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Non-Invasive Caries Control: Role of Silver Diamine Fluoride in Arresting Early Childhood Caries - A Narrative Review

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Abstract: ***Early Childhood Caries (ECC) is a widespread and persistent oral health concern, affecting a significant proportion of children under the age of six. Associated with pain, infection, compromised nutrition, and reduced quality of life, ECC disproportionately impacts socioeconomically disadvantaged populations. Traditional caries management approaches, which rely on invasive restorative procedures, often pose challenges in pediatric settings due to behavioral, developmental, and access-related barriers. In response, contemporary pediatric dentistry has increasingly embraced minimally invasive and non-invasive strategies that prioritize disease prevention and caries arrest. Silver diamine Fluoride (SDF) has emerged as a clinically effective, cost-efficient, and simple-to-apply topical agent for arresting caries, particularly in young or medically compromised children. Approved by the U. S. FDA in 2014 as a desensitizing agent, SDF has since gained widespread off-label use for caries management, supported by growing evidence of its dual antibacterial and re-mineralizing effects. This narrative review explores the evolving role of SDF in pediatric dentistry, examining its mechanism of action, clinical indications, application protocols, advantages, limitations, and future potential. This review aims to inform evidence-based integration of SDF into routine pediatric practice, advancing non-invasive management strategies for ECC.***

Keywords: SDF, silver diamine fluoride, minimally invasive treatment, KI, 38% SDF, ECC

1. Introduction

Early Childhood Caries (ECC) remains one of the most prevalent and pressing oral health challenges affecting children worldwide. Defined as the presence of one or more decayed, missing (due to caries), or filled tooth surfaces in any primary tooth in a child under six years of age, ECC disproportionately affects vulnerable populations and is associated with pain, infection, impaired nutrition, and diminished quality of life. Globally, dental caries—including ECC—impacts 60–90% of school-aged children, and if left untreated, can lead to significant functional and psychosocial consequences. [12]

Figure 1: Showing initial stage of Early childhood caries

Traditionally, the management of dental caries in children has relied heavily on restorative interventions, which often involve invasive procedures that may be difficult to perform in pediatric populations due to behavioral challenges, developmental considerations, and socioeconomic barriers to care. In response, there has been a paradigm shift toward minimally invasive and non-invasive strategies that emphasize disease prevention, caries arrest, and long-term management over surgical treatment.

Among these approaches, Silver Diamine Fluoride (SDF) has emerged as a promising adjunct in the management of ECC. SDF is a topical agent that is cost-effective, simple to apply, and supported by growing clinical evidence for its effectiveness in arresting carious lesions in both primary and permanent teeth. First approved by the U. S. Food and Drug Administration (FDA) in 2014 as a desensitizing agent, SDF has since gained widespread recognition for its off-label use in caries arrest, especially among young, uncooperative, or medically compromised children. [14 15] The compound's dual mechanism—silver ions providing antibacterial activity and fluoride ions promoting remineralization—enables effective arrest of carious lesions without the need for mechanical excavation. [13]

This narrative review aims to explore the evolving role of Silver Diamine Fluoride in pediatric dentistry, with a focus on its mechanism of action, clinical indications, application protocols, benefits and limitations, and its integration into contemporary pediatric oral health practice. By critically evaluating the expanding body of evidence, clinicians can better incorporate SDF as a non-invasive, evidence-based strategy for managing ECC and improving oral health outcomes in children.

2. History

Table 1

Time Period	Event / Milestone	Significance / Contribution	Reference
Ancient to 1900s	Use of silver compounds like silver nitrate in medicine and dentistry	Antimicrobial use in caries arresting; early foundation	[1]
1917	*Howe's solution* (silver nitrate) used for caries arrest	First formalized silver-based treatment in caries	[1]
1960s (Japan)	Development of 38% SDF by Dr. Mizuho Nishino, Osaka University	Combination of silver and fluoride; commercialized as "Saforide®"	[2]
1980s–1990s (China)	Use of SDF in public health programs and preschool caries control	Proven effective in large-scale community dental programs	[3], [4]
Early 2000s	Clinical trials in Hong Kong and Cambodia show high caries arrest rates	Sparked global interest; evidence base strengthened	[5], [6]
2014–2015 (USA)	FDA approval for hypersensitivity treatment; off-label caries arrest begins	Product: Advantage Arrest™ enters US market	[7]
2017	AAPD formally endorses SDF for caries management in children	Inclusion in pediatric dental guidelines	[8]
2016–present	Integration into non-invasive techniques like SMART; widespread pediatric use	Applied in ECC, special needs care, behavior management	[9], [10]
Recent advances	Efforts to reduce staining (e. g., KI application), combination with restoratives	Improved esthetics and long-term outcomes	[11]

Table 2: Composition of 38% Silver Diamine Flouride

Component	Chemical Formula	Function	Approximate Concentration
Silver ion	Ag^+	Antibacterial; inhibits biofilm formation	~25% w/v
Fluoride ion	F^-	Promotes remineralization of tooth structure	~5% w/v (~44, 800 ppm)
Ammonia	NH_3	Stabilizes the solution (forms $[Ag(NH_3)_2]^+$)	~8% w/v
Water	H_2O	Solvent	Balance (~62%)

Table 3: Available Concentrations of SDF

Concentration	Fluoride (ppm)	Silver (ppm)	pH Level	Commercial Products
38% (w/v)	~44, 800	~253, 870	10.4	Saforide (Japan), Advantage Arrest (USA), Riva Star (Australia), e-SDF (India), Topamine (Thailand)
30% (w/v)	~35, 000	~200, 000	10.4	CarieStop (Brazil)
12% (w/v)	~14, 150	~80, 000	10.4	CarieStop (Brazil)
10% (w/v)	~11, 750	~70, 000	10.4	CarieStop (Brazil)

Chemical Properties of Silver Diamine Fluoride

- The active complex is silver diamine fluoride: $[Ag(NH_3)_2]F$
- pH: ~10 (alkaline)
- Color: Clear or light blue liquid
- Odor: Ammonia-like

Safety Profile of SDF

SDF has been approved by the U. S. FDA as a desensitizing agent and is used off-label for caries arrest in children. The amount of fluoride and silver delivered per application (typically 1 drop or ~25 µL) is far below toxic levels. For example, 1 drop of 38% SDF contains approximately 9.5 mg of silver and 0.5 mg of fluoride, well within the safety threshold for pediatric use[11]. A pharmacokinetic study by Vasquez et al. (2012) found that serum fluoride levels remained within safe limits after SDF application in children[2].

Table 4: Commercially Available Forms of Silver Diamine Fluoride

Product Name	Manufacturer	SDF Concentration	Country
Advantage Arrest	Elevate Oral Care	38%	USA
Saforide	Toyo Seiyaku Kasei Co.	38%	Japan
Riva Star (Step 1)	SDI Ltd.	38%	Australia
e-SDF	Kids-e-Dental	38%	India
CarieStop	Biodinâmica	12% & 30%	Brazil

Table 5: Indications

Indication	Explanation
Caries arrest in primary teeth	Especially effective in non-cavitated or cavitated carious lesions
Early childhood caries (ECC)	Useful in very young, pre-cooperative children
Children with special health care needs	Safe, non-invasive alternative when conventional treatment is not feasible
Behavioral or medical contraindications to traditional care	Avoids sedation or general anesthesia
Interim treatment while awaiting definitive care	Temporizing measure until full dental treatment is possible
High caries risk patients	Reduces bacterial load and remineralizes tooth structure
Root caries in older children or adolescents	Effective due to antimicrobial and remineralizing effects

Table 6: Contraindications

Contraindication	Explanation
Silver allergy	Rare but absolute contraindication
Presence of ulcerative gingivitis or stomatitis	Can cause irritation and tissue staining
Irreversible pulpitis or periapical pathology	SDF is not effective in treating pulpal or periapical involvement
Esthetic concerns in anterior teeth	Causes black discoloration of carious lesions, which may be objectionable
Uncooperative behavior during application	Although minimal, the procedure requires some cooperation

Table 7: Advantages

Advantage	Description
Non-invasive, painless, and quick	No anesthesia or drilling needed
Cost-effective	Minimal equipment and personnel requirements
Excellent caries-arresting efficacy	Reported success rate up to 80–90% in arresting active caries
Useful for special needs and medically compromised	Reduces need for sedation or GA
Can be applied by trained auxiliaries	Ideal for community and school-based programs
Antibacterial and remineralizing properties	Targets cariogenic bacteria and promotes fluoride uptake

Mechanism of Action of Silver Diamine Fluoride

Silver diamine fluoride (SDF) is a colorless, alkaline topical agent composed primarily of silver ions (Ag^+), fluoride ions (F^-), and ammonia (NH_3), forming the complex $[Ag(NH_3)_2]F$. When applied to carious dentin, SDF arrests caries progression through a combination of antimicrobial, remineralizing, and structural modification mechanisms.

On Enamel Caries:

Figure 2: Showing Incipient lesion

1) Remineralization (Fluoride Ions)

The fluoride component of SDF promotes remineralization of demineralized enamel and dentin. Fluoride enhances the deposition of fluorapatite and calcium fluoride-like crystals within the lesion, increasing acid resistance (Mei et al., 2013) [14]. Fluoride also inhibits bacterial glycolysis by interfering with enolase activity, thus reducing acid production.

On Dentinal caries:

Figure 3: Showing dentinal caries

2) Antibacterial Effect (Silver Ions)

Silver ions are broad-spectrum antimicrobial agents. When SDF is applied to a carious lesion, Ag^+ ions interact with bacterial cell walls, DNA, and metabolic enzymes, disrupting biofilm structure and inhibiting bacterial replication. Silver binds to thiol groups in bacterial proteins, leading to protein denaturation and cell lysis (Horst et al., 2016) [11].

Furthermore, silver ions inhibit key cariogenic species such as Streptococcus mutans and Actinomyces naeslundii by blocking electron transport and metabolic enzymes (Mei et al., 2013) [14].

3) Formation of Protective Layer

SDF reacts with the hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) of dentin to form silver phosphate (Ag_3PO_4), calcium fluoride (CaF_2), and ammonium compounds. This reaction creates a hard, protective, and darkened surface layer on the lesion, which prevents further demineralization and physically blocks bacterial ingress (Zhao et al., 2019) [24].

The precipitated CaF_2 serves as a reservoir of fluoride, which can be released over time and taken up by adjacent enamel and dentin (Gao et al., 2016) [23].

4) Inhibition of Collagen Degradation

Silver ions in SDF inhibit host-derived collagen-degrading enzymes, such as matrix metalloproteinases (MMPs) and cathepsins, which are activated during demineralization. This preserves the organic matrix of dentin and reduces lesion progression (Zhao et al., 2019) [24].

5) Penetration and Sustained Action

Studies have shown that silver and fluoride ions penetrate up to 50–200 μm into carious dentin, with silver depositing deeper than fluoride. This penetration enhances sustained antibacterial and remineralizing action even after a single application (Mei et al., 2013) [14].

Table 8: Clinical Applications of Silver Diamine Fluoride in Pediatric Dentistry

Clinical Application	Significance / Description	References
1. Arrest of active dentinal caries in primary teeth	Halts carious progression non-invasively; ideal for uncooperative children	11, 23
2. Management of Early Childhood Caries (ECC)	Offers a safe, painless solution without sedation or drilling	23, 9
3. Interim therapeutic restoration (ITR) or SMART technique	Used beneath glass ionomer cement to reduce bacterial activity and prevent pulp exposure	9, 10
4. Caries prevention in high-risk children	Preventive use in children prone to recurrent decay	23, 22
5. Caries management in special needs patients	Facilitates treatment without restraint, sedation, or general anesthesia	9
6. Arrest of root caries in primary and mixed dentition	Antimicrobial effect beneficial on root surfaces, especially in children with poor hygiene or orthodontic care	25, 26
7. Temporary measure during access-to-care delays	Used in outreach and tele-dentistry programs to delay need for restoration	27
8. Minimally invasive dentistry and public health programs	Fits into non-restorative caries treatment models (e. g., CAMBRA, MID)	28
9. Recurrent caries management under restorations or crowns	Helps in controlling residual bacteria beneath existing restorations	14
10. Irrigant in minimally invasive pulpotomy procedures	Used experimentally as an endodontic irrigant; has broad-spectrum antimicrobial effects	30, 31
11. Indirect pulp capping agent	Preserves vitality in deep carious lesions; inhibits bacterial activity and MMPs	29, 30

Guidelines for Application of Silver Diamine Fluoride

Patient Selection
- Confirm indications: active dentinal caries, ECC, behavioral limitations, special health care needs
- Check for contraindications: silver allergy, esthetic concerns, irreversible pulpitis

Pre-Operative Protocol
- Obtain informed consent (discuss staining, purpose, limitations)
- Review medical history and perform oral examination

- **Lesion Isolation and Preparation**
- Clean tooth surface using cotton pellet or wet microbrush
- No need for excavation of soft caries (unless heavy debris)
- Isolate with cotton rolls or rubber dam (optional but preferred)

Apply petroleum jelly generously to the soft tissues, lips to avoid staining

SDF Application
- Shake bottle gently
- Dispense 1 drop of SDF onto mixing pad
- Apply to carious lesion using a microbrush (apply for ~1 minute)
- Avoid contact with gingiva, tongue, or mucosa (to prevent staining)

Post-Application Care
- Blot excess with gauze or cotton pellet—do not rinse
- Instruct the child not to eat or drink for at least 30–60 minutes
- Inform parents about expected dark staining of the lesion

Follow – Up
- Review after 2–4 weeks to assess lesion arrest (hardness, color)
- Reapply if lesion is still soft
- Repeat every 6 months or as needed depending on caries risk

Table 9: Disadvantages

Disadvantage	Description
Permanent black staining of carious lesions	Most significant esthetic concern, especially in anterior teeth
Unpleasant metallic taste	May be uncomfortable for some children
Requires repeated application for long-term success	Not a one-time treatment
Not a definitive restoration	Does not restore form or function—often combined with restorations later
Possible gingival or mucosal irritation if misapplied	Careful isolation needed during application

The major disadvantage is the permanent black staining of the carious lesions which can be overcome to certain extent by the application of few agents like KI.

Role and Mechanism of action of KI in Reducing Discoloration:

When **potassium iodide (KI)** is applied immediately after SDF:

1) **Chemical Reaction**:
- KI reacts with free silver ions (Ag^+) from SDF:
- Ag (NH3) 2F (aq) + KI (aq) → AgI (s) + 2NH3 (g) + F- (aq).
- **Silver iodide (AgI)** is a creamy-white or pale yellow precipitate, **much lighter** than metallic silver or silver oxide.

2) **Precipitation Mechanism:**
- The formation of **AgI precipitate** reduces the availability of silver ions that would otherwise form black silver compounds.
- This reaction effectively **masks the dark color** by converting the discoloring agents into a **lighter-colored compound** that stays on the tooth surface.

3) **Photoreduction Limitation:**
- Silver iodide is **light-sensitive**, and prolonged exposure to light can slowly decompose AgI back into metallic silver, potentially causing **delayed discoloration**.
- Therefore, while KI **initially reduces staining**, its effect may be **temporary or partial** in the long term

Figure 4: Before application of Silver diamine flouride

Figure 5: After application of Silver diamine flouride

Figure 6: After application of Silver diamine fluoride

Limitations**:**
- KI **does not reverse** existing discoloration caused by SDF.
- It may **not be completely effective** in deeply cavitated lesions.
- **Photodegradation of AgI** may lead to discoloration over time if not properly sealed.

Table 10: Side Effects of Silver Diamine Fluoride

Side Effect	Description	Frequency
Black staining of carious lesions	Permanent and expected; a sign of caries arrest	Very common
Temporary gingival or mucosal staining	Self-limiting; caused by inadvertent contact	Common
Mild gingival irritation	Transient inflammation if SDF contacts soft tissues	Uncommon
Metallic taste	May be unpleasant but harmless	Common

Rare or Reported Adverse Events
- No serious systemic adverse reactions have been reported in clinical studies[3].
- No cases of silver allergy were reported in large-scale clinical use, but hypersensitivity remains a theoretical contraindication[4].
- Evidence from Systematic Reviews and Clinical Trials
- Gao et al. (2016) reviewed 9 randomized controlled trials and reported no serious adverse events across all studies involving children receiving SDF treatment[23].
- A 2020 review by Seifo et al. reaffirmed the safety of SDF use in both community and clinical pediatric settings, emphasizing its utility in populations with limited access to care[26].

SDF VS Other Topical Flourides

The use of topical fluorides remains a cornerstone in the prevention and management of dental caries, especially in pediatric populations. Among these, Silver Diamine Fluoride (SDF) has gained increasing attention due to its unique dual action of antimicrobial silver ions and remineralizing fluoride ions, distinguishing it from conventional topical fluorides such as sodium fluoride (NaF) varnishes and gels.

Multiple clinical trials and systematic reviews have demonstrated that SDF is highly effective in arresting active dentinal caries in primary teeth, with reported caries arrest rates exceeding 70% to 90% following biannual application (Gao et al., 2016; Horst et al., 2016). This efficacy surpasses that of traditional fluoride varnishes, which primarily function by enhancing enamel remineralization but lack substantial antimicrobial activity to arrest cavitated lesions (Marinho et al., 2013). A randomized controlled trial by Chu et al. (2002) showed that 38% SDF was significantly more effective than 5% NaF varnish in arresting dentinal caries in preschool children over a 24-month period, highlighting SDF's superior clinical utility in managing established lesions.

Furthermore, SDF's simplicity and minimal invasiveness make it particularly advantageous in managing Early Childhood Caries (ECC) among uncooperative or special healthcare needs children, where conventional restorative approaches may be challenging (Crystal et al., 2017). The ability to arrest caries without the need for local anesthesia or drilling supports its integration into minimally invasive dentistry paradigms and community-based preventive programs (Slayton et al., 2018).

Despite these benefits, the major limitation of SDF therapy is the permanent black staining of arrested carious lesions, which may affect esthetic acceptance, particularly on anterior teeth (Crystal & Niederman, 2016). In contrast, other topical fluorides do not cause discoloration but offer limited capability to arrest cavitated lesions, often serving primarily as preventive agents. This esthetic concern has led to the development of adjunctive techniques such as the Silver Modified Atraumatic Restorative Treatment (SMART), combining SDF application with tooth-colored glass ionomer restorations to mask discoloration while harnessing SDF's antimicrobial benefits (Alves et al., 2020).

Safety profiles of both SDF and conventional fluorides are well established. SDF applications deliver low systemic fluoride doses and have not been associated with significant adverse effects in children (Gao et al., 2016). Similarly, topical fluoride varnishes are considered safe when used according to guidelines (AAPD, 2021). However, the antimicrobial silver in SDF adds an extra layer of biofilm disruption that traditional fluorides lack, contributing to its superior caries arrest potential (Mei et al., 2018).
While conventional topical fluorides remain essential for caries prevention, SDF offers a compelling alternative for arresting active lesions, especially in pediatric patients who have difficulty accessing or tolerating restorative treatment. The choice between SDF and other fluorides should consider factors such as lesion activity, patient cooperation, esthetic concerns, and treatment goals.

3. Advances in SDF Therapy

1) Silver Modified Atraumatic Restorative Treatment (SMART)

One of the most notable advances is the integration of SDF with atraumatic restorative treatment (ART), known as the SMART technique. This approach involves the application of SDF to arrest caries, followed immediately by restoring the lesion with a tooth-colored glass ionomer cement (GIC). The SMART technique combines SDF's antimicrobial and remineralizing effects with the esthetic and functional benefits of GIC restorations.

- **Benefits:** Arrests caries, reduces need for extensive drilling, masks black staining caused by SDF, and provides a durable restoration.
- **Clinical Impact:** Especially valuable in managing Early Childhood Caries and caries in patients with limited access to dental care.
- **Evidence:** Studies show high patient and parent acceptance, and effective caries control with SMART (Alves et al., 2020; Seifo et al., 2019).

2) Nano-silver and Nano-formulations of SDF

Advances in nanotechnology have led to the development of nano-silver particles incorporated into SDF formulations or used alongside it to enhance antimicrobial efficacy while potentially reducing staining and toxicity.

- **Rationale:** Nano-silver particles have a larger surface area and enhanced antimicrobial properties, which may improve bacterial inhibition and biofilm disruption.
- **Potential Advantages:** Improved penetration into dentinal tubules, reduced silver ion release leading to less discoloration, and enhanced remineralization effects.
- **Research Status:** Experimental studies show promising results, but clinical trials are ongoing to confirm efficacy and safety (Zhang et al., 2021).

3) Potassium Iodide (KI) Application Post-SDF

To address esthetic concerns caused by the black staining from SDF, potassium iodide (KI) has been introduced as an adjunctive application immediately after SDF placement. KI reacts with free silver ions to form silver iodide, which is less pigmented.

Table 11: Studies on different materials used for masking the discolouration caused by SDF

Study	Year	Masking Agent	Materials/Approach	Key Findings	Reference
Knight et al.	2006	KI	SDF + Potassium Iodide	Immediate color improvement; limited long-term stability	[36]
Zhao et al.	2019	KI + Composite	SDF + KI + Resin composite	Composite masked staining effectively; KI helped reduce initial discoloration	[38]
Seifo et al.	2020	GIC	SDF + GIC (SMART technique)	Improved esthetics; retained caries arrest effectiveness	[26]
Hamama et al.	2021	Bioactive materials	SDF + bioactive restorative materials	Masked discoloration with sustained ion release and remineralization	[41]
Rajendran et al.	2020	Nano-hydroxyapatite	SDF + nHAp	Reduced staining and supported remineralization	[42]
Twetman et al.	2023	Colored sealants	SDF + pigmented sealants	Effective masking on posterior occlusal surfaces	[44]
Hu et al.	2018	Reducing agents	SDF + alternative biocompatible reducers	Some agents prevented black staining in vitro	[45]
Mishra et al.	2020	Glutathione	SDF + topical glutathione application	Significant reduction in staining observed; compatible with SDF activity	[46]
Al-Harbi et al.	2022	Theobromine	SDF + theobromine solution	Decreased discoloration; potential remineralizing synergy	[47]

4) Use of 3.8% SDF as an Endodontic Irrigant

Recent research has explored 3.8% SDF's role beyond caries arrest, particularly as an antimicrobial irrigant in minimally invasive endodontic procedures.

- **Rationale:** The broad-spectrum antimicrobial activity of silver ions combined with fluoride's mineralizing properties offers potential benefits in disinfecting root canals and preserving pulp vitality.
- **Preliminary Findings:** Studies demonstrate effective inhibition of common endodontic pathogens and possible promotion of dentin hardness (Mei et al., 2019).
- **Future Directions:** Optimizing concentrations and protocols to maximize efficacy without cytotoxicity is an active area of investigation.

5) Incorporation into Preventive Regimens and Delivery Vehicles

Innovative delivery systems incorporating SDF into varnishes, gels, or slow-release devices are being developed to improve application ease and patient compliance.

Examples:

- SDF-infused dental varnishes combining fluoride release with silver's antimicrobial effects for sustained action.
- Slow-release SDF-containing materials for high-risk caries patients to provide prolonged protection.

Advantages: Enhanced convenience for clinical use and community programs, improved retention on tooth surfaces, and potentially increased caries prevention.

Research Status: Early stage but promising results from pilot studies (Lo et al., 2022).

6) Customized Concentrations and Application Protocols

Recognizing the diverse clinical scenarios, customized SDF concentrations (e. g., 12%, 30%, and the standard 38%) and tailored application frequencies are being studied to optimize effectiveness and minimize side effects.

- **Goal:** Achieve caries arrest with minimal staining and reduce treatment frequency.
- **Findings:** Lower concentrations may reduce staining but might require more frequent applications; higher concentrations provide rapid arrest but increased staining risk (Dos Santos et al., 2016).

7) SDF Therapy for Permanent Teeth

A systematic review by Gao et al. (2016) and clinical studies by Mei et al. (2018) demonstrate that SDF is effective in arresting dentinal caries in permanent teeth, including in adults and older adolescents. Its use in root caries has also shown success in reducing lesion progression and bacterial load.

Limitations:

- Esthetic concerns due to black staining
- Not a restorative treatment—does not restore function or contour
- Less commonly used in anterior permanent teeth for this reason

4. Conclusion

Silver diamine fluoride (SDF) has emerged as a valuable, evidence-based tool in the management of dental caries in pediatric populations, particularly for children who are pre-cooperative, medically compromised, or lack access to traditional restorative care. Its non-invasive, cost-effective, and highly efficacious nature makes it a cornerstone of minimally invasive dentistry, aligning well with modern principles of preventive and patient-centered care.

Over the decades, SDF has evolved from a regionally applied agent to a globally recognized caries-arresting therapy. Supported by robust clinical trials and public health initiatives, its incorporation into pediatric practice—especially in community and school-based programs—has significantly broadened access to essential dental care. Additionally, professional bodies such as the American Academy of Pediatric Dentistry have endorsed its use, further legitimizing its clinical relevance.

Looking forward, ongoing research aims to optimize application protocols, improve esthetic outcomes, and explore synergistic use with other minimally invasive techniques such as the SMART (Silver-Modified Atraumatic Restorative Treatment) approach. Innovations addressing staining concerns and enhancing patient and caregiver acceptance will further solidify SDF's role in comprehensive pediatric oral healthcare.

As the global burden of early childhood caries persists, SDF represents a promising solution at the intersection of science, accessibility, and equity in oral health. Continued interdisciplinary collaboration, research, and policy support will be essential in unlocking its full potential in pediatric dentistry and beyond.

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