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Silver Diamine Fluoride in Pediatric Dentistry: SDF Review Article

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ABSTRACT

In young children, untreated tooth decay can cause discomfort, low self-esteem, weight loss, sleeping difficulties, and loss of space, resulting in severe crowding and misalignment of succedaneous teeth. Apart from these concerns, treating young children is a difficult chore for dentists because of behavioral issues that make treatment more difficult. Considering these facts, an innovative anti-caries agent known as silver diamine fluoride has gained popularity among dentists. The aforementioned agent has antibacterial properties that perform both to prevent and arrest tooth decay. The noninvasive approach is the treatment of choice among dentists for dealing with uncooperative children since it is simple and quick to use. It can be used as preferred therapeutic agent for those patients where aerosol production is contraindicated.

Keywords: SDF; Silver diamine fluoride; Magic bullet; Nanobullet; Miracle antidote

INTRODUCTION

Early Childhood Caries (ECC) is one of the most common diseases affecting deciduous dentition, despite continual advances in disease genesis and prevention efforts, it continues to have a negative influence on the health of young children, with social and economic consequences. ECC occurs in young children as a result of a number of risk factors, including malnutrition, low socioeconomic status, prolonged bottle feeding, frequent snacking, iron and Vitamin D deficiency, and untreated ECC has additional consequences, including an increased risk of caries, loss of succedaneous teeth, pain, weight loss, low self-esteem, missed school hours, costly emergency treatment, and limited growth and development of jaw bone. As a result, untreated carious lesions and underutilization of dental treatments have emerged as two of the most urgent public health issues confronting children in developing nations. Further, traditional restoration techniques are time-consuming and difficult, requiring child cooperation for a successful outcome. Precooperative children are not ideal candidates for the same situation. Understanding the complexities of the condition and circumstances, a unique miracle panacea with anti-cariogenic properties has been developed which has proven to be a boon for both pediatric and general dentists. Various fluoride-based prevention strategies and remineralizing agents are advocated to prevent dental caries in children. Among these caries arresting methods, topical Silver Diamine Fluoride (SDF) has recently gained enormous popularity among dentists worldwide due to its non-invasive, low-cost, easy-to-apply success in stopping and preventing the progression of dental caries [1-7] (**Figure 1**).

Composition

The fluoride content of SDF solutions vary based on the manufacturer and brand. The most usually utilized SDF concentration is 38% [8] (**Tables 1 and 2**).

Table 1: Composition of SDF most commonly used in concentration 38%.

Silver Diamine Fluoride (At 38% concentration)					
S.No	**Components**	**ppm**	**W/v (%)**	**Properties**	**pH**
1	Silver	2,55,000	24.4-28.8	Antimicrobial	
2	Ammonia		7.5-11	Stabilizes high concentration of solution	10
3	Fluoride	44,800	5.0-5.9	Antimicrobial and remineralization	

Table 2: Commercially available brand names of SDF in different coun-

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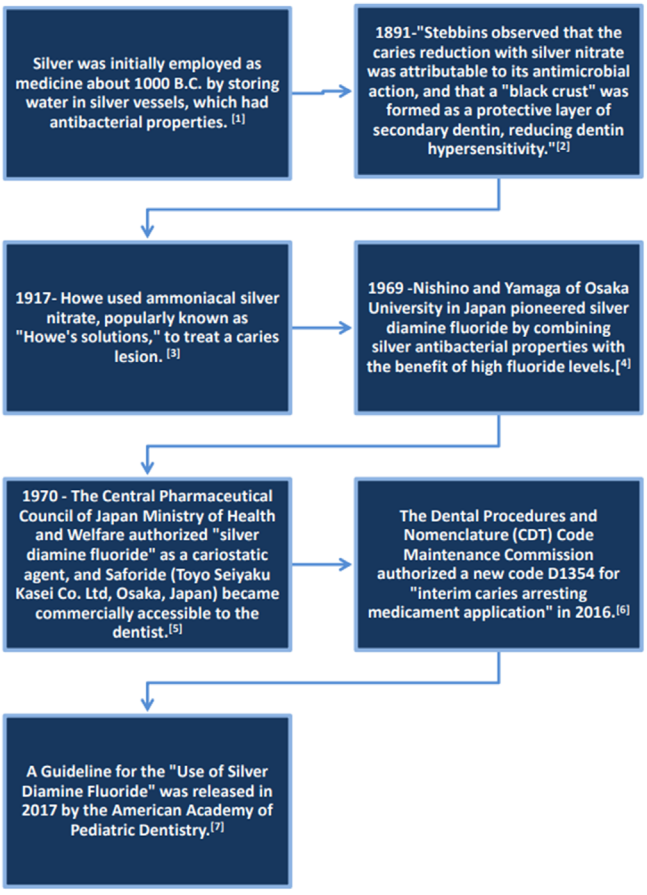
tries with concentration in percentage.

SDF (%)	Product brand	Manufacturer	Country	Product Image
Dec-30	Cariestop	Biodinamica	Brazil	
38	Saforide	Toyo Seiyaku-Kasei	Japan	
38	Advantage Arrest	Elevate Oral Care	United States	
38	e-SDF	Kids-e-dental, mumbai	India	
38	FAgamine	Tedequim SRL	Argentina	
30-35	Riva Star	SDI Dental Ltd	Australia	



Physical Properties

- It is a colorless, odorless aqueous solution containing silver ions, ammonium and fluoride ions [9].
- It is highly alkaline (pH=10)
- IUPAC name Diamminesilver (I) fluoride
- Formula-AgF $(NH_3)^2$
- Molar mass-160.927643g/mol [10]
- 3D model (JSmol) (**Figure 2**)

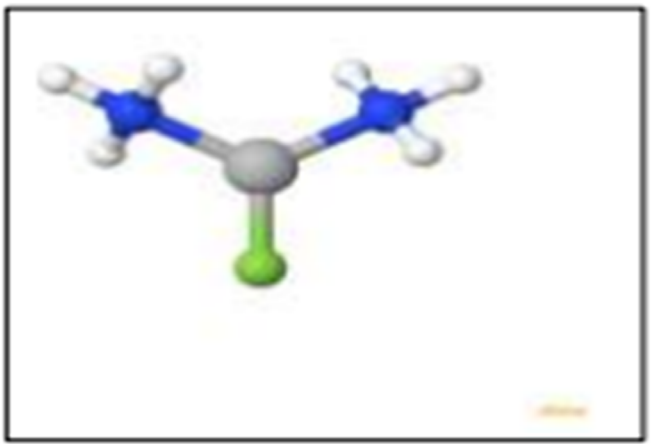


Figure 2: 3D model of Silver diammine fluoride.

Chemical Misnomer

Since 1969, the SDF compound has been incorrectly spelled or mispronounced as "Ammoniacal silver fluoride," "Silver fluoride diamine," and so on, even though the fact that the correct nomenclature term is silver diammine fluoride, which contains "ammine" groups (-NH_3) rather than "amine" groups (NH_2). "Ammine" refers to a chemical species in which one or more ammonia molecules (NH_3) are bonded in a coordination complex with a metal ion." The nomenclature term "Diamine" has achieved universal approval and is now used in both scientific and promotional contexts [11].

Indications

- Patients at a high risk of dental caries, For example, Xerostomia, salivary dysfunction, cancer therapy, and dental anxiety [12].
- Pre-cooperative children whose behavior limits invasive restorative treatment to avoid restorative care under general anesthesia or sedation [13].
- When aerosol generating procedures are unable to be performed. For example, COVID-19, Asthma, etc.
- Patient without access to dental care [12].
- Teeth that has no sign and symptoms of pulpitis.
- Active carious lesion on the root surface [14].
- Carious primary teeth that exhibit signs of exfoliation on radiographs [15].
- MIH (Molar Incisor Hypomineralization) to relieve the symptoms of dentin hypersensitivity [16].

Contraindications

- Patient allergic to silver [17].
- Patient with oral soft tissue ulcers, for examples, Desqua-

mative gingivitis, Stomatitis [12].

- Patient with thyroid medication, pregnancy, known allergy to potassium or iodide [13].
- If parents or guardians refuse to use SDF because they are concerned about color changes.
- It is not advisable to use where isolation of tooth or oral tissue is not possible.
- Clinical sign and symptoms of irreversible pulpitis [18,19].
- Radiographic sign of pulp involvement or peri-apical pathology [13, 20-23] (**Figure 3**).

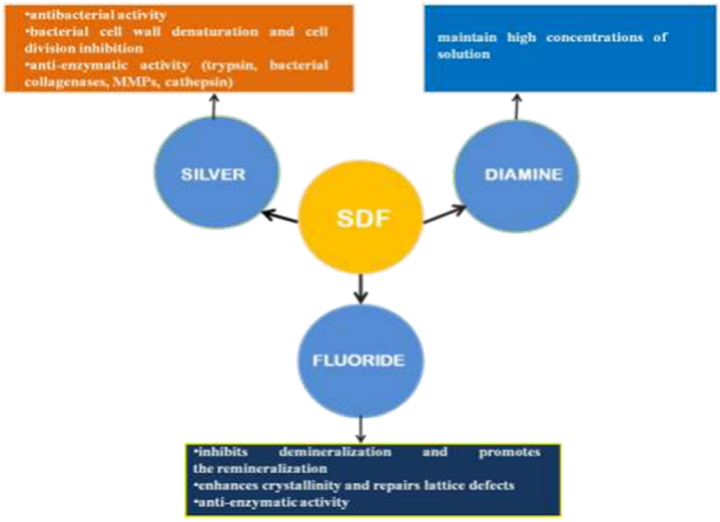


Figure 3: Flowchart representation of mechanism action of SDF.

MECHANISM OF ACTION OF SILVER DIAMINE FLUORIDE

Use of Sdf in Clinical Practice

Sdf in caries arrest of primary dentition: SDF is known for its anti-cariogenic properties, but it has been employed in a variety of applications in the literature. The **Table 3** below presents summary of published studies on caries arrest in children by SDF [24-36] (**Tables 3 and 4**).

Table 3: Summary of published studies on caries arrest in children.

Author	Study period months	Study design	Dentition studied	Study groups (sample size)	CA (%)	Application	Follow-up visits months
Chu et al.	30	PCCT	Primary anterior	38% SDF (641)	65	Annual	6, 12, 18, 24, 30
				5% NaF (576)	41		
				No treatment (273)	34		
Llodra et al.	36	RCT	Primary canine, molars and PFMs	38% SDF	85	Semi-annual	6, 12, 18, 24, 30
				-675			
				No treatment (658)	62		
Braga et al.	30	pilot RCT	first molar	Cross tooth brushing technique(22) 10% SDF(22) GIC(22)	No significant. equal in all groups	Semi-annual	3, 6, 12, 18, and 30
Yee et al.	24	RCT	Primary	38% SDF (3,396)	31	Single	6, 12, 24
				12% SDF (1,652)	22	application	
				No treatment	15		
Zhi et al.	24	RCT	Primary	38% SDF (218)	91	Annual	6, 12
				38% SDF (239)	79	Semi-annual	
				GIC (262)	82	Annual	
dos Santos et al.	12	RCT	Primary	30% SDF (183)	67	Single	12
				GIC (162)	39	application	
Duangthip et al.	18	RCT	Primary	30% SDF (458)	40	Annual	6, 12,18
				30% SDF (426)	35	Single	

						application	
				5% NaF (523)	27	Single	
						application	
Duangthip et al.	30	RCT	Primary	30% SDF (377)	48	Annual	5, 12, 18, 30
				30% SDF (367)	33	Once a week	
						for 3 weeks	
				5% NaF (484)	34		
Fung et al.	30	RCT	Primary	12% SDF (927)	55.2	Annual	6, 12, 18, 24, 30
				12% SDF (987)	58.6	Semi-annual	
				38% SDF (971)	66.9	Annual	
				38% SDF (905)	75.7	Semi-annual	

PCCT, Prospective Controlled Clinical Trial; RCT, Randomized Clinical Trial; Pfms, Permanent First Molars; Naf, 5% Sodium Fluoride Varnish; GIC, Glass Ionomer Cement; CA, Caries Arrest; M, Month

Table 4: Summary of published studies utilizing SDF as root can irrigant.

Author	Year	Study	SDF (%)	Conclusion
Hiraishi et al.	2010	*In vitro*	3.80%	They reported that 3.8% SDF showed 100% efficiency against E. faecalis after a direct 60-min exposure
Mathew et al.	2012	*Ex vivo*	3.80%	Both 3.8% silver diamine fluoride and 2% chlorhexidine showed a superior capacity to sterilize the root canals than control groups
Ebtissam and their colleagues.	2019	*In vitro*	3.80%	SDF possessed higher antimicrobial activity than 2% CHX against E. faecalis biofilms
Minavi et al.	2021	*In vitro*	3.80%	They demonstrated that SDF possesses antimicrobial properties against the opportunistic pathogen E. faecalis. Moreover, using a dentin model the substantivity of 3.8% SDF is significantly greater than 6.25% NaOCl, but is comparable to 2% CHX.
Maru et al.	2022	RCT	3.80%	A randomized, controlled clinical trial was performed that included primary molars with pulp necrosis. After analyzing samples before and after irrigation in the control group (NaOCl), they found a strong significant decrease of bacterial load. The same occurred in the 3.8% SDF group samples. SDF (Experimental) group was superior to control group.

DENTINE HYPERSENSITIVITY

Kiesow A. and colleagues (2022) "conducted an *in vitro* study in which they compared 38% SDF gel to non-viscous commercially available SDF [37]. Human root surface dentin specimens were treated with gelled or conventional 38% SDF or negative control. Penetration depths of up to 500 m were found for both SDF formulations. Both formulations occluded dentinal tubules in the same way. Precipitates were observed on the dentin surface and within dentinal tubules for both SDF formulations, with the experimental gel SDF product being slightly more abundant than the commercially available one. In terms of dentinal tubule penetration and occlusion, the 38% SDF gel formulation was indistinguishable from the commercial 38% SDF product [38-40] (**Table 5**) (**Figures 3-6**).

Table 5: Summary of SDF as indirect pulp capping agent.

S.No.	Studies (Authors, Years)	Study Type	Results/Conclusion
1	L de F (2011)	*In vivo*	Both glass ionomer and SDF can be potential IPC material.
2	Gupta et al. (2011)	*Ex vivo*	The calcium hydroxide group had the highest increase in calcium and phosphate ion levels. Fluoride ion levels increased significantly in the SDF and GC VII groups. The samples treated with GC VII showed the highest increase in microhardness. The SDF group had the highest zone of bacterial inhibition. Both SDF and GC VII can serve as excellent IPC materials.
3	Sinha et al. (2011)	*In vivo*	The percentage of calcium levels increased about equally in the GC VII and $Ca(OH_{)2}$ groups, followed by the SDF group. The GC VII group had the highest percentage rise in phosphate ions, followed by the SDF group and the $Ca(OH)_2$ group. The GC VII group had the highest percentage of fluoride increase, followed by the SDF group and the $Ca(OH)_2$ group. Both SDF and GC VII can serve as excellent IPC materials.

4	Shah A. and their co-worker (2020)	*In vivo*	SDF was evaluated as an indirect pulp capping agent in primary teeth, and the result showed that clinical and radiographic success at one month was 100% in SDF and 93.75% in calcium hydroxide, with no significant difference between the two groups. The study found that SDF can be used as a viable alternative for calcium hydroxide in primary teeth for IPC.
5	Shafi N. and Colleagues (2022)	RCT	The clinical and radiographic effects of diluted silver diamine fluoride (1:10) and light cure calcium hydroxide as indirect pulp capping agents in primary molars were evaluated. At the end of 12 months, the overall clinical and radiographic success rate of indirect pulp therapy with SDF was 96% and 91.6% with light cure calcium hydroxide, respectively, although the difference was not statistically significant. In primary molars with deep carious lesions, dilute silver diamine fluoride (1:10) can be recommended as a potential indirect pulp capping agent.

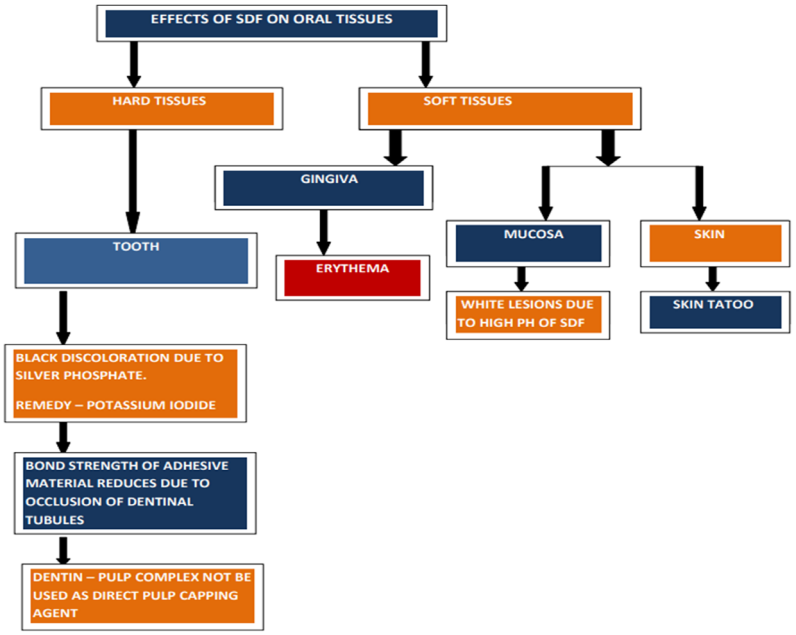


Figure 4: Flowchart representation of side effect of Silver Diammine Fluoride.

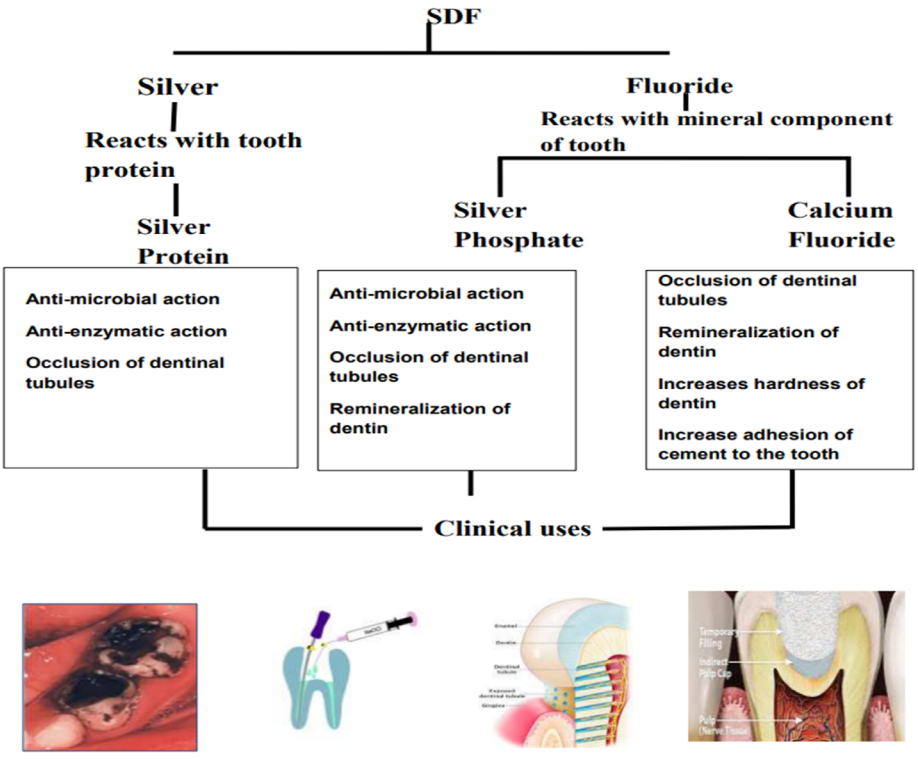


Figure 5: Flowchart of clinical summary of silver diammine fluoride including the images of Caries Arrest, Root Canal Irrigant, Desensitizing Agent and Indirect Pulp Agent.

Silver diammine fluoride information sheet

Silver diammine fluoride (SDF) is an antibiotic liquid. It is used on decayed baby teeth to treat tooth sensitivity and it can also help to stop tooth decay. It is most effective when applied twice yearly. However, treatment with SDF does not remove the need for regular dental checks, fillings or crowns to repair function or aesthetics.

The procedure: 1) Drying the affected area, **2)** Placing a small amount of SDF on the affected area, **3)** Allowing SDF to dry for one minute, **4)** Rinsing with water.

Your child's teeth should not be treated with SDF if they:

1) are allergic to silver

2) have painful gums or sores in their mouth.

Advantages of SDF

- ✓ Relieves tooth sensitivity.
- ✓ Prevents abscesses by slowing down or stopping tooth decay.
- ✓ Can buy time for children who are too young or fearful, or who have special needs, until they can manage.
- ✓ Avoids fillings or extractions by stopping decay.

Disadvantages of SDF

- The painted area will stain black permanently. Healthy parts of teeth will not stain. However, stained tooth may be covered with a filling or a crown to make it look white again.
- Tooth-coloured fillings may discolour if SDF is applied to them but this can usually be polished off to make it them white again.
- If accidentally applied to the skin or gum, a brown stain may appear. Although this cannot be washed off, it causes no harm and will disappear in 1-3 weeks.
- If accidentally spilled on clothes, it can leave a stain that does not come out.
- A metallic taste may be noticed during the application. This will go away rapidly.

Alternatives to SDF to discuss with your child's dentist (not limited to the following):

- No treatment, which may lead to continued deterioration of tooth structures and cosmetic appearance. Symptoms may increase in severity.
- Depending on the location, extent of the tooth decay and your child's ability to cooperate, other treatment options may include a filling, a silver crown, or an extraction.

If SDF is being used to stop tooth decay, sometimes the decay will still progress. If this happens, the tooth may require further treatment, such as reapplication of SDF, placement of a filling or a crown or extraction.

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Figure 6: Silver Diammine Fluoride information sheet

CONCLUSION

SDF is an antibacterial agent that is simple, safe, non-invasive (painless), and cost-effective for the treatment of carious lesions across the age spectrum. It is advised or can be the material of choice for children or individuals who are unable to tolerate conventional restorative treatment modalities, those with special health care needs, and populations with limited access to a dental care. SDF is not only the best possible way to arrest and prevent dental caries in individuals at the dental clinic but also at the community level.

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CONFLICT OF INTEREST

The author declares that there no conflict of interest regarding the publication of this paper.

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