Chapter

The Use of Silver Diamine Fluoride in Pediatric Dentistry

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Abstract

This book chapter aims to discuss the main aspects related to the use of silver diamine fluoride (SDF) in Pediatric Dentistry. The composition and mechanism of action of the SDF are presented, as well as the application technique and indications. The effectiveness of SDF is reported based on contemporary scientific evidence from laboratory and clinical studies, focusing on its effect in enamel and dentin remineralization and caries arrestment. Parental and professional acceptance of tooth staining is presented, as well as the use of potassium iodide as a possible alternative to manage this side-effect. Taking all the discussed information together, it is possible to conclude that the SDF is a simple and effective treatment to halt the dental caries progress in children.

Keywords: silver diamine fluoride, dental caries, child, Pediatric Dentistry, tooth remineralization

1. Introduction

Untreated caries lesions in deciduous teeth affect more than 570 million children around the world. One very disturbing evidence is that the prevalence of untreated caries lesion remained stable from 1990 to 2015 [1] and the peak of the disease is among very young children, aging 1–4 years old [2].

Dental caries is a dynamic, multifactorial, non-communicable and biofilm-mediated disease. It has a very strong behavioral component, with a direct influence of diet and hygiene habits. When there is an imbalance in the biological, behavioral, and environmental factors, carious lesions will develop [3].

Therefore, alternative treatment strategies are needed to modify this scenario. First of all, one should be aware that dental caries is a preventable disease, that can be controlled by reducing the amount of fermentable carbohydrates available in the diet and by disorganizing the dental biofilm systematically [4]. However, if these simple and effective measures fail, carious lesions may develop and they should be treated according to the Minimal Invasive Dentistry philosophy. The management of these lesions depends on the invasiveness of the lesion (in enamel or dentin) and the degree of tissue removal associated with the procedure. It includes dietary and biofilm control, mineralization techniques, sealing, restorative techniques and non-restorative techniques [5].

Currently, a non-invasive agent has received renewed interest: silver diamine fluoride (SDF). It is an efficient, affordable, equitable and effective cariostatic agent. This non-restorative approach can halt the progression of carious lesions and it can be an alternative to control the burden of dental caries in children around

the world [6]. This is an interesting treatment approach for deciduous teeth that is recommended by the American Academy of Pediatric Dentistry, that published a guideline, in 2017, named "Use of Silver Diamine Fluoride for Dental Caries Management in Children and Adolescents, Including Those with Special Health Care Needs" [7].

The use of SDF for arresting dental caries in deciduous and permanent teeth is not a novelty in Dentistry. Since the 1970s, when it was developed, it has been widely used in Japan, as well as in other countries such as Brazil, Argentina, China, and Australia [8]. Notwithstanding, it was not commonly used in the United States of America until 2014, when the use of SDF was cleared by the Food and Drug Administration (FDA) as an agent to treat tooth hypersensitivity and, in an off-label indication, for caries arrestment management.

A significant number of randomized clinical trials ascertain the usefulness of SDF for Pediatric Dentistry, aiming to control and/or arresting dental caries in deciduous teeth [9–13] and first permanent molars [14, 15].

This chapter will guide clinicians regarding the use of diamine silver fluoride in their daily practice, using a critical appraisal of the available scientific literature regarding its action mechanism, effectiveness, and child/parent acceptance. This theoretical approach is in concordance with evidence-based dentistry and will enable the professional to understand the benefits and shortcomings behind the use of SDF in Pediatric Dentistry.

2. Composition and action mechanisms: how does SDF work in a carious lesion?

SDF ($AgF[NH_3]_2$) is a colorless solution with alkaline pH (pH 8–10). Its main components are silver, fluoride and ammonia. Basically, the silver is an antimicrobial agent, the ammonia stabilizes the solution, while the fluoride aids remineralization [16]. Nevertheless, the action mechanisms of SDF is much more complex as it will be shown hereinafter.

The most common concentration is 38%, which represents 44.800 ppm of fluoride and 255.000 ppm of silver [17]. These two elements, in such a high concentration, will have a synergistic activity, with a bactericidal action on cariogenic microorganisms, promotion of mineralization, inhibition of demineralization of tooth hard tissues, and decrease of the destruction of the organic portion of the dentin [18]. Other concentrations of SDF (10, 12, 30%) are available in Brazil from different manufacturers. **Table 1** shows the commercially available brands of SDF.

When SDF is applied to the tooth, the following reaction occurs:

$$Ca_{10}(PO_4)_6(OH)_2 + Ag(NH3)_2F \rightarrow CaF_2 + Ag_3PO_4 + NH_4OH$$

$$(\text{hydroxyapatite} + \text{SDF} \rightarrow \text{calcium fluoride} + \text{silver phosphate} + \text{ammonium hydroxide})$$

The main action of fluoride is related to the remineralization of the dental hard tissues. After SDF application on a carious lesion, two compounds are formed: calcium fluoride and fluorhydroxyapatite. Calcium fluoride is loosely bound to the teeth and it can be considered a reservoir of fluoride that will be released if a pH

Trademark (manufacturer)	Country	SDF concentration	Commercial appearance
Advantage arrest (Elevate Oral Care)	EUA	38%	
Cariostasul (Iodontosul)	Brazil	10, 12 and 30%	
Cariestop (Biodinâmica Química eFarmacêutica SRL)	Brazil	12 and 30%	
Ancarie (Maquira)	Brazil	12%	
Fagamin (Tedequim SRL)	Argentina	38%	
Fluoroplat (NAF Laboratórios)	Argentina	38%	
Saforide (Toyo Seiyaku Kasei Co. Ltda)	Japan	38%	
CSDS - Caries Status Disclosing Solution (Creighton Dental)	Australia	40%	
e-SDF (Kids-e-dental)	India	38%	

Trademark (manufacturer)	Country	SDF concentration	Commercial appearance
Riva Star (SDI Dental Limited)	Australia	38%	

Table 1.
SDF products available in different countries.

drop occurs; therefore, there will be available fluoride during the DES-RE process. Silver phosphate can also act as a reservoir of phosphate ions for the next caries challenge [19].

The fluorhydroxyapatite is formed when fluoride is incorporated into the hydroxyapatite crystals; it helps remineralization and makes the tooth more resistant to further demineralization [18, 20]. Also, high concentration of fluorides can inhibit the formation of biofilm, since fluoride can influence the carbohydrate metabolism and the sugar uptake of the microorganisms [8]. The silver ions (Ag^+) exert a great antimicrobial effect, killing or interfering in the microorganisms' metabolic processes [8]. There are different mechanisms involved in this effect. Silver ions can bind to the cell-wall structure and inhibit the mobility of the bacteria or promote the rupture of the membranes. They also can form organometallic complexes inside the bacterial cell, liberating silver ions that will interact with the DNA of the microorganisms, resulting in inactivation of bacterial DNA/RNA or mutation of the DNA, leading to the death of the bacteria [20].

However, the progression of a carious lesion evolves not only the demineralization of the enamel and dentin as a result of bacterial acids, but also the destruction of the organic content of the dentin, composed mainly by type I collagen (around 90%). The loss of dentin minerals exposes the organic matrix, which is degraded by bacterial and host-derived enzymes [21]. Maintenance of the collagen fibrils is important because it acts as a scaffold for the deposition of mineral crystals [22] and might inhibit the diffusion of calcium and phosphate for further demineralization. Therefore, it is very important for the arrestment of a carious lesion that SDF can also exert inhibitory effects on the degradation of dentin collagen fibrils by inactivating the endogenous metalloproteinases and cathepsins [23].

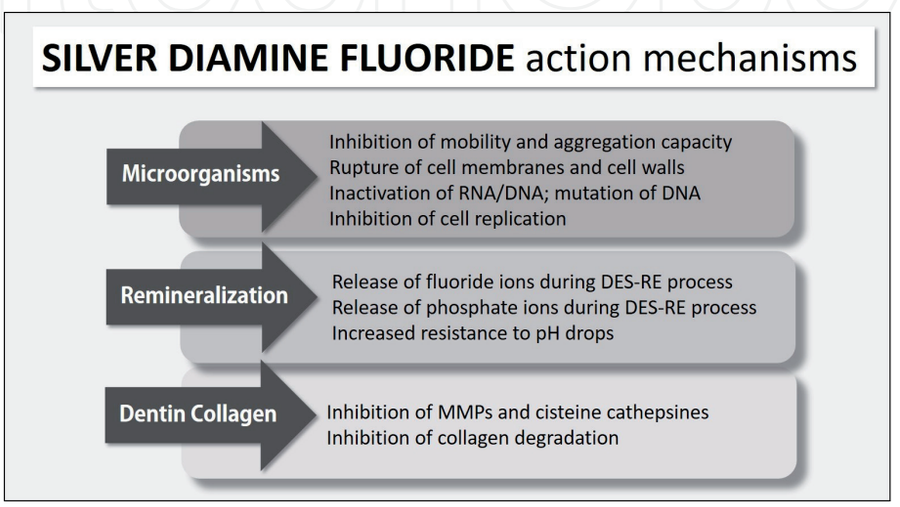

Figure 1.
Silver diamine fluoride action mechanisms [8, 20, 23, 24].

For descriptive purposes only, the action of each SDF compound was presented apart. Notwithstanding, the effectiveness of SDF is a result of the combination of fluoride and silver ions and they occur simultaneously (**Figure 1**).

3. Why use SDF? Indications, advantages, and disadvantages

SDF is an effective, safe, and equitable product [25]. It offers the clinician the possibility of avoiding invasive treatments and the use of dental local anesthesia and dental drills, which triggers for dental fear and anxiety. In young patients with behavioral problems that cannot be manageable in a normal clinical setting, the option for an SDF treatment may avoid sedation and general anesthesia and the risks associated with them.

The low cost and the simplicity of the treatment make the use of SDF an interesting option to provide oral care for vulnerable populations, without regular access to dental health professional or in Public Health Dentistry. It can also be considered an inclusive treatment, since it may be used in a large range of patients. Due to its facility of application, the treatment with SDF can be accomplished in a dental office, but also at alternative venues like daycares facilities for children, hospitals, and nursing homes.

As a non-invasive and non-restorative procedure, SDF is a smart choice if the dentist wants to arrest active carious processes quickly, in deciduous and permanent teeth, and create the time to improve the oral conditions without worsening the clinical signs of the disease. At this moment, the patient may be stimulated to modify wrongful dietary and oral hygiene practices and oral homeostasis may be obtained. Simultaneously, the carious lesions will be arrested, and, if the patient/parents want to improve form or esthetics, further restorative treatment may be accomplished in a more responsive and positive environment. Anyway, restoration is not paramount to maintain health.

In Pediatric Dentistry, the extra time obtained with the use of SDF may also be fundamental to improve the behavior of the patients and their ability to cope with the dentist during the dental treatment [24]. Besides that, the main indications are listed as follows and includes patients that have [26]:

- early childhood caries;
- behavioral problems (SDF is an alternative to sedation or general anesthesia treatment);
- special needs like severe cognitive or physical disabilities;
- dental phobia or those who cannot tolerate standard dental treatment for medical or psychological reasons, including pre-cooperative children;
- multiple cavitated active lesions that need immediate intervention to avoid the progression of the carious lesions, that can become symptomatic while waiting for the completion of the traditional restorative treatment;
- extensive lesions that are too extensive to restore and are not associated with spontaneous pain and/or infection.

Regarding the tooth, the application of SDF will only be possible in the absence of clinical signs of pulpal inflammation, spontaneous or nocturnal toothache, and pulp exposition [7].

SDF can also be used in enamel lesions, to control proximal carious lesions in deciduous teeth [27], and to arrest incipient occlusal caries in erupting permanent first molars [14].

The use of SDF is contraindicated in patients who have a history of silver allergy, since it may cause gingivitis or mucositis [26].

The staining of the tooth is the main disadvantage of SDF usage. It is expected that carious tissue in enamel and dentin will become dark brown or black after application. Parents and patients must be aware that the staining is the clinical sign of the arrestment of the carious lesion, that the stain will remain over time, and that its removal will only be possible with the use of burs. Sound enamel will not be stained.

4. What about the concentration and periodicity of application?

The current literature recommends the use of 38% SDF solution [10, 12, 22, 28], with two annual application (every 6 months) [13, 28, 29], without previous removal of carious tissue [26].

This recommendation is based on randomized clinical trials, that focused on the effectiveness of SDF in arresting or inactivating carious lesions in dentin in deciduous teeth. Data from different studies [10, 12] comprehended a total of 1864 patients, that were followed-up from 24 [12] to 30 months [10]. The concentrations of 12 and 38% SDF were compared, and the 38% SDF was consistently more effective than 12% in inactivating carious lesions in prescholars [10, 12, 28].

The annual application of SDF 38% is effective in arresting dentin carious lesions. However, increased frequency of application will raise the caries arrest rates by about 15%. It was shown that the caries arrest rates of 38% SDF were 66.9% for annual application and 75.7% for semiannual application [10].

4.1 Additional information

Other variables regarding individual characteristics of the patients should be considered when choosing SDF concentration and periodicity.

Children's oral hygiene is the most important one since there is a significant interaction between frequency/efficacy of SDF application and oral hygiene status [10]. Children at high caries risk, as reflected by their high mean baseline dmfs and plaque scores, may not achieve the expected results with the exclusive use of SDF, even at a concentration of 38%. Therefore, these patients will be highly benefited by the biannual application of this solution at 38%.

There is also an interaction between the SDF concentration and the lesion site. The combination of lesion site and SDF concentration should be taken into consideration when applying SDF solution for caries arrest, and 38% SDF should always be used, particularly in posterior teeth [28]. Cavities that show a retentive design may provide sites for dental biofilm retention and may difficult the contact with fluoride dentifrice and toothbrush on a daily basis; this is more probable to occur in cavities of posterior teeth.

At the surface level, SDF treatments on smooth surfaces of anterior teeth as well as on the buccal or lingual tooth surfaces had a higher chance to become arrested [13].

To overcome these minor setbacks, the SDF treatment, as any other dental treatment, must be associated with dental hygiene education/motivation, as well as other topical fluorides if possible [10]. Besides that, the retentive cavities can be reshaped or partially opened with the use of manual instruments, aiming to remove

the sites of plaque retention before SDF application and to facilitate the cleanability of the tooth and the disturbance of the dental plaque.

5. Evidence of silver diamine fluoride effects

The process of remineralization involves the replacement of minerals in partially demineralized enamel and dentin [30]. SDF is one of the fluoride-based treatments that has supporting evidence for its use for remineralization. In vitro, in situ, and ex vivo research design models make it possible to evaluate the mineral density, microhardness, lesion depth, and many other variables that reflect the remineralization effect both in enamel and dentin. Clinically, consistent reports of inactivated carious lesions in children are shown by a significant number of randomized clinical trials as well as systematic reviews and metanalysis.

5.1 Remineralizing effects in enamel

In vitro studies demonstrated that initial lesions in enamel can be remineralized with 38% SDF. In an artificial enamel caries model with bacterial pH challenge, the use of 38% SDF resulted in enhanced mineral density, with a higher depth of remineralization and better remineralization percentage when compared to the use of fluoride toothpaste alone [31]. The ability of remineralize early proximal enamel lesions was also demonstrated in an *in situ* study that showed similar increases in the mineral density after treatment with SDF and glass ionomer cement [32].

SDF was also effective in preventing demineralization. The demineralization inhibition effect of SDF treatment is mainly associated with the F2 in SDF [26]. When SDF is applied in sound enamel blocks and these blocks are artificially demineralized, SDF prevented the development of the enamel carious lesions when compared to $AgNO_3$ or KF [33]. After pH cycling, the SDF treated enamel remained with a relatively dense surface when compared to the use of NaF alone, with a higher content of fluoride and mineral density values and decreased lesion depths [34].

5.2 SDF in dentin

Dentin remineralization after SDF application promoted an outer layer of high mineralized dentine (approximately 150 μ), with a considerable presence of calcium and phosphate [23]. As a consequence of the remineralization, dentin carious lesions treated with 38% SDF also showed enhanced microhardness, which can be used as an indirect way (or a surrogate outcome in research) to identify changes in the mineral content of mineralized tissue. This was shown in an ex vivo study, where primary upper anterior teeth with dentin carious lesions received 38% SDF (one application every 12 months) [35].

Besides surface mineralization which is related to increased hardness, functional mineralization is also obtained; both characteristics can be achieved with the use of 38% SDF and are related to the mineral content of the tooth [36].

There are also important changes in the collagen fiber network. While in carious dentin, the collagen fibers are exposed due to demineralization, after 38% SDF application, the mineral loss and collagen exposure are reduced and a dense granular structure of spherical grains on the surface of the demineralized dentin is seen in artificial carious dentin treated with SDF under SEM [37]. It was also shown, in extracted teeth with carious lesions, that the collagen fiber network is protected with mineral after SDF treatment and the hydroxyapatite crystals exhibited a

Authors, year of publication	Number of included RCT/ number of patients	Objective	Main findings
Rosenblatt et al., 2009	2/827	To evaluate the effectiveness of silver diamine fluoride (SDF) to prevent caries when compared to fluoride varnish	SDF is more effective than fluoride varnish and may be a valuable caries-preventive intervention
Duangthip et al., 2015	4/967	To assess the effectiveness of non-surgical treatments of dentin caries in primary teeth in preschool children	SDF applications once/twice a year and daily toothbrushing with fluoride toothpaste appear to arrest or slow down the progression of active dentin caries in primary teeth in preschool children, but there is limited evidence to support this finding
Gao et al., 2016a	17/not reported	To investigate the clinical efficacy of professional fluoride therapy in remineralizing and arresting caries in children	Professionally applied 5% sodium fluoride varnish can remineralize early enamel caries and 38% silver diamine fluoride is effective in arresting dentine caries
Gao et al., 2016b	19/not reported	To investigate the clinical effectiveness of silver diamine fluoride (SDF) in arresting dental caries among children	38% SDF was effective in arresting dentin caries in primary teeth among children. The overall percentage of active caries that became arrested was 81%
Chibinski et al., 2017	11/4328	To evaluate the efficacy of silver diamine fluoride (SDF) in controlling caries progression in children when compared with active treatments or placebos	The use of SDF is 89% more effective in controlling/arresting caries than other treatments or placebo
Contreras et al., 2017	7/not reported	To evaluate the scientific evidence regarding the effectiveness of silver diamine fluoride (SDF) in preventing and arresting caries in the primary dentition and permanent first molars	SDF is a preventive treatment for dental caries in community settings. At concentrations of 30 and 38%, SDF shows potential as an alternative treatment for caries arrest in the primary dentition and permanent first molars
Oliveira et al., 2019	4/not reported	To investigate whether silver diamine fluoride (SDF) is effective in preventing new caries lesions in primary teeth when compared to placebo or active treatments	When applied to caries lesions in primary teeth, SDF compared to no treatment, placebo or fluoride varnish appears to effectively prevent dental caries in the entire dentition. However, trials specifically designed to assess this outcome are needed
Trieu et al., 2019	4/746	To evaluate the dentine caries arrest capabilities of silver diamine fluoride (SDF) and sodium fluoride (NaF).	SDF is a more effective caries management reagent than NaF (fluoride varnish)

Table 2.
Systematic reviews and meta-analysis that evaluated the effectiveness of SDF use in primary teeth.

well-aligned deposition. These favorable characteristics of the carious dentin were observed in an ex vivo study that analyzed exfoliated teeth 24 months after SDF treatment [23].

5.3 Clinical SDF effectiveness: systematic reviews and meta-analysis

For this book chapter, it was chosen to describe the effectiveness of SDF based on systematic reviews and meta-analysis about SDF use/effectiveness in children.

Systematic reviews (SR) and meta-analysis (MA) can be seen as a magnifying glass [38] from which the available evidence is evaluated. In applying a rigorous and methodic way to collect and analyze the data, systematic reviews and meta-analysis group the evidence and facilitate the decision-making process for stakeholders and clinicians. Therefore, the use of SR and MA eliminates the need of analyzing individual randomized clinical trials, while providing a broad and rigorous process of study selection and a statistical analysis of the data retrieved from all the papers that fulfill the quality control established by the authors.

The set of systematic reviews and meta-analysis about SDF are listed in **Table 2**. From the eight available papers, three are systematic reviews without meta-analysis [6, 39, 40]; and two did not evaluate SDF specifically, but as part of professionally applied fluoride treatments [41] and non-surgical treatments for caries arrestment [39].

Although different SR and MA establish distinct approaches to treat data, especially regarding the inclusion of high risk of bias papers in the metanalysis [41, 42] and the lack of overall quality of the evidence evaluation (GRADE) [6, 19, 39–43], all the papers concluded that SDF is superior to other tested strategies when caries arrestment is considered. SDF was found to be more effective than fluoride varnish [6, 22, 44], atraumatic restorative treatment [22] or placebo treatments [22].

The possibility of SDF application offering protection to all the deciduous dentition from the patient that received SDF treatment was analyzed by one of the RS and MA [43]. Despite the reduced number of included studies, the authors pointed out that it seems to be a protector effect after SDF use, since it decreased the number of new lesions in 77%, which shows that maybe SDF can be able to prevent the development of carious lesions in all deciduous dentition.

Finally, an umbrella review has been published in 2019 [45]. This type of study can be considered an overview of systematic reviews and aimed to provide a low-bias, comprehensive assessment of the evidence from the available systematic reviews related to the use of SDF for the management of carious lesions in children and adults. This paper concluded that the effectiveness of SDF for arresting coronal caries in deciduous dentition is a consistent finding among all the systematic reviews evaluated and the available evidence is strong. Therefore, the pediatric dentist can be very confident when using SDF in his/her daily practice, since this non-invasive treatment has a strong history of evidence behind it.

6. How silver diamine fluoride is applied?

6.1 What is important to know before clinical treatment with SDF?

The use of SDF preserves all dental tissue. Therefore, total or selective carious tissue removal is not needed.

Accidental contact of SDF with patient's or practitioner's skin can cause a brown stain that will be eliminated within 2–14 days due to natural exfoliation of the dead

outer skin tissues. A brown stain will be permanent if there is accidental contact of SDF with clothes and other surfaces of dental clinic not protect by a barrier like a plastic liner [46].

SDF is an alkaline solution, if inadvertent contact with gingival tissue or mucosa occurs, reversible localized changes, represented by small and mildly pain white lesions or transient gingivitis, will appear [47]. These lesions disappear in 48 h, without any treatment [26]. Therefore, it is recommended to cover soft tissues nearby the site of SDF application, as well as lips and skin around the mouth, with petroleum jelly to prevent accidental contact.

Informed consent must be obtained from parents before SDF treatment. The informed consent form should describe all the benefits and side-effects related to the use of SDF, including the fact that SDF is not a restorative procedure, but a very effective anticaries agent. The dentist must provide all the needed information about the procedure in a simple and clear language, aiming for an easy understanding of the parents. At this moment, additional resources like pictures of teeth treated with SDF can be used to aid the professional in explaining the treatment. Photos showing the appearance of teeth before and after SDF application are a valuable resource to describe the darkening of the teeth; at the same time, the parents must be ensured that sound enamel will not be stained.

6.2 Application technique

The first step is the selection of the material needed for the SDF application: toothbrush, petroleum jelly, glass Dappen dish, disposable applicators, cotton rolls, and SDF solution (**Figure 2**). If the application is done in the dental office, the toothbrush is not needed, since dental prophylaxis with Robinson brush can be done.

The application technique of the SDF is a very simple procedure and is exemplified in **Figures 3–6**. The steps involved are described below [48]:

- Dental prophylaxis: the biofilm must be removed from the dental surface (enamel or dentin). For this purpose, the professional may use toothbrush, wet cotton pellets or, if dental office is available, a dental prophylaxis with Robinson brush and pumice/water paste;

- Soft tissues must be protected with petroleum jelly, including lips, gums, and perioral soft tissues to avoid direct contact with SDF solution;

- The operation field must be isolated with cotton rolls;

- Before dispensing a drop of SDF solution in a glass Dappen dish, the solution must be agitated for homogenization;

- The tooth surface or cavity that will receive the SDF treatment must be dried with dry cotton pellets or a gentle flow of compressed air;

- SDF solution must be actively applied with disposable tips; application time should be about 1 minute;

- A gentle flow of compressed air can be applied to help the solution to dry; during this process, the isolation of the operatory field must be on place;

- After approximately 3 minutes, if possible, the isolation can be removed.

Figure 2.
Material used for a SDF treatment.

Figure 3.
Patient with early childhood caries, exhibiting active caries lesions in enamel and dentin.

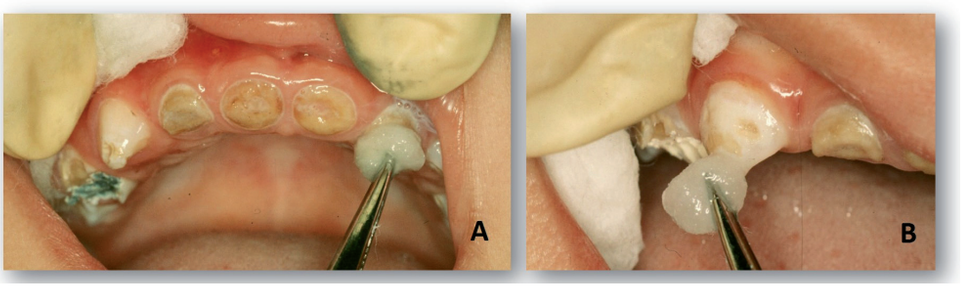

Figure 4.
*(A and B) SDF application was done in all active lesions, including upper anterior teeth (**Figure 4A**) and enamel lesions (**Figure 4B**). This procedure was taken to paralyze the progression of carious lesions during the modification of dietary and oral hygiene habits. Operative treatment was done afterward in specific teeth.*

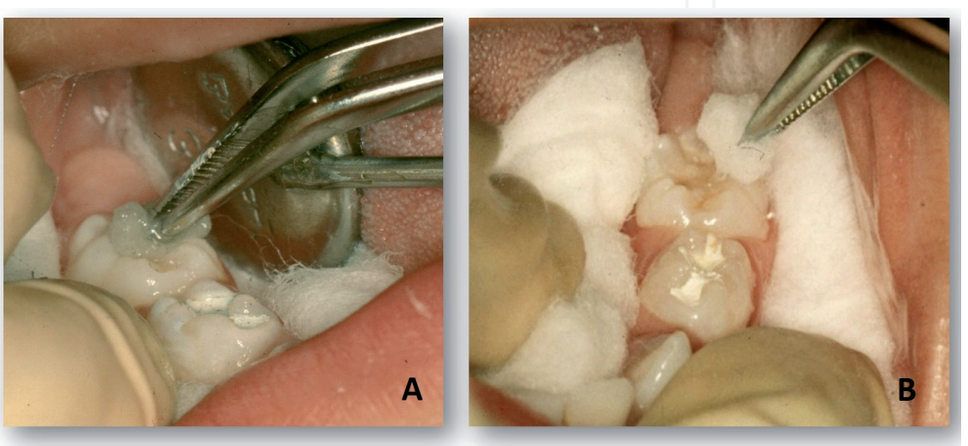

Figure 5.
(A and B) SDF was also applied on occlusal surfaces of deciduous primary molars.

Figure 6.
Clinical aspect in a follow-up consultation: darkening is evident without the progress of the carious lesions.

The application times can be shortened without any prejudice for the cariostatic effect when treating very young or very difficult to manage patients. Notwithstanding, the professional must monitor carefully at post-op consultation the lesion appearance; if it does not exhibit a darker and harder surface, re-application is needed.

6.3 Tooth staining: how do parents, patients, and dentists deal with?

Tooth staining is the main adverse effect related to the SDF application. It is related to the formation of metallic silver from silver compounds [19]. As a result, all carious tissue – enamel and dentin – will become dark brown or black in a short period after SDF application and this may be an obstacle to SDF usage.

The dental literature shows that distinct factors can influence the parent's acceptance. Between these factors included the type of tooth (anterior or posterior), family income, parental schooling, ethnicity, and need for advanced behavior control methods [49].

Parents of uncooperative children tend to better accept the tooth staining to avoid more advanced behavior guidance, like sedation or general anesthesia [49–51].

The possibility of pain-free treatment is considered the most important factor when choosing a treatment by 74% of the parents; esthetics were considered the main goal only by 26% of the parents [51]. It is also common the statement that the staining would not be of major concern if the dental problem of the children can be solved [52, 53]. Notwithstanding, these results came from studies developed in Saudi Arabia [51] and Brazil [52, 53] and may not reflect the reality in other countries.

Anyway, the SDF application is better accepted in posterior compared to anterior teeth [10, 50, 51] and in deciduous compared to permanent teeth [51].

There is a trend toward high-income parents to choose esthetics. Parents with high or middle income and with a higher educational level are less likely to accept the use of SDF and the staining [10, 49].

Regarding professionals, a prejudice toward SDF staining may prevent a broader use or even make it difficult for them to offer this treatment to patients and parents [49]. In other words, dentists may assume that parents will not accept SDF treatment, with a preconception that esthetic is their main concern [49].

Therefore, it is important for the professional to fully understand the advantages and disadvantages of SDF treatment and the clinical situations that SDF can be a valuable resource. At the same time, the parent's and patient's opinions must be taken into account when deciding a treatment plan for a child. This should be done after a conversation about all the available treatment methods, considering not only

the dentist's personal preferences but mainly the needs and wishes of the patient and his/her parents.

6.4 Tooth staining: is potassium iodide (KI) the answer?

The use of potassium iodide (KI) after SDF application has been proposed as an alternative to eliminate or minimize the tooth staining [54]. Currently, there is only one product that presents this association (Riva Star – SDI, Australia).

Silver phosphate is the subproduct of the SDF reaction with hydroxyapatite that is the main responsible for the tooth staining. If a saturated solution of KI (1 g KI/mL) is applied after SDF treatment, the subsequent reaction will result in silver iodide (AgI) and tripotassium phosphate (K_3PO_4). The last one is the chemical substance responsible for the reduction of tooth staining, while silver iodide can still promote some staining because it is a photosensitive subproduct [55].

The protocol of the SDF application is as follows:

- after application of SDF, keep the relative isolation in position and remove the excess of the SDF solution with a gauze or a cotton roll;
- KI solution must be applied to the tooth with a new disposable applicator;
- at this point, the solution will become creamy white; this is due to the formation of tripotassium phosphate;
- the application of KI solution should be repeated for 2 or 3 times, with a 5–10 s interval between applications, until no more white precipitates can be seen;
- the excess of the KI solution must be removed with gauze or cotton roll;
- the tooth is washed with water and the relative isolation can be removed.

So far, there are no randomized clinical trials that evaluate the effect of the association of SDF with KI. A systematic review of in vitro studies that evaluated the reduction of tooth staining after the SDF + KI application concluded that there seems to exist a positive effect in this association. However, since the methodologies of the studies are very different, direct comparisons are difficult and this conclusion must be validated by future well-designed studies [56].

7. How is the deciduous pulp reaction to the SDF application?

The possibility of an increased incidence of pulp lesions associated with the SDF application is not supported by data from randomized clinical trials [56, 57].

This finding is corroborated by histological studies, which showed that carious deciduous dentin treated with 38% SDF exhibited hypermineralization of the intertubular dentin [58], with a higher content of calcium and phosphorus [59] and a few blocked tubules [58]. Beneath that hypermineralized region, the tubules had characteristics of normality.

At the pulp area associated with the carious lesion, chronic inflammatory infiltrate could be seen [58], which did not halt the formation of tertiary dentin [58, 60]. This apposition of minerals in the intra and intertubular dentin after an exogenous stimulus is representative of a tooth with a vital pulpo-dentinal organ [23]. The odontoblastic layer may be flattened, but without further histological changes [60].

Silver deposits are more commonly seen along dentinal tubules than in the body of dentin. The silver penetration is facilitated by the demineralization of enamel and dentin and it can reach dental pulp tissue in deep cavities [59].

The literature is very limited on this topic and the data described in this chapter is based on ex vivo studies with very small samples, on which deciduous teeth that received 38% SDF application 6–12 months before exfoliation were collected and studied [58, 60]. Therefore, the findings, despite encouraging, should be considered preliminary and new studies are needed to further clarify this topic.

8. Conclusion

SDF is a non-invasive, painless, and effective treatment for the management of carious lesions in children. Considering the simplicity and safety of its use, it is a strategy that can be applied in individual or collective levels and can be associated with other non-invasive, micro-invasive or minimally invasive strategies.

The use of SDF fulfills the World Health Organization (WHO) Millennium Development Goals for Health and can contribute to the reduction of the inequities in oral health around the globe as well as provide a friendly treatment approach in Pediatric Dentistry daily clinic.

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Conflict of interest

The author declares no conflict of interest.

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