Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

PROTOCOL FOR CARIES ARREST USING SILVER DIAMINE FLUORIDE: RATIONALE, INDICATIONS AND CONSENT.

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ABSTRACT

Introduction: Caries is considered the most prevalent health condition in the world. For a long time, fluor has been used to prevent and treat caries. But silver diamine fluoride (SDF) is a new product that have been introduced in Japan in the 1960s. It shows great results in terms of caries arrest. **Objectives:** The principal objective of this review is to analyze the use of SDF to stop caries progression in the general population. As secondary objectives, we will evaluate the benefits and limitations of SDF over traditional treatments and review the protocols. **Methodology:** The search strategy was carried out between October 2022 and January 2023. We analyzed different articles from the last 10 years, according to our search equation, in the PubMed and Medline databases. **Results:** We submitted all the articles found to the PRISMA checklist and obtained 30 articles that, after systematically presenting them in the results table, have been analyzed to respond to the objectives set previously. **Conclusions:** SDF has been proven to arrest caries by promoting remineralization and inhibiting demineralization. It presents a lot of benefices compatible with children by its non-invasiveness, ease, and fastness of use. It also showed great compatibility for treating the elderly as it can treat hypersensibility and root caries. SDF showed less demineralization than caries treated with traditional sodium fluoride. The principal benefices of SDF were that it is rapid, safe, affordable, painless, and very effective. Its limitations were mostly the aesthetic effect caused by staining that might not be accepted by patients. It is, therefore, important to provide informed consent to patients. Also, dentists should know common protocols to use the product.

Keywords: Dentistry; Silver diamine fluoride; Patients; Caries arrest; Fluor.

RESUMEN

Introducción: La caries es considerada la condición de salud más prevalente en el mundo. Durante mucho tiempo, el flúor se ha utilizado para prevenir y tratar la caries. Pero el fluoruro diamino de plata (SDF) es un producto nuevo que se introdujo en Japón en la década de 1960. Muestra grandes resultados en términos de detención de caries. **Objetivos:** El objetivo principal de esta revisión es analizar el uso de SDF para detener la progresión de caries en la población general. Como objetivos secundarios, evaluaremos los beneficios y limitaciones de SDF sobre los tratamientos tradicionales y revisaremos los protocolos. **Metodología:** La estrategia de búsqueda se realizó entre octubre de 2022 y enero de 2023. Analizamos diferentes artículos de los últimos 10 años, según nuestra ecuación de búsqueda, en las bases de datos PubMed y Medline. **Resultados:** Sometimos la totalidad de artículos encontrados a la lista de verificación PRISMA y obtuvimos 30 artículos que tras exponer de forma sistemática en la tabla de resultados, analizamos para dar respuesta a los objetivos planteados. **Conclusiónes:** Se ha demostrado que SDF detiene la caries al promover la remineralización e inhibir la desmineralización. Presenta una gran cantidad de beneficios compatibles con los niños por su no invasividad, facilidad y rapidez de uso. También mostró una gran compatibilidad para el tratamiento de ancianos, ya que puede tratar la hipersensibilidad y la caries radicular. SDF mostró menos desmineralización que la caries tratada con fluoruro de sodio tradicional. Los principales beneficios de SDF fueron que es rápido, seguro, asequible, indoloro y muy eficaz. Sus limitaciones fueron principalmente el efecto estético causado por la tinción que podría no ser aceptado por los pacientes. Por lo tanto, es importante proporcionar el consentimiento informado a los pacientes. Además, los dentistas deben conocer los protocolos comunes para usar el producto.

Palabras clave: Odontologia; Fluor diamino de plata ; Patientes ; Detención de carie; Fluor.

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1 INTRODUCTION

Thomas A. Edison said, “The doctor of the future will give no medication but will interest his patient in the care of the human frame, diet and in the cause of prevention of disease”(1) which highlights the new objectives of dentistry nowadays that are not focused on healing but more on prevention.

Pierre Fauchard in the 18th century, a French surgeon, who is defined as the father of modern dentistry, redefined this profession by adding prosthesis and dental filling to it. But more recently in the early 20th century, dentists started to acknowledge the importance of preventive dentistry and started to use new methods to promote this new area of dentistry. Dentists have realized that prevention is the new key to have then better treatments and to preserve at most the teeth and the surrounding tissues (2).

As time goes on, preventive dentistry should be the new field of choice and should have the best effect on the population and the community in the future. It has shown great results in the last 30 years (3).

Caries is the most prevalent health condition in the world. Even though it has decreased considerably in the past 50 years, World health organization (WHO) has shown that early childhood caries (ECC) is present in 60 to 90% of children (4). 37% of children between 2 to 8 and 58% of adolescents between 12 to 19 years old suffer from dental caries. Over 20 years old 90% of adults had caries in their life (5).

In Spain 35 million people have caries. 35% of children that are less than 6 years old, 30-35% of adolescents, and 94% of young adults will suffer from it. In the elderly population in Spain, the totality of the population has suffered from dental caries (6).

It really shows us the magnitude of the problem whether from the Spanish or a worldwide point of view.

1.1 **Preventive dentistry**

1.1.1 Definition

Prevention is defined as the action of stopping something from happening or arising and has been categorized into three main stages.

1.1.2 Stages of prevention

Primary prevention is used before any health problems happen and to prevent them prior to their incidences (7), such as vaccination, education programs, and campaigns against dangerous behavior like the use of tobacco, alcohol or bad diet habits. In dentistry, primary prevention will be used by using prophylaxis treatment to prevent future teeth problems and make sure our patients keep good dental hygiene. It can also be specific protection like the use of fluoridated toothpaste or fluoride treatments used in cariogenic patients and will be used especially in children (8).

Secondary prevention is used to identify a disease in its early stage by using screening before the apparition of signs or symptoms (7). For example, in dentistry, it will be associated with a simple restorative dental procedure like obturations (8).

Tertiary prevention is defined as slowing the speed or stopping a disease through harsher measures such as rehabilitation (7). Odontology will express it by the practice of root canal treatment when the tooth of the patient will be necrosed or with irreversible pulpitis in some cases. Or by using a removable or fixed prosthesis to rehabilitate the patient's phonation, support the surrounding tissue, and eat (8).

As the importance of prevention has increased over time, the community has expanded and improved its means over certain aspects and has put forward the necessity of preventive dentistry. Especially for patients with low incomes and medically compromised patients.

It has been shown at the beginning of the 20th century, the relation between fluoride

and the reduction of the prevalence of caries (9). This relationship will be developed in the following points.

1.2 **Dental caries formation**

Dental caries is the most spread disease in the world. It is induced by the formation of dental plaque that is produced by the accumulation of microorganisms in the oral microbiota.

First within minutes after cleaning the teeth an acquired pellicle composed of glycoprotein will form around the teeth. This pellicle will work as a protective barrier around the teeth and will be loosely adhered. But due to the substrate present in this acquired pellicle between 0 to 4 hours after tooth brushing, bacteria will collect reversibly. Then primary colonization will occur between 4 to 24 hours after tooth brushing, and irreversible bacteria colonization of streptococcus sanguis, oralis, and mitis take place. In the following two weeks, the bacterial plaque is increased both in thickness and complexity. This is made possible by the multiplication of the preexisting bacteria and the addition of a new bacterial strain, streptococcus mutans, which depends on the presence of sucrose. This is called secondary and tertiary colonization. After 2 weeks this bacterial biofilm will mature, mineralize itself, and form calculus (10,11).

Streptococcus mutans were identified as the main pathological bacteria present in the oral cavity. But streptococcus mitis also contribute to the demineralization of the enamel. These bacteria can survive in low pH and have a high cariogenic ability. The dental plaque will ferment carbohydrates and form acids which will damage the tooth structure. But caries formation is a multifactorial disease and is not only due to the formation of the plaque. It is induced by genetic and environmental factors, such as poor diet habits, bad oral hygiene, or even low salivary flow (12).

1.3 **Caries prevention**

1.3.1 Fluorine compounds

The initial stages of caries are reversible and can be remineralized, especially thanks to the action of fluoride.

The role of fluoride has been acknowledged for over 70 years, but its use has increased more recently as we understand it and its functioning better. Fluoride will work by strengthening the enamel tissue, thus making it more resistant to decay (7).

Nowadays various ways have been found to prevent and control dental caries.

Some of them are used to increase the resistance of the teeth with the systemic use of fluoride by water fluoridation or even fluoride supplement tablets. Topical use of fluoride is also used thanks to fluoride toothpaste, mouthwash, fluoride gel, and varnishes (8). Those have shown great results over the last decades to a certain extent as they can lead to fluoride overdose and can conduct to fluorosis in children while teeth are forming (9).

1.3.1.1 Water fluoridation

Fluoride is a mineral that has been proven to prevent caries. As water is the main dietary source of fluoride, it is a good way to incorporate it into children's everyday life (13). As the concentration of fluor in water is very mild, there is less likelihood to develop dental fluorosis and is therefore a good manner to prevent caries. It is considered the best collective prophylaxis (14).

In Spain the concentration of fluor recommended is 0,7 mg/l and has been lowered as fluoride is also present in drinking water that is incorporated in food during its preparation (3,14).

1.3.1.2 Fluoride varnishes

In the dental office, practitioners are mostly using fluoride gels and varnishes on high-risk caries patients.

Fluoride varnishes are used to have prolonged contact between the fluoride and the tooth surface. They have a high concentration and can only be used by professionals. It shows a significant decrease in caries prevalence on permanent and primary teeth when applying it 1 to 4 times a year. We use it for non-cooperative children and disabled patients. Studies have shown better results on enamel hypersensibility rather than on dentine (3).

1.3.1.3 Fluoride gel

Fluoride gels have the same objectives as varnishes but are used in lower concentrations and can be applied by a professional or self-use. It has great results in preventing caries but has little to no action over patients with low caries risk. It can be applied up to 4 times a year. Self-applied fluoride will be recommended for patients with high-risk caries. It should not be applied before 6 years old (3).

1.3.2 Non-fluoride preventions

1.3.2.1 Sealants

Pits and fissure sealant will be used in high-risk caries children. It is a way to prevent caries by applying a resin into the pits and fissures of the molars. This will provide a barrier and impedes the growth of biofilm by blocking the feeding of the cariogenic bacteria (15).

It has shown great outcomes to prevent caries on the occlusal surface of the teeth(3).

In case there are small caries present only in the enamel surface and not in the dentin, we can perform ameloplastia by enlarging the occlusal fissure with a little bur and then filling the fissure with sealant (16).

1.3.2.2 Plaque removal

As we explained, caries is mainly formed by the accumulation of dental plaque. One of the main ways to prevent its formation is by brushing your teeth 2 to 3 times a

day for 2 minutes and having a regular dental checkup every 6 months to a year to perform dental cleaning using ultrasound in the dental office (3). Ultrasonic scalers will work by using high vibration that will break down calculus (17).

Even though fluoride, sealant, and dental prophylaxis are very useful and have shown clear protection against cariogenic bacteria over teeth once the cavity has been done it has not shown any efficiency over already cavitated lesions. The only way to treat them is to perform restorative dentistry, which is more invasive.

1.4 **Silver diamine fluoride**

1.4.1 Definition

Silver diamine fluoride (SDF) is a colorless, topically applied medication used to prevent and treat dental caries developed in Japan in 1960s (18). It provides an easy, affordable, efficient, and barely non-invasive process to arrest the progression of dental caries. It has been proven to also treat dentin hypersensitivity (19).
It is composed of silver particles that act as an antimicrobial and kill the bacteria responsible for wearing your teeth down, and fluoride ions (containing silver ammonia fluoride and water) that promote remineralization and inhibit demineralization of the enamel, dentin, or top layer of the teeth. It forms a complex with ammonia that can maintain a constant concentration of the solution for a certain moment.
It has shown great ease and efficacy among other intervention products (20).

1.4.2 Mechanism of action of silver diamine fluoride

This product is widely used for many years in several countries as Argentina, Japan and China (21). It has been shown that this product has higher effectiveness to prevent and treat caries than sodium fluoride (NaF).
Applied over the dentinal surface, SDF will significantly decrease the growth and adherence to the tooth surface of S. mutans, actinomyces, and lactobacillus acidophilus, cariogenic bacteria that are mainly responsible for the development of carious lesions.

After the application of SDF, the tooth surface will darken, and the lesion depth of the demineralized surface will decrease. The progression of the lesion will also slow down, and the surface will become harder. This mechanism works because SDF will promote the reabsorption of calcium and inhibit calcium dissolution from the enamel (21).

A squamous layer of silver protein will form over the exposed dentin that will seal partially the dentinal tubules (Figure.1), which has not been seen with any other anti-caries drugs. Hydroxyapatite and fluorapatite will form over the exposed organic matrix of the dentin (20) and silver chloride and metallic silver will form when in contact with hydroxyapatite (22) (Figure.2).

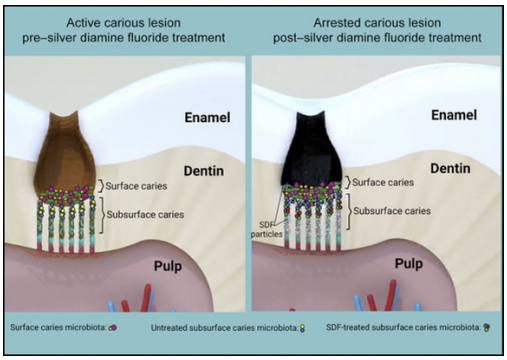


Figure.1 Effect of SDF over caries (23).

Hydroxyapatite crystallization will happen and have an important role in the remineralization process of the tooth. Studies have shown that SDF reacts with calcium and phosphate ions and will produce fluorapatite that has reduced solubility and make the tooth less sensitive to acid attack as it is more resistant to demineralization than hydroxyapatite (24).

$$Ca_{10}(PO_4)_6(OH)_2 + Ag(NH_3)_2 \rightarrow CaF_2 + Ag_3PO_4 + NH_4OH$$

$$CaF_2 \rightarrow Ca^{++} + 2F^-$$

$$Ca_{10}(PO_4)_6(OH)_2 + 2F^- \rightarrow Ca_{10}(PO_4)_6F_2 + 2OH^-$$

Figure.2 Simplified chemical reaction of the reaction of SDF with hydroxyapatite to release calcium fluoride and silver phosphate (25).

SDF inhibits matrix metalloproteinases; cathepsins; and bacterial collagenases, which are proteins that break down the organic matrix of the exposed dentin.
Silver ions will work directly over bacteria present in carious lesions by inhibiting DNA replication, breaking the walls, and denaturing the proteins (20).

SDF in deep lesions will stop caries progression. If used in more artificial ones, these lesions will be resistant to biofilm and future cavitations, as SDF will reactivate itself when the bacteria killed by silver ions will be added to living bacteria (20). It provides long-time protection over the teeth surfaces, also thanks to the ammonia present in the solution (Figure.3).

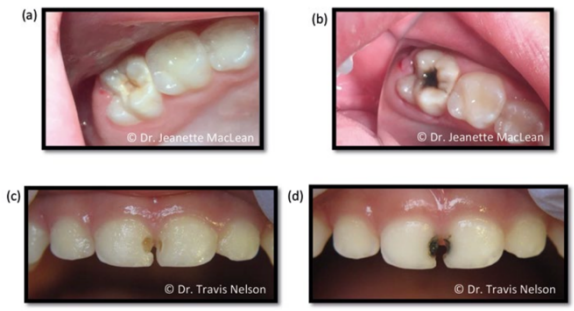


Figure.3 Teeth before and after the application of SDF. (a) and (b) on an upper first permanent molar, (c) and (d) on upper primary central incisors (26).

1.4.3 Utilization of silver diamine fluoride

1.4.3.1 An alternative to invasive treatments

SDF showed its efficacy and can be used for caries arrest in high-risk caries patients. This approach to dental caries will be non-invasive and have great outcomes.
Usually, to heal caries, the dental practitioner would use a rotatory instrument or excavator to take out the infected dentin. Even though this method presents great results, it has some limitations as it can weaken the tooth structure. This is a great problem, especially in young patients where it can also trigger fear and anxiety (25).

1.4.3.2 In prevention of pits and fissures caries

Topical fluoride has demonstrated a lesser efficacity for preventing pits and fissures caries than on the smooth surface of the teeth.
Hence, SDF can be used as a preventive measure but must be carefully used and recorded as it may stain the fissures of the teeth and may be mistaken as caries (25,27).

1.4.3.3 Prevention of secondary caries

Nowadays, restorations may suffer from infiltrations due to poor adhesion of the restorative materials to the dental wall. This can lead to secondary caries. But SDF has shown great inhibition of recurrent caries in restoration previously treated by it (25,28).

1.4.3.4 Arrest of root caries

With age, root caries prevalence increased. An annual application of SDF has been shown to decrease efficiently the apparition of these lesions over the root surface (25,29).

1.4.3.5 To treat dentin hyper-sensibility

SDF can clog the dentinal tubules. Thus, it can be very efficient in patients suffering from dentinal hypersensitivity. It has demonstrated also great results against dentinal erosion and abrasion. A threshold of 4 applications has been found and no further desensitization effect can be obtained (30).

1.4.4 Targeted patients

SDF is mostly used in the part of the population where prevention is the most useful, which means in children. Early childhood caries (ECC) remains a problem as if left untreated, it can damage the pulp and progress into pulp problems and even tooth loss. These can have further problems on children's health, as poor dentition will affect their nutrition and hence their development and general health. The current restorative

methods to treat those ECC are not available nor affordable for children with socioeconomic issues. SDF can be a great choice, as it is affordable and has great results for preventing, as well as treating ECC (31). It has also shown effectiveness in children to reduce their fear and anxiety related to the dental office, as this method is noninvasive. In contrary, to the conventional restoration which will use a rotatory instrument or excavator that can be traumatic on the patient. Later, when the child will be able to rationalize his fear, we will proceed to the removal of the caries that has been arrested by the action of the SDF (25).

As the population keeps their teeth longer, they will be more confronted with oral health diseases. It is important to treat problems such as coronal, root caries, and tooth sensibility in older adults. SDF will strengthen the dentin and thanks to the silver ions present in it, it has an antimicrobial effect. It will be great to prevent and treat older adults' caries (32).

SDF is very effective for dependent adults. As most of the time, the oral health of these patients is not well maintained, they have more tendency to suffer from caries. It can be challenging to treat these patients, as they suffer from other health complications, cognitive defects, physical handicaps, or even problems with mobility. But it is still important to find a way to treat them, as oral health problems can lead to other health problems in the future such as respiratory failure or cardiovascular disease.
SDF has been found as a solution to treat these patients by applying it once a year and has shown great results to stop the progression of root caries (29).

Justification:

According to what has been previously exposed, there are several methods used to prevent the appearance of caries and to reduce, or totally limit the advance of this pathology. We consider it important to know the characteristics of SDF and its use as an agent capable of controlling the advance of caries.

In this systematic review, we would ask ourselves: Can SDF stop completely caries growth in the general population?

2 OBJECTIVES

2.1 Primary objectives

To analyze whether the use of silver diamine fluoride stops the progression of caries in the general population.

2.2 Secondary objectives

A secondary objective was to evaluate the benefice and limitations of silver diamine fluoride over traditional fluoride treatments for caries arrest.
Also, we will review the protocol for the use of SDF.

2.3 Hypothesis

Silver diamine fluoride will stop completely caries growth.

3 METHODOLOGY

3.1 Search strategy

This search was conducted from October 2022 to January 2023. We analyzed the different articles by selecting those in line with the objectives of our work. This process is described below. We used only articles of the last 10 years.

3.1.1 Database

In order to carry out this work and with the aim of locating and identifying relevant studies, we have used several search sources:
Medline, PubMed, Scihub, Scielo, PDF drive, Google, Cochrane library, CRAI Dulce Chacón Library for the development of the introduction.

We have focused on Medline and PubMed as search sources to meet the objectives of this review by establishing a reproducible search equation, which is detailed in the following paragraphs.

3.1.2 Research equations

3.1.2.1 PubMed

We have used, as search terms, key words for our study combined by means of the Boolean operators AND and OR, obtaining the following equations.

("patient s"[All Fields] OR "patients"[MeSH Terms] OR "patients"[All Fields] OR "patient"[All Fields] OR "patients s"[All Fields]) AND ("silver diamine fluoride"[Supplementary Concept] OR "silver diamine fluoride"[All Fields]) AND ((("carie"[All Fields] OR "dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields] OR "caries"[All Fields]) AND ("prevent"[All Fields] OR "preventability"[All Fields] OR "preventable"[All Fields] OR "preventative"[All Fields] OR "preventatively"[All Fields] OR "preventatives"[All Fields] OR "prevented"[All Fields] OR "preventing"[All Fields] OR "prevention and control"[MeSH Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields] OR "prevention s"[All Fields] OR "preventions"[All Fields] OR "preventive"[All Fields] OR "preventively"[All Fields] OR "preventives"[All Fields] OR "prevents"[All Fields])) OR (("carie"[All Fields] OR "dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields] OR "caries"[All Fields]) AND ("arrestant"[All Fields] OR "arrestants"[All Fields] OR "arresting"[All Fields] OR "arrestment"[All Fields] OR "arrests"[All Fields] OR "heart arrest"[MeSH Terms] OR ("heart"[All Fields] AND "arrest"[All Fields]) OR "heart arrest"[All Fields] OR "arrest"[All Fields] OR "arrested"[All Fields])))

3.1.2.2 Medline

“Silver diamine fluoride” AND “patient” AND “caries prevention” OR “caries arrest”.

3.2 Eligibility criteria

The criteria used to identify the publications used in the work were determined by the PICO clinical question. Criteria that help us to critically evaluate the studies and determine their validity.

3.2.1 Inclusion criteria

-Clinical trials.
-Patients under 14 years old.
-Patients older than 14 years old.
-Application of silver diamine fluoride.
-Studies where caries arrest is proposed.
-Article between 2012 and 2023.
-Full text available.
-Language: English, French, Spanish.

3.2.2 Exclusion criteria

-Not enough follow-up.
-Article before 2012.
-Only abstract or summary available.
-Articles from unaccredited scientific journals.

4 RESULTS

4.1 Study selection process

To collect all the data necessary for our title we used the following technique:

-First, we go on the browsers PubMed or Medline.

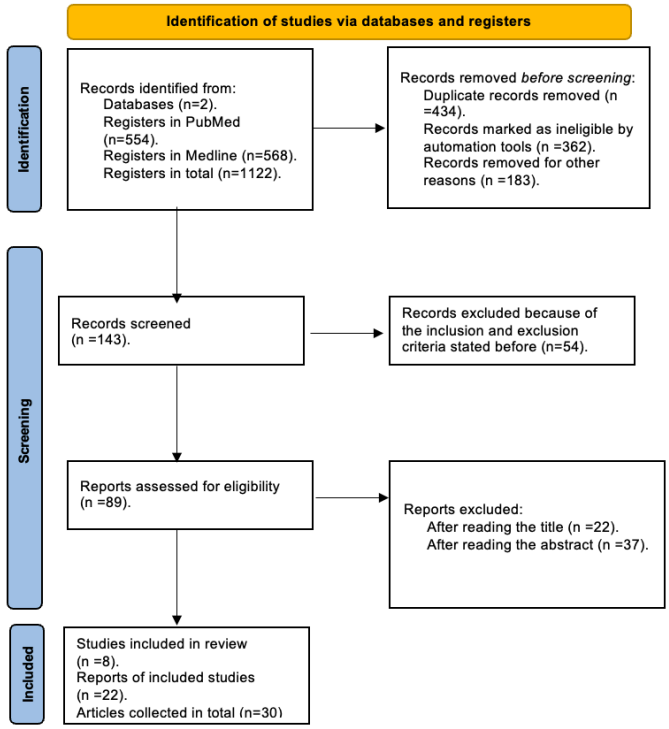
-Then we go into advanced research and type our keywords previously detailed.

-Using the inclusion and exclusion criteria, we can narrow our research and we can find the most relevant and up-to-date articles.

4.2 Flow chart

As a guideline to perform this review, we used the Preferred Reporting Item for Systematic Review and Meta-Analysis (PRISMA) checklist (Figure.4).

Figure.4 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

4.3 Tables of results

Author, date	Sample	Type of study/design	Kind of treatment	Results/ conclusion
Lea Angst et al. **2022 (33)**	*17 general dental practitioners GDPs (10 women 7 men)*	*Thematic analysis*	*SDF*	-Lack of basic knowledge (indications). - Aesthetic concern by the GDPs. - restricted availability (biggest problem). - Preservation of the dental structure and non-invasiveness.
Lluís Brunet-Llobet et al. **2022 (27)**	13 articles	Critical analysis	SDF 38%	-SDF is a useful therapeutic strategy to prevent and control the carious lesions in pediatric patients. -Main disadvantage of SDF → dark stains that appear in the treated areas and the impossibility of restoring the destroyed dental tissue. -**BEST PROTOCOL**→recommended concentration: 38% applied 2 times a year.
Iliana Gehui Yan et al. **2022 (34)**	14 protocols from 15 publications from 4 manufacturers, 3 dental associations, and 7 author teams	Review	SDF	-SDF protocol (can be different depending on the practitioner)→protect gingiva with petroleum jelly, isolation with cotton roll, clean carious lesion, dry carious lesion, apply SDF for **60 sec**, remove excess and apply sodium fluoride varnish on top. - 4 out of 6 protocols suggest no carries excavation before the application of SDF. -Suggested application time→ 60 sec (might be too long for children), but studies showed we can apply it **from 10 to 240 sec.**
Violeta Contreras et al. **2017 (35)**	7 studies	Systematic literature review	-SDF 38% -SDF 30%	-SDF at concentrations of 30% and 38% → more effective than other preventive management strategies for arresting dentinal caries in primary dentition. -30% and 38% concentrations of SDF useful as a caries preventive treatment in primary teeth and permanent first molars.
Araya Phonghanyudh et al. **2022 (36)**	302 children, 12 were excluded because they were not presenting any enamel caries 290 children. Grp 1→147 (SDF) Grp 2→ 143 (NaF)	Randomized Clinical Trial	-SDF 38% -NaF 5% varnish (sodium fluoride)	-Semiannual application of 38% SDF and 5% NaF varnish had comparable effectiveness in arresting enamel caries in primary teeth at 18 months (group 59,1% and group 2 58.8%)→ better to use NaF as there is no staining effects. -Non-cavitated enamel caries had higher chances of stability than cavitated enamel caries.

				-SDF 38% showed high effectivity on stopping progression dentin caries in children in comparison to enamel caries. -The use of 38% SDF had no notable adverse effects and no impact on parental satisfaction with the dental appearance of children.
Yasmi O et al. **2018** **(37)**	6 systematic reviews	Systematic review and meta analysis	SDF 38%	-SDF arrest 80% of treated lesions. -Caries arrest on primary teeth on children→81%. -Caries arrest in permanent teeth on children→ 77%. -Caries prevention on children→ 70,3%. - Decrease of progression of dentin caries→ 77,5%. -Carries arrest and prevention in elderly→ preventive fraction 725% greater in a 24-months follow up and 100% better than placebo in 30-month study. -SDF should not be used in lesion with pulpal involvement because it does not prevent progression of infection. -**Black stained**→ present between 66% to 76% but parental satisfaction in 30 months follow up for their children was about 62% to 71%. -Many studies suggest **potassium iodide** to control or reverse the staining, but it has been showed that it does not work on root caries in the long term.
Yasmi O et al. **2016** **(38)**	10 studies	Systematic review	SDF 38%	-SDF 38% applied 2x a year→80% reduction of caries progression and future caries. -SDF 38% twice as more effective than fluoride varnish. -On primary and permanent dentition→65,9% caries arrest over the dentin. -Apply product between **30 to 60 sec with air drying.** -Better for posterior teeth because of aesthetics concerned. -Better rates of arrest → anterior teeth. -Good treatment for children who can't receive traditional restorative treatment for dental decay.

				-Safe and affordable.
Peter Milgrom et al. **2018 (39)**	66 preschool children with 1 or more carious lesions. Placebo or SDF was applied; 36 placebo, 30 SDF	Randomized control trial and analysis. Double-blind randomized placebo-controlled superiority trial with 2 parallel groups	SDF 38%	-Average proportion of treated surface with arrest lesion at follow up was significantly higher in SDF group than placebo group→0,72 for SDF and 0,05 for placebo. -Over half of the SDF group has 100% of lesion arrested. -No gingival or soft tissue stomatitis or ulceration were observed. -Based on enrolled participants, the adverse event rate was 11.1% in the placebo group and 16.0% in silver diamine fluoride group→ no statistically significant differences by treatment. -Topical 38% silver diamine fluoride arrests tooth decay and is effective for the short-term treatment (act between 14-21 days) of dental caries in pre-school age children. -The effect is **rapid and safe.** -No bacteria associated with caries changed significantly but rather a diminution of all the bacteria in the lesion→The potential for microbial resistance appears low.
Richard J. Wierichs et al. **2018 (40)**	Bovine incisors roots were cleaned, and 400 dentin blocks were prepared with sound surface and artificial cavity lesion.	In vitro study	-SDF -NaF -Tricalcium phosphate (TCP) -Calcium phosphate complex (CPP)	-SDF application instead of NaF showed significantly less demineralization compared to conventional NaF varnish. -SDF prevent further mineral loss on sounded surface and as well on carious lesions. -97% of the lesions after application of SDF present **black discolorations.**
Irene Shuping Zhao et al. **2018 (21)**	29 articles	Literature review	SDF	-Dentin surface treated with SDF present significantly less growth of streptococcus mutans than those treated without SDF. -Lesion depth of a demineralized tooth surface decreased after SDF application. It is also effective to slow down the progression of the caries. - Carious lesions treated with SDF had significantly higher surface microhard-ness, to a depth of approximately 150 lm, compared with the control lesions treated with deionized water.

				- SDF promotes calcium reabsorption and inhibit calcium inhibition from the enamel. -Enamel surface treated with SDF have significantly lower mineral loss than those treated without SDF. -**SDF 38% contains 44,800 ppm** fluoride which is the highest among fluoride agent for dental use. - Fluoride promotes the remineralization of hydroxyapatite in enamel and dentine. -SDF reduces the growth of cariogenic bacteria. -The **silver ion is bactericidal**. - The possible mode of action of SDF for arresting caries may be attributed to its inhibition of mineral demineralization, promotion of mineral remineralization and protection of the collagen matrix from degradation.
Tomoko Ishigur et al. **2018** **(41)**	Bovine incisors were cut into crown and root specimens. S. mutans were add to some of the specimen and the rest was control groups. Specimen treated either with SDF 38% or NaF 2%. -RD (root dentin) -CE (coronal enamel)	Study research Statistical analysis	-SDF 38% -NaF 2%	-Fluoride treated specimen has higher pH values than the untreated controls. (CE: NaF 4.62 vs 4.34, SDF 5,23 vs 4.44) (RD: NaF 5.10 vs 4,54, SDF 6,65 vs 4,64). - At 120 min after glucose addition, significantly higher pH values were detected at the S. mutans cell/fluoride-treated tooth surface interfaces than at the control interfaces. - The pH values were significantly higher at the S. mutans cell/SDF-coated tooth interfaces than at the S. mutans cell/NaF-coated tooth interfaces, irrespective of the tooth substrate. - The pH values detected at the S. mutans cell/SDF-coated RD (root dentin) interfaces were significantly higher than those detected at the S. mutans cell/SDF-coated CE (coronal enamel) interfaces. -SDF specimen has greater release of fluoride and silver. They exhibit lower lactate production and decalcification (calcium release) than the control samples. -Significantly lower amounts of calcium dissolved from aged NaF- and SDF-coated RD samples than from NaF- and SDF-coated CE samples, respectively.

				- This antimicrobial effect was weakened by 1 week's aging, while the acid resistance of the fluoride-treated surfaces seemed to increase with aging. - Fluoride-treated tooth surfaces inhibit bacterial acid production at the bacteria/tooth interface. The SDF-coated RD had the strongest inhibitory effect. -SDF has proven to be effective to stop dentin caries in children and prevent and stop root caries on elderly. -These results indicate that the application of fluoride to tooth surfaces is effective at preventing caries. -The study found that SDF coating on RD had the most potent inhibitory effects on bacterial acid production, indicating that SDF may be a promising tool for preventing caries on root surfaces.
Shalin Shah et al. **2014 (25)**	42 articles	Systematic review	SDF	-SDF address the issue of a high prevalence of caries among young children with a strategy that involves minimal invasion. -The use of 38% SDF inhibited demineralization and preserved collagen from degradation in demineralized dentin. -SDF is used to arrest caries in the anterior sector of primary teeth. -SDF useful to **prevent pits and fissure caries** of first molar teeth. -Effective to **arrest root caries** and prevent secondary caries. -SDF can also be used to **desensitize** teeth. -Due to its ability to occlude dentinal tubules, SDF shows promise in treating patients with **dentinal hypersensitivity**. -Studies also found no severe pulpal damage after SDF applications. - SDF is an economical therapeutic agent that is easy and fast to use, making it suitable for use in developing countries.
M.L. Mei et al. **2017 (24)**	4 groups containing SDF. Samples were then analyzed with trans- mission electron	Research report Statistical analysis	SDF	-Results showed a positive correlation between the percentage of crystal size and the concentration of SDF. -Fluorohydroxyapatite and silver chloride were formed in all the SDF groups.

	microscopy (TEM) with energy-dispersive X-ray spectroscopy (EDS), powder X-ray diffraction (P-XRD), and Raman spectroscopy (detailed later).			-According to the study's findings, SDF reacted with calcium and phosphate ions to create fluorohydroxyapatite, which has reduced solubility. -As the concentration of SDF increased, the crystals became longer and thicker, and there was a positive correlation between the increased percentage of crystal size and the concentration of SDF. -This preferential precipitation of fluorohydroxyapatite could be one of the primary reasons for the arrest of caries lesions treated with SDF. -Fluoride/calcium and fluoride/phosphorus ratios increased as SDF concentration increased. -**Formation of fluorohydroxyapatite** was observed in all SDF groups, with fluoride content increasing with SDF concentration. -The reaction between SDF and calcium/phosphate ions leads to the formation of fluorohydroxyapatite, which has lower solubility and is more likely to precipitate. This selective precipitation of fluorohydroxyapatite may be a key contributor to the effectiveness of SDF in halting caries lesions.
Ollie Y. Yu et al. **2018** **(42)**	Demineralized dentine blocks were treated with SDF + NaF (Group 1), SDF (Group 2), NaF (Group 3) and water (Group 4) and subjected to a Streptococcus mutans biofilm challenge.	Case control study	-SDF -NaF	-Both SDF and NaF treatments significantly reduced lesion depth compared to water treatment, and an interaction effect was found between NaF and SDF treatment. -The addition of NaF to SDF did not result in better remineralization of demineralized dentin compared to SDF alone ($p = 0.491$). -The presence of NaF reduced the antibacterial effect of SDF ($p < 0.001$). -The presence of silver chloride and metallic silver was detected in Groups 1 and 2. -The SDF + NaF group (Group 1) showed a superior antibacterial effect compared to the NaF group (Group 3) ($p = 0.001$). -It is not recommended to use SDF solution and NaF varnish together to treat

				dentin caries based on the study's findings. -Dentine caries treated with SDF presented superior reductions in the lesion depth of the dentine blocks than the NaF group and water group. -SDF promotes the formation of insoluble calcium fluoride, which dissolves in a salivary environment to release calcium and fluoride ions, facilitating the subsequent replacement of the hydroxyl ion of hydroxyapatite by fluoride to form acid-resistant fluorapatite. -Silver chloride formed in the SDF group might have contributed to the caries-arresting effect of SDF because it precipitated on the surface of the demineralized dentine, working as a protective layer and decreasing the loss of calcium and phosphate from the dentine. -The SDF + NaF group and SDF group showed less collagen exposure and more mineral precipitation than the NaF and water groups, as SDF inhibited the activities of proteases and collagen degradation and protected the collagen from subsequent exposure and degradation.
O. Urquhart et al. **2018 (43)**	48 reports→ 7,378 participants	Meta-analysis/ systematic review	-SDF -NaF	-5% NaF varnish was the most effective for arresting or reversing non cavitated facial/lingual carious lesions and that 38% silver diamine fluoride solution applied biannually was the most effective for arresting advanced cavitated carious lesions on any coronal surface. -On cavitated lesion: After 30 months of follow-up, 30% SDF solution applied annually on primary teeth showed a 1.5-times-greater chance of arresting advanced cavitated lesions in primary teeth versus 30% SDF solution applied once a week for 3 weeks (high certainty). -After 30 months of follow-up, 38% SDF solution applied biannually on primary teeth was superior to 12% SDF solution applied biannually (high certainty) and

				38% SDF solution applied annually (moderate certainty).
Anthony Tzong-Ping Tsai et al. **2022** **(44)**	A review of dental and photographic records of 61 caries-free subjects under age 3 who received SDF application was performed.	A Case Series evaluation	SDF	-Three groups of staining outcomes after SDF application were identified: no staining (32.8%), removable staining (31.1%), and permanent staining (36.1%). -The patterns of staining were similar to initial lesion distributions in Early Childhood Caries (ECC). -The deft scores for all subjects were zero before treatment and remained so at the end of the study, except for one subject from Group 3 who showed clinical signs of caries at follow-up visits. -SDF application may be useful in identifying previously undetected young children with high caries risk. -SDF staining of carious dentin is caused by silver/protein reactions. -Upon application of SDF to a decayed tooth surface, a squamous layer of silver-protein conjugates immediately begins to form. -The formation of metallic silver compounds is the cause of black staining. -Brown or black stains can result from the reaction of silver ions with phosphates present in both plaque and tooth structure. -The chemical reaction mechanism of SDF with hydroxyapatite suggests that silver phosphate is the main silver-containing reaction product, initially appearing yellowish but turning black over time. -Removable brown or black stains found in group 2 indicate that the reaction occurred within the plaque rather than the tooth structure. -Black staining can appear due to silver sulfide formation on the external tooth surface or within the enamel after SDF application. -Regular plaque removal or topical fluorides may improve the unfavorable environmental conditions and prevent active lesions from progressing into visible cavities.

				-SDF application may help identify young children with high caries risk who were previously undetected.
Upasana Shrivastava et al. **2021** **(45)**	36 children aged 2-10 years with active caries lesions in primary teeth were selected based on ICDAS criteria. 30 patients were treated with 1-2 topical applications of SDF (38%). Lesions were reassessed at 1 week and 3 months, and parents were surveyed for their perception of SDF.	Clinical study	SDF 38%	-80% of carious lesions were arrested at the first recall, and 93.3% were arrested after 3 months. No pain or infection occurred. Parental perception of SDF's simple application, taste, and esthetics was statistically significant. -The study supports SDF as an effective treatment for preventing active carious lesions in primary teeth, and parents had a positive perception of the treatment. -Majority of parents agreed or strongly agreed that SDF application was easy and painless, with acceptable discoloration and taste (49.2% and 46.7%, respectively), while 4.1% had a neutral response; none of the parents disagreed or strongly disagreed. - Parental acceptance for SDF application in primary teeth was above 95% in this study. -SDF was found to be more effective after 3 months compared to 1 week. - The study found that SDF (38%) arrested caries lesions up to 93%. -The study used 38% concentration of SDF, which has been found to inhibit Matrix Metallo-Proteinases (MMP) more effectively than 30% and 12% SDF. -Studies have shown that increasing the frequency of SDF application from yearly to every 6 months can enhance its effectiveness in arresting caries lesions. -Clinical significance→SDF provides a noninvasive remedy to inhibit active carious lesions in primary teeth without causing psychological trauma to children.
Faith Miaomiao Zheng et al. **2022** **(46)**	-	Review articles	SDF	-SDF is commonly available as a 38% solution containing 255,000 ppm silver and 44,800 ppm fluoride ions. -Silver is an antimicrobial and inhibits cariogenic biofilm, while fluoride promotes remineralization and inhibits demineralization of teeth.

				-It inhibits biofilm formation, promotes remineralization, counteracts demineralization, prevents collagen degradation, and occludes dentinal tubules. - SDF arrests caries without affecting dental pulp or causing dental fluorosis. -Indirect pulp capping with SDF causes no or mild inflammatory pulpal response. However, direct application of SDF to dental pulp causes pulp necrosis. -SDF therapy to arrest caries is simple, painless, non-invasive, non-aerosol-generating, and inexpensive.
Ryan Richard Ruff et al. **2023 (47)**	2998 children between 5 to 13 yo in 47 New York City primary schools either treated with SDF with fluoride varnish or an active comparator consisting of glass ionomer sealants and atraumatic restorations with fluoride varnish.	Randomized clinical trial.	-SDF -NaF varnish -Glass ionomer sealant -atraumatic restoration	-10.5% presented at baseline with preexisting dental sealants on any tooth, and 29.2% had untreated dental caries. -Hispanic or Latino and Black children comprised 63.8% of the analytic sample (887 of 1390). -Analytic sample for caries arrest was 413 patients, and for prevention was 985 patients. -The mean proportion of children with all caries remaining arrested was 0.56 in the experimental group and 0.46 in the control group. -The mean proportion of children without caries at baseline who remained caries free at follow-up was 0.81 in the experimental group and 0.82 in the control group. -Experimental group rates were noninferior to those of the active control. Either for caries arrest or caries prevention over a 2-years period. -The arrest rate for the experimental treatment was higher than for the active control, and there was nearly a demonstration of superiority. -SDF can be an attractive alternative approach to school-based caries prevention.
Michelle L. Thomas et al. **2020**	2 groups: -treatment group→ 97 pediatric patient	Cohort study	SDF	-81% of the tooth surfaces treated with SDF were recorded as arrested at a follow-up visit.

(48)	aged 13 to 71 months treated with SDF. -comparison group→216 children from 13 to 71 months not treated with SDF.			-There was a greater than 80% decline in dental emergencies after adopting SDF in the Pediatric Dental Center compared to the period preceding its adoption. -SDF can manage ECC (early childhood caries) patients, particularly those without access to dental care or with difficulty accessing it. -SDF is an effective, inexpensive, and **minimally invasive** strategy.
Abdullah Faraj Alshammari et al. **2019** **(49)**	222 parents complete a survey about the acceptance of staining regarding the use of SDF on primary teeth. 39.2% of participants were male and 60.8% were female, with ages ranging from 20 to 52 years.	Cross sectional study	SDF	-Parents judged staining on the anterior teeth to be esthetically not acceptable (90% strongly refused) and staining on the posterior teeth to be not acceptable (28.4% refused, 68.5% strongly refused). - There was no statistically significant difference in parental ratings of using SDF on the anterior and posterior teeth. -There was a statistically significant difference in acceptance ratings between male and female with SDF on posterior teeth, but not on anterior teeth. -Parents with lower education levels had a lower acceptance of staining, with 100% strongly refusing to use SDF on anterior and posterior teeth.
Yasmi O. Crystal et al. **2017** **(50)**	120 parents who has children with high risk of dental caries completed the survey→98 mothers and 22 fathers coming from diverse backgrounds, took part in the study.	Cross sectional study	SDF	-Most parents (67.5%) judged SDF staining on posterior teeth to be esthetically tolerable, but only 29.7% of parents made this same judgment about anterior teeth. -In the absence of behavioral barriers to conventional restorations, 53.6% of parents reported that they were likely to choose SDF to treat their child's posterior teeth, but only 26.9% of parents were likely to choose SDF to treat their child's anterior teeth. -Approximately one-third of parents found SDF treatment unacceptable under any circumstance. -The parents' level of acceptance of SDF treatment increased as the number of children's behavioral barriers to conventional restorations increased. -Parents' acceptance of SDF treatment increased to 68.5% on posterior teeth and 60.3% on anterior teeth when deciding

				whether their children should undergo general anesthesia during treatment. -Parents' acceptance of the treatment varied according to their socioeconomic status. And patients with less education had a greater acceptance of staining. -Clinicians should provide **informed consent** forms with photographs of staining to identify parents who find the treatment unacceptable under any circumstance.
Seema Thakur et al. **2022 (51)**	42 children with primary tooth presenting carious lesions randomly assigned in 3 groups with different times of application of SDF: -Group 1: SDF absorbed for 30 seconds. -Group 2: SDF absorbed for 60 seconds. -Group 3: SDF absorbed for 120 seconds. Each group was then rearranged into 2 subgroups: -Subgroup 1→ cavitated lesions -Subgroup 2→ non cavitated lesion.	Randomized trial	SDF	-Caries arrest percentage at different time intervals: • 3 weeks: 70.13% • 3 months: 83.77% • 6 months: 97.4% -Caries arrest percentage by group at 6 months: • Group 1 : 33.12% • Group 2: 31.81% • Group 3: 32.47% -51.9% of lesions belonged to subgroup 1 and 45.5% belonged to subgroup 2. -No statistically significant difference in caries arrest between Group 1, Group 2, and Group 3. -The caries arrest rate was higher with 120 seconds of SDF application, but the difference was not statistically significant. -The study suggests that a minimally cooperative patient should not be a contraindication to SDF use, especially if isolation of the tooth for at least 30 seconds is possible. -The longest possible absorption time is recommended to decrease concerns about systemic absorption and the need to remove SDF with a posttreatment rinse. -Caries arrest with SDF application is consistent in both cavitated and non-cavitated lesions, as the caries arrest rate does not significantly vary with different application durations.
D. Duangthip et al. **2018**	888 preschool children. -Group 1: 12% SDF applied annually.	Randomized clinical trial	SDF	-**Protocol**: 1) Lay the child on their back on a table.

(52)	-Group 2: 12% SDF applied semiannually. -Group 3: 38% SDF applied annually. -Group 4: 38% SDF applied semiannually. Each group was either getting applied SDF or the placebo.			2) Eliminate any food particles and plaque from the decayed cavities. 3) Isolate the affected teeth of the child using gauze. 4) Apply the solution onto the decayed tooth surfaces using a microapplicator for roughly one minute. 5) Use gauze to remove any excess solution if necessary. Notify the child's teacher that they should refrain from eating, drinking, or rinsing their mouth for the next 30 minutes. -No significant differences in oral pain were found among groups at all follow-ups. -Complaints of gum swelling ranged from 1.5% to 2.9% at different follow-up periods→ no significant difference. -Complaints of gum bleaching ranged from 3.0% to 5.7% at different follow-up periods→ resolved in 2 days. -Out of 3,268 lesions examined, 25.8% were active and 74.2% were arrested at 30-month follow-up. -Significant differences in the numbers of blackened carious lesions were found among 4 SDF groups at 18- and 30-month follow-up. -Lesions treated with 38% SDF had a higher chance of becoming black than those treated with 12% SDF. -Lesions treated semiannually had a higher chance of becoming black than those treated annually. - The study found that similar proportions of parents in groups 1 and 3 reported that their children had adverse effects at the follow-up when they received only placebo. It is difficult to identify whether a complaint of pain is an adverse effect of SDF treatment or if it is caused by underlying dental disease.
Sarah E. Raskin et al. **2021**	Patient n = 2269 teeth n = 7787 3 groups: 1) SDF alone	Naturalistic study	SDF	-Overall survival rate of SDF alone: 76%. -SDF placed with sedative filling: 50%. -SDF with a same-day restoration: 84%, likely reflecting treatment intent.

(53)	2) SDF applied with a sedative filling 3) SDF with a same-day restoration			-SDF alone performed exceptionally well on primary cuspids, permanent molars, and permanent bicuspids, and among patients aged 10 to 20 years, with modest variation across caries risk assessment categories. -Single annual application of SDF successful in 75% of cases. - SDF applied to patients with a high caries risk was likely to fail at approximately one-and-a-half times the rate of SDF applied to low-risk patients. -SDF was significantly more likely to fail among patients aged 1–5 years and older than 41 years of age. -On primary teeth, lower molars had significantly higher rates of failure than other teeth. -On permanent teeth, lower bicuspids were about 25% less likely to fail than lower molars, while upper incisors were about 2.7 times more likely to fail.
Andreas Kiesow et al. **2022** **(54)**	Human root surface dentin specimens were treated with gelled or standard 38% SDF or negative control.	In vitro investigation	-SDF 38% gel -Standard SDF 38%	-Both SDF formulations exhibited penetration depths up to 500 µm and occluded dentinal tubules similarly. -Precipitates were found for both SDF formulations, with a slightly higher abundance for the experimental gel SDF product. - The experimental 38% SDF gel was indistinguishable from the commercial 38% SDF product with respect to dentinal tubule penetration and occlusion. - Placebo (B) did not show surface precipitation or tubule occlusion.
Surapong Srisomboon et al. **2021** **(55)**	4 groups done on extracted teeth specimen. -Group 1 (control): 25 µL of deionized water was applied. -Group 2 (30 s): 25 µL of SDF was applied and left for 30 s. -Group 3 (60 s): 25 µL of SDF was	In vitro study	SDF 38%	-Results showed a significant increase in mineral apatite precipitation in the 180 s group (group 4) after 1 week. -After 2 weeks comparable mineral density between the 30, 60, and 180 s groups were notable. -The precipitation of silver chloride and calcium phosphate crystals that occluded dentinal tubules was similar in all experimental groups. -Mineral precipitation was only detected in the specimens treated with SDF, and

	applied and left for 60 s. -Group 4 (180 s): 25 µL of SDF was applied and left for 180 s.			fluoride crystals were not generally detected. -Silver salts that precipitated on the specimen surface may be AgCl (sodium chloride) salts, which potentially act as a protective layer against dental caries and blocks dentinal tubules to protect the pulp–dentin complex.
Chelsea Mitchell et al. **2021 (56)**	55 participants >55 yo with at least one root caries lesion. Treated lesions were re-evaluated at 2–3 weeks and repeated every six months.	Prospective case series	SDF 38%	-The probability of lesion arrest with treatment ranged from 82.9 to 91.6%. - The crude lesion arrest rates for the 55 participants were 85.9% (73/85) for root surface lesions, 86.6% (103/119) for lesions at crown margins, and 100% (7/7) for lesions in the furcation. -Arrest rates at 18 months were slightly higher in root surfaces than around crown margins: 91.6 % versus 89.8 %. - All furcal lesions (n=7) were arrested by 6 months, 100%. - High caries lesion arrest rates were observed in older adult patients with active root surface lesions treated repeatedly with 38 % SDF in this case series.
May L. Mei et al. **2013 (57)**	Human dentine blocks were demineralized and allocated to four groups: SF, F, S and W. -Group SF received a topical application of 38% SDF solution (253,900ppm Ag, 44,800ppm F) -Group F received a 10% sodium fluoride solution (44,800 ppm F) -Group S received a 42% silver nitrate solution (253,900 ppm Ag) -Group W received deionised water (control).	In vitro study	SDF 38%	-Surface morphology showed evident demineralization with exposed collagen in groups S and W, but not in group SF. -Group SF specimens had relatively smooth surfaces, and dentine collagen fibers were not exposed. -Group F specimens had a relatively rough surface with exposed collagen and an increased inter-fibrillar distance. -Groups S and W showed evidence of partial demineralization with exposed reticular nanostructure of collagen fibers on the surface. -Exposed fibers were visible in both inter-tubular and intra-tubular areas. - SDF 38% could reduce mineral loss and collagen exposure from acid challenge. - The inhibitory effect of 38% SDF on dentine demineralization and collagen degradation was greater than that of 10% NaF and 42% AgNO3 solutions.

				- The concentration of fluoride and silver ions in 10% NaF and 42% AgNO3 solutions, respectively, was equivalent to that of 38% SDF. - The use of 38% SDF can enhance the process of dentine caries remineralisation.
Kulnipa Punyanirun et al. **2017 (58)**	18 artificial caries slabs were created from the proximal surfaces of 9 chemically demineralized premolars. -Test group was applied with 38% SDF in adjunct to fluoride toothpaste -the control group was treated with fluoride toothpaste alone.	In vitro study	SDF 38%	- Mineral density increased in both the SDF and control groups through the lesion depth and became stable when approaching sound enamel. - A significant difference in mineral density between baseline and post-cycling in the control group and SDF group was observed from 0–260 µm and 0–300 µm in depth, respectively. - A significantly greater mean mineral density gain was found in the SDF group at 0–120 µm. - The remineralizing effect of SDF (% Remineralization) was evaluated, and the SDF group showed a significantly higher percentage **increase in remineralization** compared to the control group. - The percentage increase in mineral density of the SDF group compared with the control group (mean ± SD) was 35.89% ± 20.23. - The study found that the mineral density, depth of remineralization, and remineralization percentage in the SDF group were significantly higher than the control group. - SDF application is simple, fast, and non-invasive, but may cause black staining and an **unpleasant metallic taste**.

GDP → general dental practitioner

5 DISCUSSION

5.1 Silver diamine fluoride and caries arrest

SDF is a topical medication that has been demonstrated to be very useful for caries to treat and prevent caries. As shown in Peter Milgrom et al. (39) study, over half of the SDF-treated lesions were presenting a 100% caries arrest.

SDF is mainly available as a 38% solution containing 255,000 ppm of silver that is antimicrobial and will inhibit cariogenic biofilm and is bactericidal (21,46), and 44,800 ppm of fluoride ions that promotes remineralization and inhibit demineralization of teeth (46,57). SDF 38% has the highest among fluoride agents for dental use (21).

According to Araya Phonghanyudh et al.(36) study, non-cavitated enamel caries are more likely to remain stable compared to cavitated enamel caries. In Iliana Gehui Yan et al.(34) study, 4 out of 6 of the protocols used for SDF application suggested no caries excavation before the application of the product.

Studies have highlighted also that one of the advantages of this treatment is its effectiveness as a short-term treatment, as it acts between 14 to 21 days (39).
Also, authors such as Yasmi.O et al.(38), Lluís Brunet-Llobet et al.(27) and Upasana Shrivastava et al.(45) have demonstrated that there is a better outcome of the treatment when applied bi-annually. And that there will be a reduction of 80% in caries production and future caries (38).

Literature has shown that dentin surfaces treated with SDF present significantly less growth of streptococcus mutans than those treated without SDF. Following the application of SDF, a reduction in the depth of the demineralized tooth surface will be observed and will hence slow down the progression of caries (21).

Peter Milgrom et al.(39) study showed that there is, after the application of SDF on the carious surface, a diminution of all the bacteria present in the lesion, rather than specific bacteria related to caries.

The mode of action of SDF will promote calcium reabsorption and inhibit calcium inhibition (21,42). This will form insoluble calcium fluoride and will consequently harden the treated surface as stated in Ollie Y. Yu et al.(42) study. It has been demonstrated also that the enamel surfaces treated with SDF have significantly lower mineral loss than those treated without SDF (21).

The study of May L. Mei et al.(57) shows us that 38% SDF can enhance the process of dentin caries remineralization and could reduce mineral loss and collagen exposure from the acid challenge (21,57). The silver fluoride present in SDF will act as a protective layer and will help arrest and prevent caries by decreasing the loss of calcium and phosphate ions from the dentin (42).
In Tomoko Ishigur et al.(41) study, it has been shown that the antimicrobial effect is weakened one week after the application but that the acid resistance increases with time.

Various authors as Shalin Shah et al.(25), Faith Miaomiao Zheng et al.(46) and May L. Mei et al.(57) have stated in their studies that SDF 38% inhibits demineralization and preserved collagen from degradation in demineralized dentin. It will also occlude dentinal tubules and will therefore protect teeth from dentin hypersensibility (46). Andrea Kiesow et al.(54) in vitro study has demonstrated that there are no differences in dentinal tubule penetration and occlusion when using standard SDF 38% or SDF 38% gel.

M.L.Mei's et al.(24) study has shown that SDF increases the crystal size of fluorohydroxyapatite and that the more concentrated the SDF is, the bigger the crystals. This can explain the arrest of caries thanks to SDF. As fluorohydroxyapatite will strengthen the tooth complex and will impede the progression of caries. SDF in contact with calcium and phosphate ions will form fluorohydroxyapatite. Which has lower solubility and is more likely to precipitate, hence halting caries progression. This selective precipitation of fluorohydroxyapatite may be a key factor in the effectiveness of SDF to stop caries lesions.

In Upsana Shrivastava's et al.(45) clinical study, SDF was found to be more effective after 3 months than after a week. Also, this study showed that SDF 38% is more efficient than other concentrations found on the market as SDF 30% or SDF 12%. As SDF 38% will inhibit the matrix metalloproteinases (MMP) more effectively, which is an enzyme responsible for the breakdown of collagen.

The in vitro studies of Surapong Srisomboon et al.(55) and Kulnipa Punyanirun et al.(58) indicate a greater mineral density observed in enamel after the application of SDF 38%.

5.1.1 Children

As SDF presents various benefice as how fast, easy to use, and non-invasive it is. It has been demonstrated in various studies that SDF is an effective therapeutic approach for the prevention and management of dental caries in young patients (27).
Araya Phonghanyudh's et al.(36) study showed that SDF 38% was very effective to stop the progression of dentin caries rather than enamel caries in children.
Authors have agreed that SDF is more useful to stop dentin caries and that it is very efficient for caries prevention on children (37,45).
Michelle L. Thomas et al.(48) cohort study has demonstrated the usefulness of SDF over ECC, especially for patients without or difficult access to dental care.
SDF 30% and 38% have been proven to be more effective than any other prevention for arresting dentinal caries in primary dentition and over the first permanent molar as stated in Violeta Contreras et al.(35) and Yasmi. O et al.(38) studies.

Shalin Shah's et al.(25) study has shown better rates of effectiveness on anterior teeth. But this use can be discussed as it presents esthetical concerns (25,38). This study also demonstrated that SDF is very useful to prevent and treat pits and fissure caries of the first permanent molars (25).

In Anthony Tzong- Ping Tsai's et al.(44) case series evaluation, the author has stated the usefulness of SDF to identify undetected caries in high-risk children. It can therefore be

used as a diagnostic tool as it presents a staining effect that is easily noticeable. Consequently, it may be used in school as an easy and affordable caries prevention (47).

Sarah E. Raskin's et al.(53) study showed a higher success rate of SDF in patients with low-risk caries but presents still, performant results in high-risk patients.

5.1.2 Elderly

Various studies have demonstrated that SDF is a good utensil to use for caries arrest and prevention in the elderly too (37,48,56).

Tomoko Ishigur's et al.(41) study showed that SDF is beneficial to stop and prevent root caries lesions that are often observed in elderly patients. As it has a very potent inhibitory effect on bacterial acid production (25,41).

Shalin Shah's et al.(25) study has stated that SDF is employed for the purpose of stopping root caries and preventing secondary caries. It is also used to desensitize teeth (25) by occluding dentinal tubules as shown in Faith Miaomiao Zheng et al.(46) and Andreas Kiesow's et al.(54) studies.

Chelsea Mitchell et al.(56) prospective case series proved that SDF 38% can be used in high-risk caries lesion in older patient, that presents active root surface lesion or furcal lesions. And that there is a good caries lesion arrest rate by using SDF 38%.

5.2 Comparison of SDF with traditional techniques

5.2.1 NaF (Sodium fluoride)

Several studies have compared the utilization of SDF and NaF which is more traditionally used for tooth prevention.
A study from Araya Phonghanyudh et al.(36) showed that the semiannual application of SDF 38% and NaF 5% was comparable in terms of effectiveness in arresting enamel

caries in primary teeth. They concluded that it may be better to use NaF 5% as it does not provide staining effects in comparison to SDF 38%.

But on the other hand, in the study of Yasmi O et al.(38), it has been proven that SDF 38% was twice as effective as fluoride varnish. It might be due to the fact that SDF contains 44,800 ppm of fluoride which is the maximum fluoride content for dental purposes (21), and that it has a greater release of fluoride and silver than traditional NaF (41). The study of Richard J. Wierichs et al.(40) demonstrates that SDF showed significantly less demineralization and prevent further mineral loss over sound and carious tooth surface in comparison to NaF varnish.

Ollies Y. Yu et al.(42) and Tomoko Ishigur et al.(41) studies showed that SDF has been considered to be better to treat dentin caries as it presents a better inhibitory effect and more efficiency overall than NaF.
But this study displays that the use of SDF and NaF simultaneously reduced the antibacterial effect of SDF but even though they both reduced lesion depth, using them together do not enhance remineralization than using SDF alone (42).

Some authors as O. Urquhart et al.(43) say that NaF 5% varnish is the most effective to stop non-cavitated facial and lingual caries. But the use bi-annually of SDF is better to arrest advanced carious lesions on any coronal surface.

5.2.2 Benefice of SDF

SDF is a treatment that presents various benefice. Most authors such as Lea Angst et al.(33) ,Peter Milgrom et al.(39) ,Faith Miaomiao Zheng et al.(46), Michelle L. Thomas et al.(48) and Kulnipa Punyanirun et al.(58) came to the conclusion that it is rapid, safe, affordable, non-invasive, painless, and non-aerosol generating. It is also very preservative of dental structure and is considered very effective (33).

It also has been considered by Yasmi O et al.(38) study the best treatment for patients who cannot receive traditional restorative treatment for dental decay.

The study by Seema Thakur et al.(51) demonstrated that it can be used also on non-cooperative patients as it is very fast of use and takes only 30 seconds to isolate the tooth. Shalin Shah et al.(25) study revealed that SDF is an economical therapeutic agent that is easy and fast to use, making it fit for use in developing countries.

Moreover, studies by Faith Miaomiao Zheng et al.(46), Peter Milgrom et al.(39), and D. Duangthip et al.(45) tell us that SDF arrests caries without affecting the dental pulp or either causing dental fluorosis (46) or that no gum swelling or oral pained was observed after the use of SDF (52). Also, SDF use does not present significant adverse effects and it was observed no gingival or soft tissues stomatitis or ulceration (39).

Upasana Shrivastava's et al.(45) study indicates that SDF provides a good way to stop and prevent caries in children without involving psychological trauma as it is fast and non-invasive.

5.2.3 Limitations of SDF

SDF's adverse effect might be considered negligible in comparison to its benefice (52).

As insignificant as those side effects may be, authors such as D. Duangthip et al.(52) detect in their study that some patients may encounter gum bleaching after using SDF, but this effect will resolve itself rapidly.

One of the limitations for the moment of this product is availability (33) and the most common side effect observed by authors was staining which may be unpleasant and unaesthetic to patients and may deter the patient from accepting the treatment (33,37).

Yasmi O et al.(37,38) studies in 2016 and 2018, observed that stained appears 2 out of 3 times but that it might be controlled or reversed by using potassium iodide (37). Therefore, due to aesthetics concerns, it is recommended to apply SDF on posterior teeth rather than anterior ones (38).

However, some studies as the one from Lluis Brunet-Llobet et al.(27) told us that staining might be impossible to remove.

Kulnipa Punyanirun et al.(58) study told us that SDF might come with an unpleasant metallic taste.

In a study conducted by Anthony Tzong-Ping Tsai et al.(44), they identified that the staining obtained by SDF showed a similar pattern to the initial lesion. This staining is due to the silver/protein reaction and the formation of metallic silver that will produce staining. As these stains are also related to plaque accumulation, they might be avoided with regular plaque removal and topical fluoride application to improve the staining. Also, regular plaque removal and topical fluoride application will impede the lesion to progress into deeper cavities.

D. Duangthip's et al.(52) study concluded that lesions treated with SDF 38% have a higher chance of becoming black than those treated with SDF 12%. Also, lesions treated semi-annually had higher chances of becoming black than those treated annually.

Authors like Yasmi O et al.(37), Shalin Shah et al.(25) and Faith Miaomiao Zheng et al.(46) told us that SDF should not be used in lesions with pulpal involvement because it does not prevent the progression of the infection (37). Nevertheless, there is no severe pulpal damage after the application of SDF (25,46), but if applied directly to the pulp it might cause necrosis (46).

As this product presents aesthetical concerns, it is important to know the perception of the patients or the parents of the patients, as it might be used over children’s teeth.

Upasana Shrivastara's et al.(45) study tells us that parents have a positive perception of the treatment as it is safe easy and painless. Thus, they accept the discoloration and have an even higher acceptance of staining on primary teeth rather than permanent ones. But in Abdullah Faraj Alshammari et al.(49) and Yasmi O. Crystal's et al.(50) studies, the authors state that staining might not be accepted by parents, especially in the anterior sector. But might be more tolerable in the posterior one.

Patients will be more likely to use it when there is a lack of behavioral barriers in their child or if it was an alternative to general anesthesia. But the answers depend on the parents and their socioeconomic status.

Because of the likelihood of patients not accepting the treatment because of the aesthetical point of view, it is important to provide the parents and patients with informed consent and photographs about the treatment and to explain to them the pros and cons of it (50).

5.3 Protocols and use of SDF

As there is a lack of knowledge among general dental practitioners about the use of SDF (33), it is important to supply indications and protocols for the product.
Seema Thakur's et al.(51) study informs us that there is no difference between applying the product for 30 or 60 seconds (51).
It has been recommended by various studies as Lluis Brunet-Llobet et al.(27) and Yasmi O et al.(38) to use it 2 times a year and with a preferable concentration of 38%.

The protocol of use of SDF depends on one practitioner to another other but we can bring out a common one with the most common way to use it which is:
-Protect the gingiva with petroleum jelly
-Isolate the tooth with cottons roll
-Clean the carious lesion. This step is controversial as most of the studies like Iliana Gehui Yan et al.(34) don’t suggest caries excavation before the application of SDF.
-Dry the carious lesion
-Apply SDF for 60 seconds with air drying (38). This suggested application times might be too long for children, but other studies recommended applying it from 10 to 240 seconds.
-Remove excess and apply sodium fluoride on top (not mandatory) (34).

Surapong Srisomboon's et al.(55) study concluded that after one week there is a more significant increase in mineral appatite when SDF is applied for 180 seconds but as time goes there are no significant differences with the times of application. Also, the occlusion of dentinal tubules does not depend on application times either.

Another protocol can be used in preschool for children as a prevention and treating tool as explained in D. Duangthip et al.(52) study.

Protocol:

1) Lay the child.
2) Eliminate any food particles and plaque from the decayed cavities.
3) Isolate the affected teeth of the child using gauze.
4) Apply the solution onto the decayed tooth surfaces using a microapplicator for roughly one minute.
5) Use gauze to remove any excess solution if necessary.

Notify the child's parent and professor that they should refrain from eating, drinking, or rinsing their mouth for the next 30 minutes.

6 CONCLUSIONS

Under the conditions established by the graduation project, we can conclude the following points:

-Silver diamine fluoride has been proven to be very useful for caries arrest. Its concentration of 44,800 ppm in fluor is the highest find on the market for dental use. By this, it will promote remineralization and inhibit demineralization. The tooth surface will harden by forming insoluble calcium ions because SDF presents a mode of action that promotes calcium and phosphate reabsorption.

It presents an antimicrobial effect and because it is acid resistant it will impede future caries formation.

The more concentrated SDF is, the bigger the fluorohydroxyapatite will form and the stronger the tooth surface will be. Therefore, the more efficient concentration and the one we mostly found on the market is SDF 38%.

As SDF presents a lot of benefices compatible with treating children, like its ease of use, its non-invasiveness, and fastness of use. It is considered a great therapeutic strategy for pediatric patients.

SDF has been proven to be more efficient in stopping dentin caries rather than enamel caries. It is very useful for caries prevention on primary caries. It can also be used as pits and fissure treatments for first permanent molars. Another of its benefice over children is that it can be used as a diagnostic tool, as its staining effect is easily noticeable over caries.

Moreover, SDF has also proven to be beneficial to the elderly, as its action occludes dentinal tubules and treats dentin hypersensibility. Another struggle observed in the elderly, that may be treated by SDF is root caries, furcal lesions, and secondary caries thanks to its very potent inhibitory effect on bacterial acid production.

- In preventive dentistry sodium fluoride (NaF) has been used for a very long time in caries arrest and prevention. SDF and NaF have comparable effectiveness in arresting enamel caries but when it comes to dentinal caries, SDF is twice as effective as NaF. Caries treated with SDF will suffer from way less demineralization and further mineral loss than caries treated with NaF. Its simultaneous use does not display an enhancement of remineralization when compared to the single use of SDF.

-The principal benefices of SDF are that it is rapid, safe, affordable, non-invasive, painless, non-aerosol generating, and moreover very effective. It is considered the best treatment for patients who cannot receive traditional restorative dental treatments and is very suitable to use in developing countries. Also, it is judged useful for non-collaborating patients since it takes seconds to use it and will not create psychological trauma. It does not provide any bad adverse effect as gum swelling, oral pain, or dental fluorosis.

But as with every product, there are limitations and adverse effects that can impede patients from receiving the treatment. The main one being staining. This outcome might be controlled or reversed using potassium iodine. But it is considered better to use SDF on posterior teeth rather than anterior's ones. Another side effect that can occur is a metallic taste. As the aesthetic concern can hold back patients to use the product, it is important to provide the patients with informed consent and photographs of the treatment. It may be a better treatment for primary teeth as they will not stay in the mouth. The acceptability of the treatment might depend on patients and depend also on their socio-economic background.

- As there is a lack of general knowledge of SDF and its use. It is important to provide protocols to the dentist. It exists a lot of them, but we came to the conclusion that most of them were similar and only a few steps were changing from one to the other.

A common protocol is:

- Protect the gingiva with petroleum jelly.
- Isolate the tooth with cottons roll.
- Clean or not the carious lesion.
- Dry carious lesion.
- Apply SDF for 60 seconds with air drying (between 10 to 240 seconds).
- Remove excess and apply sodium fluoride on top (not mandatory).

Because of its benefice and if patients are willing to go over the aesthetic side effect, SDF might be the best new way to prevent and arrest caries. Therefore, the hypothesis of this review is accepted.

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8 ANNEXES

8.1 Abbreviations

SDF= Silver diamine fluoride

WHO= World health organization

ECC= Early childhood caries

NaF= sodium fluoride

GDPs= General dental practitioners

RD= Root dentin

CE=Coronal enamel

8.2 Figures