restoration. *Int J Mol Sci.* 2017;18(2):340. doi:10.3390/ijms18020340.
10. Quock RL, Barros JA, Yang SW, Patel SA. Effect of Silver Diamine Fluoride on Microtensile Bond Strength to Dentin. *Oper Dent.* 2012;37(6):610-6. doi:10.2341/11-344-1.
11. Crystal YO, Janal MN, Hamilton DS, Niederman R. Parental perceptions and acceptance of silver diamine fluoride staining. *J Am Dent Assoc.* 2017;148(7):510-8. doi:10.1016/j.adaj.2017.03.013.
12. Rosenblatt A, Stamford TCM, Niederman R. Silver Diamine Fluoride: A Caries "Silver-Fluoride Bullet". *J Dent Res.* 2009;88(2):116-25. doi:10.1177/0022034508329406.
13. Zhang C, Kimura Y, Matsumoto K. The Effects of Pulsed Nd:YAG Laser Irradiation with Fluoride on Root Surface. *J Clin Laser Med Surg.* 1996;14(6):399-403. doi:10.1089/clm.1996.14.399.

Author biography

Pallavi Anand, Post Graduate Student

Pulkit Jhingan, Reader

Manvi Malik, Reader

Shivani Mathur, Professor (Co-Chairperson -Research Lab)

Vinod Sachdev, Professor and HOD

Cite this article: Anand P, Jhingan P, Malik M, Mathur S, Sachdev V. Silver diamine fluoride - Magic alternative in caries management: A review. *J Dent Spec* 2020;8(2):47-51.