



GRADUATION PROJECT

Degree in Dentistry

SILVER DIAMINE FLUORIDE IN PAEDIATRIC DENTISTRY: EFFECTIVINESS IN PREVENTING AND ARRESTING DENTAL CARIES

Madrid, academic year 2024/2025

Identification number: 170

ABSTRACT

Introduction: Dental caries denoted a significant public health challenge among children, affecting their oral health and overall quality of life. Conventional treatments were often challenging, especially for those with behavioral difficulties or limited access to dental care. Silver diamine fluoride, particularly at 38% concentration, had emerged as a minimal invasive option with proven antimicrobial and cariostatic properties; **Objectives:** This study aimed to evaluate the effectiveness of 38% silver diamine fluoride in preventing or arresting dental caries in pediatric patients aged between 0- and 12-year-old with primary dentition, compared to other atraumatic preventive treatment; **Material and Methods:** An comprehensive electronic search was conducted in November 2024 across databases PubMed/Medline complete, Scopus and Web of Science, focusing on English written studies from the past ten years; **Results:** out of 134 initially identified articles, 17 randomized clinical trials met the inclusion criteria. Fourteen studies investigated the ability to arrest caries progression, two focused on its preventive potential and one addressed both; **Conclusions:** The findings showed that 38% of silver diamine fluoride effectively arrested dental caries, with success rate ranging from 56,3% to 99%. While silver diamine fluoride matched or outperformed other minimally invasive options, its effectiveness was influenced by factors such as lesion severity and oral hygiene. Overall, silver diamine fluoride proved to be a valuable tool for managing and preventing childhood dental caries.

KEYWORDS

Dentistry; silver diamine fluoride; paediatric patients; dental caries.

RESUMEN

Introducción: La caries dental es un desafío relevante de salud pública infantil que perjudica la salud bucal y calidad de vida. Los tratamientos convencionales resultan ser difíciles de aplicar en niños con dificultades conductuales o acceso limitado al cuidado dental. En este contexto, el fluoruro diamino de plata ha surgido como una alternativa efectiva gracias a su acción antimicrobiana y cariostática lo convierte en una opción mínimamente invasiva; **Objetivo:** evaluar la efectividad del fluoruro diamino de plata al 38% en la prevención o detención de caries dentales en pacientes pediátricos de entre 0 y 12 años con dentición primaria, en comparación con otros tratamientos atraumáticos; **Materiales y Métodos:** se realizó una búsqueda electrónica exhaustiva en noviembre de 2024 en las bases de datos PubMed/ Medline complete, Scopus y Web of Science, incluyendo estudios escritos en inglés publicados en los últimos diez años; **Resultados:** de 134 artículos encontrados inicialmente, 17 ensayos clínicos aleatorizados cumplieron con los criterios de inclusión y 14 estudios de ellos evaluaron la capacidad del fluoruro diamino de plata para detener la progresión de la caries, dos se centraron en su potencial preventivo y uno abordó ambos aspectos; **Conclusiones:** Los hallazgos mostraron tasas de detención de caries entre 56,3%-99%, Aunque igualó o superó a otros tratamientos atraumáticos, su efectividad fue influida por factores como la severidad de las lesiones y la higiene. En general, los resultados posicionaron que el fluoruro diamino de plata al 38% como herramienta eficaz para el manejo y prevención de la caries infantil.

PALABRAS CLAVE

Odontología; fluoruro diamino de plata; pacientes pediátricos; caries dental.

Table of contents

1. INTRODUCTION.....	5
1.1 Silver diamine fluoride	5
1.1.1 What exactly is silver diamine fluoride?	5
1.1.2 Silver diamine fluoride: A historical perspective.	6
1.2 Understanding the action mechanism of silver diamine fluoride	8
1.2.1 Antimicrobial action.....	8
1.2.2 Demineralization and remineralization	9
1.2.3 Dentin desensitization	10
1.2.4 Cariostatic effect	10
1.3 Potential application of silver diamide fluoride.....	10
1.3.1 Pre-treatment considerations	10
1.3.2 Clinical application of SDF.....	11
1.3.3 Post-treatment recommendation	12
1.4 Indications	12
1.4.1 Patient with high-caries risk.....	12
1.4.2 Patient with special needs	13
1.4.3 Management of dentinal hypersensitivity.	13
1.4.4 Management of Molar Incisor-hypomineralization.....	13
1.4.5 Pre-restorative treatment.....	14
1.4.6 Caries management in developing countries	14
1.5 Advantages and disadvantages.....	14
1.6 Future innovations.....	15
1.7 Justification	15
2. OBJECTIVE	16
3. MATERIAL AND METHODS	17
3.1 Search strategy	17
3.2 Studies selection	17
3.2.1 The inclusion criteria.....	18
3.2.2 The exclusion criteria.....	18
4. RESULTS.....	19
5. DISCUSION.....	30
5.1 Assessing the effectiveness of 38% Silver diamine fluoride in caries prevention and arrest in primary dentition.	30
5.2 Limitations.....	31
6. CONCLUSIONS.....	32
6.1 Conclusion for Primary objective	32
6.2 Overall effectiveness of 38% SDF for caries arresting	32
6.3 The role of 38% SDF in early caries prevention and secondary prevention for moderate and extensive lesions.....	32
7. SUSTAINABILITY.....	33
8. REFERENCES.....	34

1. INTRODUCTION

Dental decay is a chronic condition with multiple contributing factors affecting the health and quality of life of children from various socioeconomic groups. Untreated caries can lead to pain, infections and health issues, especially in preschoolers. Socioeconomic factors and high treatment costs limit access to dental care in disadvantaged populations (1–4). Modern approaches such as minimally invasive dentistry (MID), now emphasize tooth preservation with atraumatic non-invasive restorations (5).

The integration of atraumatic non-invasive restoration has marked an essential transition in pediatric practice (6). Preventing dental emergencies visits and improving the workflow with uncooperative, anxious and special patients (7). Nowadays, Evidence-based guidelines endorse non-restorative treatment, including silver diamine fluoride for primarily reducing hypersensitivity and easily arresting active caries in deciduous dentition (8).

1.1 Silver diamine fluoride

1.1.1 What exactly is silver diamine fluoride?

Silver diamine fluoride (SDF), with the chemical formula $\text{Ag}(\text{NH}_3)_2\text{F}$, is a topical fluoride solution applied to the teeth with an active carious lesion aimed at arresting the progression of dental disease. The liquid is an alkaline solution containing a pH range of 10-13 and is available as colorless or bluish color (9). The composition and concentration may vary depending on the brand and manufacturer, with available concentrations of 10%, 12%, 30% and 38% (9–11). The most common concentration used is 38%, containing 44,800 parts per million (ppm) of fluoride and 255,000 ppm of silver (Figure 1) (2). Typically, the composition by weight/volume consists of 25% silver, 5% fluoride and 8% ammonia (9). Silver provides antimicrobial effects, fluoride aids in remineralization of dental tissue and preventing caries, while ammonia acts as a stabilizer and helps deliver active ingredients into the tooth. These components complement each other to prevent and arrest caries (12,13).



Figure 1 Illustration of 38% silver diamine fluoride representing their concentration of its different composition. Self-made image (2,9,10,14,15)

Proven evidence supports the topical use of SDF to be effective in halting caries in both in primary teeth and early mixed dentition, this conclusion is reinforced by recently published systematic reviews, which consistently demonstrate comparable results (16,17). SDF has been recommended as a caries management option by the World Health Organization, the International Association in Pediatric Dentistry and the American Academy of Pediatric Dentistry (8,18,19). However, it is important to remember that SDF is recommended within a thorough management strategy, rather than a frontline, especially for children experiencing severe caries that are unsuitable for conventional interventions (18).

1.1.2 Silver diamine fluoride: A historical perspective.

In the 1960s, Japan was the first country to introduce a 38% SDF solution fusing the silver antibacterial properties with fluoride preventive effects (20). In the 1970s it was widely used as a cariostatic therapeutic agent for management of early childhood caries in children (11,21). Unfortunately, the silver reaction caused tooth discoloration, which reduced interest in using SDF products in children decades ago. Nevertheless, SDF has lately been reintroduced for the management for root caries in senior patients who are socially handicapped and suffer from dementia (21).

Globally SDF has sparked interest in managing caries and dentin desensitizing across various age groups, particularly in children and elderly patients and those individuals with special needs (22). Most of the countries have developed their own specific clinical guidelines and many offer SDF training programs for dental students (11,21,23).

For decades, SDF has been used in countries like Japan, Australia, Brazil, Argentina and Hong-Kong (23). There are several commercial brands and concentrations available, produced and exported by Japan, Australia, Brazil, India and most recently the United States of America (11,24). However, after the U.S Food and Drug Administration approved SDF solution as a desensitizing agent in 2014, its use among clinicians expanded as off-label solution as remineralizing agent for arresting and preventing caries (12,20).

The Adoption of SDF in Europe has been limited, the evidence supporting its effectiveness in caries prevention is gradually increasing its acceptance among dentists in many other countries (Figure 2) (20,23). The SDF solution of 38% Riva Star is commercially available in Western countries, often used off-label for patients with special needs or those who struggle with conventional treatments (21,26). Moreover, the European Academy of Pediatric Dentistry officially published a guideline in 2022 recommending the use of 38% SDF for treating deep dentinal carious lesions without pulp involvement in deciduous dentition (27).

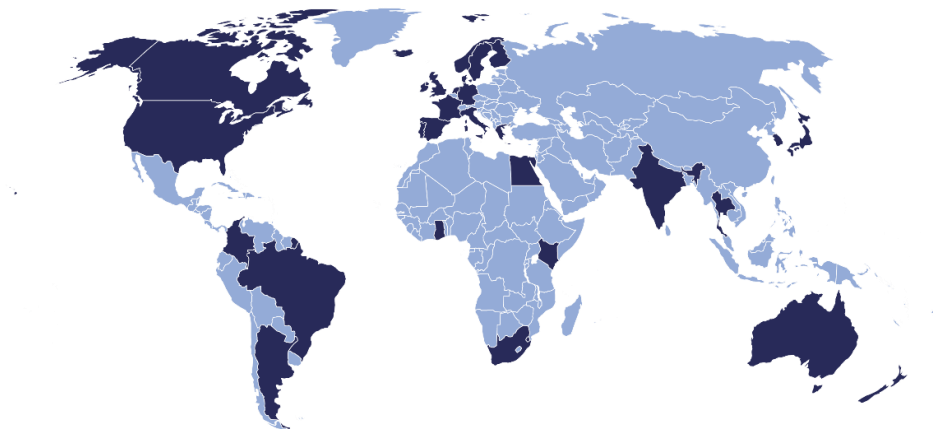


Figure 2 Examples of countries employing silver diamine fluoride, self-made image (11,21,25)

1.2 Understanding the action mechanism of silver diamine fluoride

The composition of SDF primarily consists of silver and fluoride ions. Since neutral silver fluoride is unstable, when coupled with water that contains ammonia, the resulting structure is more stable (11). The result is a complex silver diamine in which two ammonia molecules are attached to a single silver ion (10). In general, SDF provides antimicrobial action from silver and remineralization from fluoride. Furthermore, it prevents biofilm growth, reduces enamel and dentin demineralization and creates a rich mineral layer that halts decay progression (12). In addition, SDF induces proteolytic action against collagenases, protecting dentin collagen and creating a barrier to reduce dentinal hypersensitivity (2,28).

1.2.1 Antimicrobial action

Silver ions interact with bacterial enzymes and inhibit their electron transport system, making them toxic to cariogenic bacteria that have colonized the lesion (29). Eventually, the intention is to damage the bacterial cell walls and interfere with DNA production and replication of the bacteria. Silver ions react with the thiols groups of amino acids and deoxyribonucleic acid (DNA), changing their hydrogen bonding. Consequently, cell death will result from preventing their intercellular metabolic activity (30).

Subsequently, dead bacteria seem to act as carriers for silver ions, enabling them to kill living bacteria by reactivating the silver component when encountered. This process is called Zombie effect and helps to maintain the silver reservoir capacity for SDF in both dead bacteria and dentin proteins to provide a prolonged antimicrobial activity (31).

Silver ions prevent the progression of caries by disrupting biofilm formation and limiting the activity of cariogenic bacteria. This interference occurs through their action on glucosyltransferases enzyme, which is responsible for the synthesis of glucan from sucrose. The bacterial biofilm thickening and adherence to the teeth surfaces depend on glucan (11,22). Silver ions once again demonstrate their capacity to prevent the progression of caries, attributed to their acquired antimicrobial properties.

Finally, when fluoride elements are used in high concentrations it exerts an antimicrobial effect by interfering with the metabolic action against cariogenic bacteria. This inhibition primarily results from the interaction of fluoride ions with essential bacterial enzymes, leading to a reduction in both carbohydrate metabolism and sugar transport (11,32).

1.2.2 Demineralization and remineralization

SDF contains the highest concentration of fluoride among topical treatments, measured at 44,800 ppm. This agent is highly effective in preventing the demineralization of both enamel and dentin by facilitating their remineralization processes and decreasing the tolerance of bacteria to acids (12,20,33). Recent findings from a systematic review further affirmed that it is similarly effective in caries prevention across both primary and permanent teeth (17).

The remineralization of the tooth structure through the interaction between hydroxyapatite on tooth surface and SDF to form silver phosphate, calcium fluoride and ammonium hydroxide (2). These compounds act as reservoirs for fluoride and phosphate ions to facilitate deposition of fluorapatite which is more resistant to bacterial acid attack than hydroxyapatite. Meanwhile, the ammonium hydroxide keeps an alkaline environment which poses great antimicrobial activity and being known as an effective disinfectant (20). Fluoride ions are gradually released over time, continuously aiding in the remineralization of enamel and the dentin while inhibiting demineralization of the tooth structure (33). Simultaneously, in demineralizing conditions, fluoride ions combine calcium and phosphate to create a high mineral rich protective layer onto the dentin surface, strengthening it against bacterial acid attack (10,34). Silver phosphate resists bacterial acid attacks, while calcium fluoride serves as fluoride ion reservoir, supporting the formation of fluorapatite to repair bacterial damage (33). Fluorapatite is less soluble in acidic environments than hydroxyapatite, thereby preventing deeper acid penetrating into deep dentin tissue.

An in vitro investigation reveals SDF combined with potassium iodide (KI) exhibits superior efficacy compared to other alternative anti-caries therapies in reducing cariogenic bacterial colonization within dentinal tubules (35). The enhanced long-term remineralization process and bacterial resistance are attributed to the tooth structure, acting as a reservoir for these substances (20). SDF is capable of deeply infiltrating both enamel and dentin, depositing two to three times more fluoride than conventional sodium fluoride varnish (2,23,33). Additionally, silver ions infiltration plays a critical role in antimicrobial defense, as their release during reacidification contributes to sustained antibacterial action. Research indicated that both silver and fluoride have been shown to penetrate approximately 25-30 microns into the enamel, 200-300 microns into dentin and deep carious lesion (4,20,26). Notably, the mineral content of silver and fluoride accumulates to a greater extent in demineralized dentin than healthy dentin,

thus demineralized dentine demonstrates more resistance against acid-induced dissolution by bacteria, as well as enzymatic degradation (36,37).

1.2.3 Dentin desensitization

Since the late 1960s, SDF has been acknowledged as an effective solution to treat dentin hypersensitivity by occluding dentinal tubules (11). When applied onto the demineralized dentin, it creates a protein-silver layer which seals dentinal tubules (36). The collaborative action of fluoride and silver ions creates insoluble compounds like fluorhydroxyapatite and silver protein complexes, which can penetrate and precipitate within dentinal tubules, increasing mineral density and sealing them (2,37). Eventually this will prevent fluid movements that typically trigger pain in the pulpal nerve endings (28,38).

1.2.4 Cariostatic effect

Silver diamine fluoride preserves dentin collagen and structural integrity by inhibiting proteins that degrade the exposed dentin organic matrix, such as bacterial collagenases, matrix metalloproteinases and cysteine cathepsins (10,34). Besides, by preventing collagen breakdown and biofilm development, SDF arrests caries and increases surface microhardness with a depth of 150 microns (33,39). Moreover, the characteristic black staining of SDF treated teeth indicates arrested caries, as silver compounds precipitate onto carious exposed collagen matrix, forming a mineralized barrier that stabilizes the lesion. The staining can be observed clinically and is an indication of arrested caries since silver compounds help to form a mineralization barrier that stabilizes the lesion (10,29,40). Even though staining can be considered as an aesthetic drawback, it is an indication of SDF's effectiveness in halting the caries process and presence of an antimicrobial barrier preventing tooth for further decay (4,29).

1.3 Potential application of silver diamide fluoride

1.3.1 Pre-treatment considerations

Assessment of caries condition of the teeth when using SDF treatment, it is advisable that practitioners first examine the current standards and protocols that dictate clinical practice within their specific setting before proceeding with any intervention. For instance, the best way

to use SDF is as part of a chronic illness management strategy that enables risk assessment, disease control and clinical efficacy monitoring (18).

Before choosing which teeth to treat with SDF, it is essential to obtain radiographs and assess whether there is any indication of pulp involvement. SDF should only be applied to teeth that do not exhibit signs of inflamed pulp, have no history of spontaneous pain and no presence of carious lesion impacting the pulp chamber (40). Additionally, SDF can serve as a cariostatic agent prior to the placement of restorations (4).

An explanation to the patient or caregiver about the major effects their children could experience following SDF treatment, the frequency of reapplications at follow-up appointments, and the reason for the appearance of black staining at the site of the lesion. The patient and the caregivers may not always accept the black staining side effects. Therefore, before beginning the therapy, a documented informed consent should be signed (18,36). Lastly, the workstation should be prepared for prior application, and the clinician and patient should both wear safety eyewear (41).

1.3.2 Clinical application of SDF

A thorough cleaning on the teeth should be done prior to the application of the solution, ensuring that any plaque or debris is eliminated from the cavity to facilitate optimal contact with the affected area. The gingival tissue and lips could be protected with petroleum jelly, to avoid staining in soft tissue. The treatment area must be isolated using either cotton rolls or a rubber dam, ensuring that the site remains uncontaminated during the process (2,4,26,30,42).

The amount should be dependable according to the brand used, however with just one drop of step-1 solution and two drops of step-2 solution should be enough to treat five teeth per patient. In cases where re-application is needed, it is recommended to reapply after one week (42).

The lesion should be dried using a steady flow of compressed air or by employing a cotton pellet. On a disposable godet dappen dispense one drop of step-1 solution onto a micro-brush, remove the excess of the liquid and carefully placed only onto the affected lesion site for 10 seconds. After, two drops step-2 solution are dispensed on the godet dappen and onto a new micro brush. A generous amount of the solution should be applied on the treatment site which

will appear creamy white. This should be kept active by rubbing until the color disappears (2,16,31,44). The addition of the step-2 potassium iodide solution to the mixture facilitates the formation of silver iodide, which precipitates, effectively eliminating excess of silver ions and minimizing black discoloration (9,26).

Some studies recommend waiting time between applications should be between 10 seconds to 3 min (12,36,40). The excess should be removed carefully with a cotton pellet to avoid staining and metallic taste of the silver ions and minimize systemic ingestion (36). A careful application with a micro brush should not be a problem for exposure of staining at extraoral tissue. Lastly, the isolation should be removed after three minutes which is required for exerting its effect (18).

1.3.3 Post-treatment recommendation

There is no list of postoperative limitations provided specifically by the manufacturer, but various studies suggest that individuals should refrain from eating or drinking for a duration ranging from 30 min to 1 hour after the procedure (43). First follow-up visits are advisable after 2-4 weeks to assess the staining and hardness of the surface (4). A re-call appointment for re-application and additional SDF application will depend on the evidence of the caries activity or progression (36). Lesions can be restored with glass ionomer or composites, known as Silver atraumatic restorative treatment (SMART). If this is not preferred, it is advisable to apply the treatment biannually for optimal results and to maintain the effectiveness of caries arrest (12,27,40).

1.4 Indications

1.4.1 Patient with high-caries risk

Children presenting early childhood caries (ECC) are frequently considered as high-caries risk patients. These children may exhibit numerous active cavitated lesions in both anterior and posterior teeth, which potentially may require several restorative treatments. Consequently, the affected areas often include tooth surfaces that are typically less susceptible to the onset of caries (1). Therefore, the implementation of SDF can successfully stop the advancement of cavities in young children, minimizing the necessity for invasive restorative procedures that may be difficult to perform due to behavioral challenges (19). Subsequently, this preventive measure

helps to avoid tooth loss, maintains healthy jaw development and assists the correct emergence of permanent teeth (29).

1.4.2 Patient with special needs

Patients with behavioral or medical complexities often present cavitated caries lesion which are challenging to treat in some circumstances. Consequently, patients in need of special health care often require the use of general anesthesia to carry out standard restorative dental treatment (44). However, the concern about the increased health risk with the repeated use of general anesthesia in these children for routine dental care, has increased interest in the need of atraumatic alternative treatment such as SDF solution (45). This is a non-invasive option that can arrest dental caries without the need for local anesthesia, either used until permanent dentition exfoliation or as temporary treatment. Subsequently, this will permit the reduction of general anesthesia exposure and reducing the emergency visits for dental care for patient with special needs who cannot tolerate conventional dental treatments or placed on hospitals waiting list for sedation or general anesthesia (7,45–47).

1.4.3 Management of dentinal hypersensitivity.

Dental caries leads to tooth tissue demineralization, it results the exposure of collagen matrix and dentinal tubules. Moreover, the exposure triggers dentinal hypersensitivity which causes discomfort due to various stimulus such as thermal, chemical or erosive effect or osmotic stimuli (38,48). However, the SDF blocks the dentinal tubules by precipitating silver ions and reducing the neural stimulation in the dentin-pulp complex (37,48,49). Studies, including a randomized clinical trial (RCT), show a single 38% SDF application can relief sensitivity for 24 hours which can last for 7 days (50). Moreover, other studies confirmed immediate relief after application and sustained relief without dentin sensitivity even after 30 days (48,51).

1.4.4 Management of Molar Incisor-hypomineralization

The Molar incisor hypomineralization (MIH) is a common developmental disorder affecting the enamel of the first permanent molar and occasionally the incisors. Unfortunately, in young children the MIH increases the risk of enamel demineralization, sensitivity and higher caries risk (52). Ultimately, the management of MIH is challenging where SDF can be used as desensitizing agent and effectively halt caries followed by smart restoration technique with high viscosity glass ionomer. Besides, studies have proven that the technique has been effective for reducing sensitivity and improving longevity of the restoration (52–54).

1.4.5 Pre-restorative treatment

Silver modified atraumatic restorative technique (SMART) combined the application of SDF followed by partial removal of carious tissue, coupled with the use of high viscosity cement. When using self-curing bulk fill restorative material, it helps to address aesthetic concerns and is suitable for cases where pulp therapy is to be avoided (20). Another viable method for treating caries in primary dentition is the Hall technique, which proposes the use of a stainless-steel crown, without any prior tooth preparation cemented with glass ionomer cement. This approach seems to be shown to lower restoration failures rates associated with atraumatic restorative restoration on multiple cavitated lesion (27). Additionally, SDF functions as an interim restorative treatment (IRT), helping to postpone more invasive procedures for very young patients. However, employing SMART, HALL technique and IRT in combination with glass ionomer cement provides effective solution for ECC. All of them are classified as tertiary prevention of ECC, which significantly decreases the progression risk of ECC, improves children's overall quality of life and avoids unnecessary extraction or future extensive treatment that might need to be done at hospital settings (19,55).

1.4.6 Caries management in developing countries

The availability of dental care can be restricted for certain patients, which complicates their treatment choices. The use of SDF at the community level is especially advantageous for children at high risk of developing ECC who face barriers to receive regular dental services. Furthermore, the versatility of SDF as a material such as low cost, minimal equipment requirement, low sensitive technique render to be suitable to use in community level programs. Moreover, in cases where financial difficulties hinder traditional conservative treatments, the SDF may serve as a viable alternative by helping to prevent further deterioration of oral health conditions (30).

1.5 Advantages and disadvantages

The major important benefit of SDF is its economic accessibility, affordability and simple application which eliminates the need for carious tissue removal, making methods fast and easy to apply (43). Additionally, by inhibiting bacterial growth, it reduces pain and infection, serving as a helpful interim solution for managing carious lesions until children are ready for

traditional dental care, particularly in cases involving challenging behaviors, special needs, disadvantaged children where general sedation is either unwanted or cannot be afforded (48).

There are several important limitations to keep in mind regarding the application of SDF. Nonetheless, no major systemic adverse effects have been reported following its clinical use. The main notable side effect is that carious lesion turns black, leading to aesthetic concerns for some patients (56). Moreover, SDF is a temporary solution that arrests caries but does not restore the tooth structure, therefore this approach should be avoided if there are signs of infection or symptoms suggesting that caries has progressed to the pulp level. Regular follow-ups are required to monitor treatment efficacy, which may deter some parents who prefer conventional dental care. (40). Additionally, accidental contact with the skin or the mucosa tissue can result in temporary staining and cause irritation, which lasts approximately 48 hours post-exposure (18). It is crucial to refrain from its application in patients presenting allergy to silver, ulcerative gingivitis, stomatitis or pregnancy and in the first six months of breastfeeding (36).

1.6 Future innovations

Several approaches have been put out to mitigate the main disadvantage of black discoloration associated with SDF to increase its acceptance. Although, one commonly suggested approach is the application of potassium iodide (KI) immediately after SDF treatment to address aesthetic concern. An in vitro study demonstrated that using KI right after applying SDF can minimize the black staining from metallic silver, which appears not to interfere with SDF protective capabilities (57). Furthermore, adding nano-silver particles to the SDF solution represents another potential approach. Nonetheless, further research is still ongoing regarding how this modification would influence the overall effectiveness of the solution (58).

1.7 Justification

Dental caries is a common oral disease in children, affecting their oral health and well-being. The use of traditional medicine may be challenging for uncooperative young patients. SDF provides a non-invasive and effective option for both managing and preventing dental caries. This documentary review will help us to evaluate the efficacy of SDF in preventing or arresting caries in deciduous dentition, contributing to further deeper understanding of its function in pediatric dentistry.

2. OBJECTIVE

The primary objective is to assess the effectiveness of 38% silver diamine fluoride (SDF) in preventing or arresting dental caries in pediatric patients aged between 0- and 12-year-old with primary dentition, compared to other atraumatic preventive treatments.

Secondary objectives:

- To assess the overall effectiveness 38% of SDF for caries arresting.
- To evaluate the effectiveness of 38% SDF preventing early-stage caries (ICDAS 0-3) and using secondary prevention (ICDAS 4-6) to stop further progression.

3. MATERIAL AND METHODS

3.1 Search strategy

A comprehensive systematized electronic search of scientific articles has been conducted across the databases PubMed/Medline complete, Scopus and Web of Science. This electronic search was conducted in November 2024, and the research was centered on studies published within the past ten years from 2014 to 2024 and written in English language. The PICO research question of this review, in children under 12-year-old who have active caries in primary dentition (P), is the use of 38% silver diamine fluoride (I) more effective than other atraumatic preventive treatments (C) in preventing or arresting the progression of carious lesion (O)?

Using the Boolean operator the following search equation was formulated: (((("children") OR ("pediatric patients")) AND (("dental caries") OR ("tooth decay")) AND ("silver diamine fluoride*")) AND (("fluoride varnish") OR ("fluoride treatment")) AND (("preventing") OR ("arresting") OR ("progression of dental caries"))))

The following keywords were used to conduct this research: silver diamine fluoride, pediatric patients, dental caries, tooth decay, fluoride treatment, preventing, arresting.

3.2 Studies selection

A PRISMA diagram was used, observed in the outline in the results section (Figure 2) (59). The search was filtered and focused on studies published from 2014 to 2024 using the search equation during the preliminary screening phase. The process initially identified a total of 134 articles from the databases PubMed/ Medline, Scopus and Web of Science. Furthermore, to facilitate the selection process, an electronic tool named Rayyan was employed. Among these 134 scientific articles, it was found that 81 were duplicated and subsequently 47 were removed. A comprehensive screening of 87 articles was conducted based on their titles and abstracts to determine their relevance to the research objective, resulting in the exclusion of 38 articles. Subsequently, a retrieve of 49 articles was performed, but a full assessment of two of these was not possible. Finally, a fully evaluated 47 articles against established inclusion and exclusion criteria relevant to the search. From this evaluation process, a total of 17 were ultimately included in the research findings.

3.2.1 The inclusion criteria

- a) Participants must be children aged 0 to 12 years
- b) Studies focus on primary dentition or a mixed dentition where primary teeth outcomes can be extracted.
- c) This review focuses exclusively on healthy pediatric patients undergoing treatment during primary dentition stage without any developmental alteration in their teeth.
- d) The intervention must include the application of 38% silver diamine fluoride as one of the treatments options.
- e) Studies could have or not a control group receiving either SDF, sodium fluoride varnish or other relevant interventions for comparison.
- f) Outcome of the studies either for caries prevention in or arresting caries.
- g) Study design should be only in vivo studies, such as randomized controlled trials (RCTs) published in English will be considered.
- h) Participants are required to have at least 6 months of follow-up after the intervention, along with verified confirmed informed consent from parents or caregivers.

3.2.2 The exclusion criteria

- a) Studies not designed as randomized clinical trial.
- b) Children are older than 12-years-old, adult population and focus only on permanent dentition.
- c) Children with caries at interproximal surfaces.
- d) Children presenting systemic diseases or having dental developmental defects were omitted for this research.
- e) Additionally, studies not written in English were discarded.
- f) Studies with follow-up periods shorter than 6 months were rejected.
- g) Exclusion of studies using control groups treated with 10%, 12%, 30 % SDF.
- h) Studies where SDF is not used as primary intervention and is used as adjunctive treatment such as SDF modified atraumatic restorative technique (SMART) or Hall technique.
- i) Other outcomes were excluded, if they do not report relevant outcomes related to arrest or prevention of dental caries.

4. RESULTS

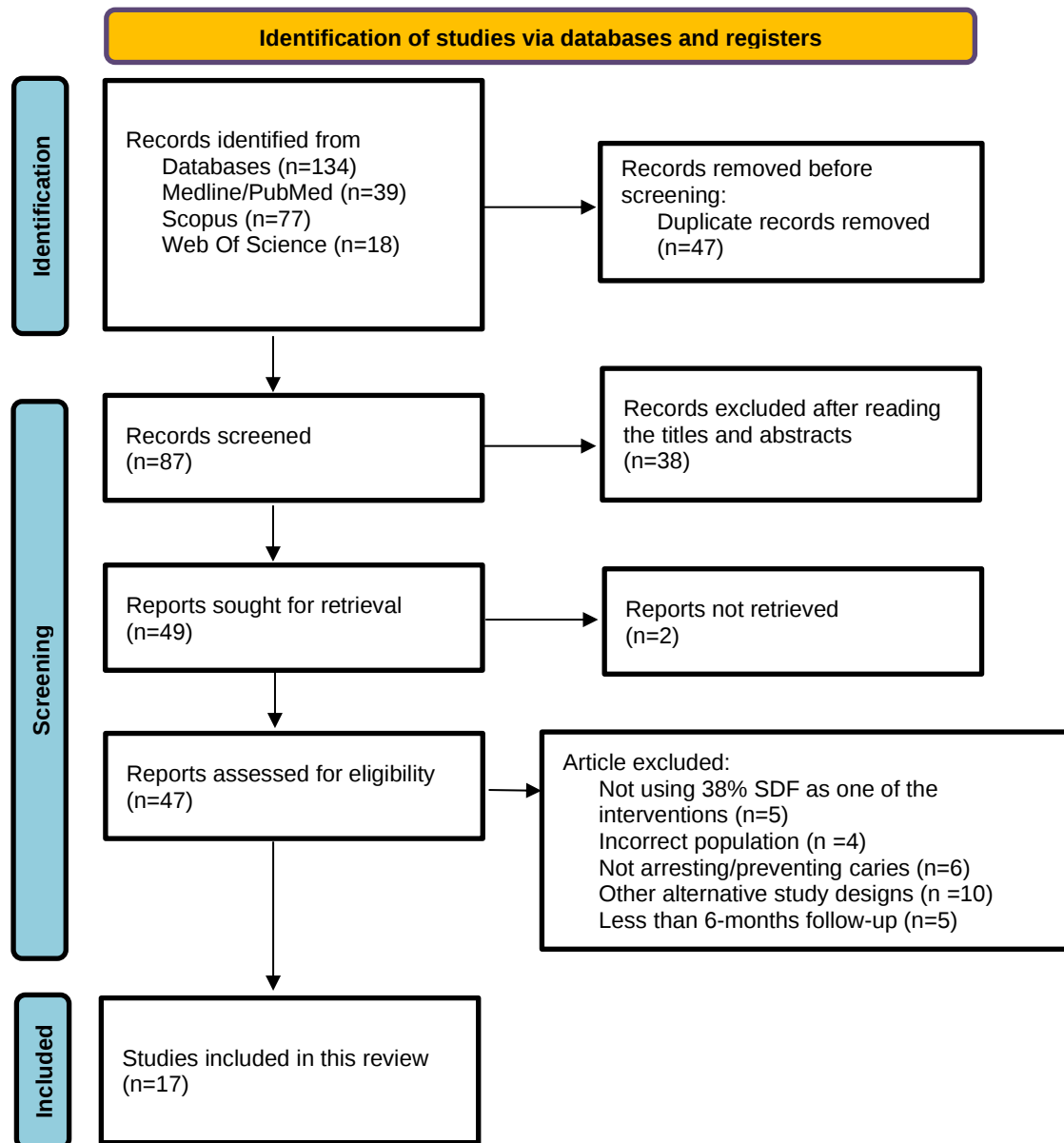


Figure 3. PRISMA 2020 flow diagram of literature search and selection process (59).

The selected randomized clinical trial aimed to assess the effectiveness of silver diamine fluoride (SDF) in either arresting or preventive dental caries. Among the studies, 14 studies focused on SDF ability to arrest the progression of dental caries, two evaluated its preventive efficacy and one examined both outcomes. This distribution is illustrated (Figure 4). All participants in the selected studies had primary dentition, ranging in age from 1 to 12 years, with follow-up periods varying between 6 and 30 months. The studies employed different various assessment methods and criteria used to determine lesion severity. A summary outlining the general attributes of these studies was provided (Table 1).

In addition, a quantitative analysis was conducted on 15 articles that examined caries arrest outcomes to assess the overall effectiveness of SDF. The findings of this analysis are presented (Table 2 and 3).

For the tertiary objective, a summary of the effectiveness of arrested caries based on the International Caries Detection and Assessment Systems (ICDAS) score was collected. Ten studies were selected, providing arrest rate information at the tooth surface level. These findings are illustrated in (Table 4 and Table 5).

Regarding patient treatment, SDF compared to other minimally invasive dentistry (MID) products or placebo. The distribution of comparator products is shown in Figure 6. Some studies also explored the combination of SDF with other agents, such as potassium iodide (KI) or fluoride varnish. The distribution of different types of SDF products used is illustrated (Figure 5).

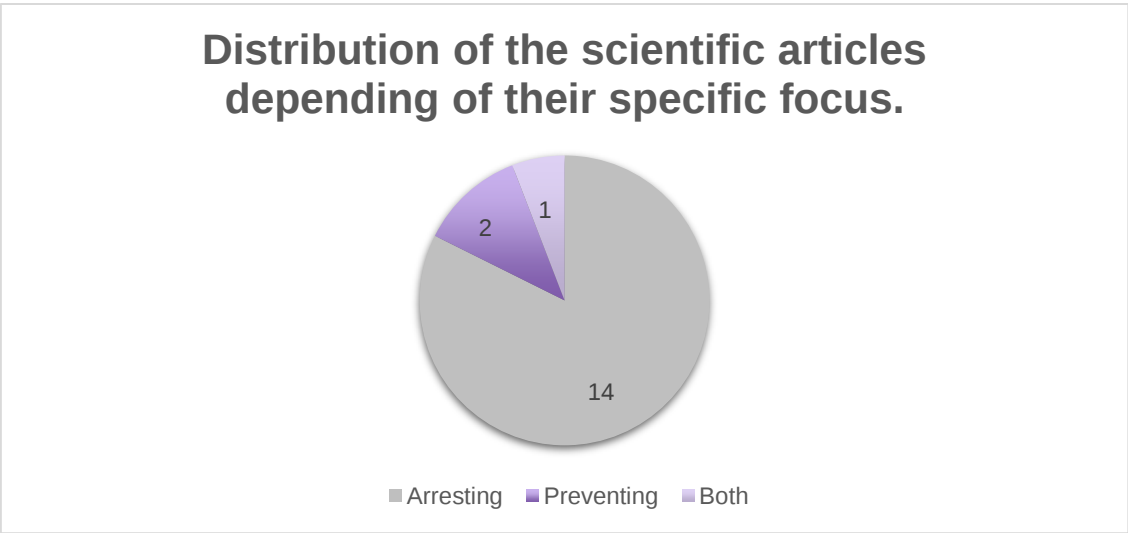


Figure 4 Distribution of the scientific articles, according to their specific focus.

Categories of silver diamine fluoride types used in the scientific articles

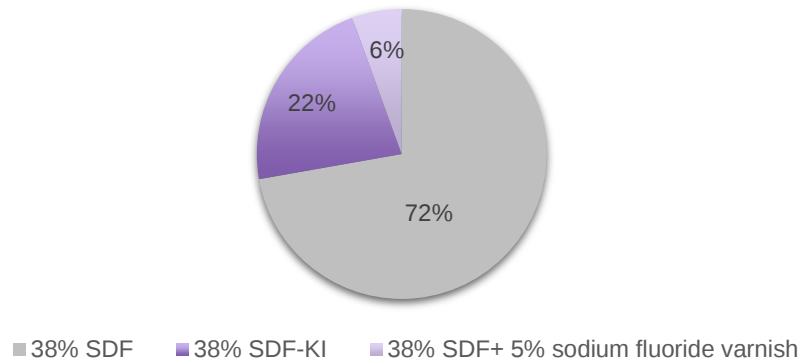


Figure 5 Distribution of different types of silver diamine products used among the scientific articles analyzed.

Destruction of comparators used in the scientific articles

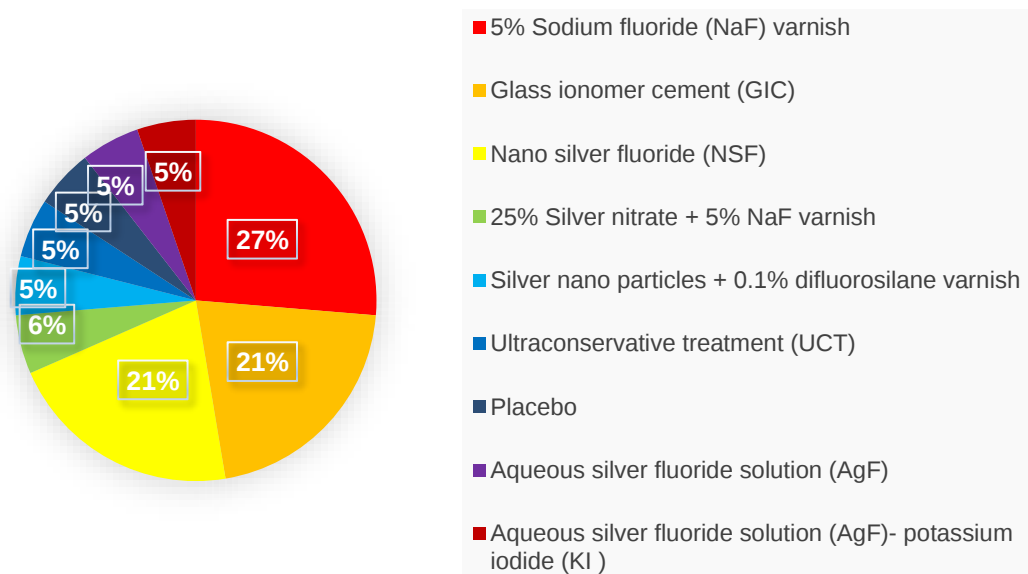


Figure 6 Distribution of comparators used in the scientific articles analyzed.

Table 1 General characteristics of the randomized clinical trial

Author/ year	Sample size (n)	Weight (%)	Age (year)	Follow- up period (month)	Lesion severity criteria	Outcome assessment	key findings
Tirupathi S,et al./ 2019(60)	50	1.2%	6-10	12	Mount & Hume classificatio n (1, 2, 3)	Visual- tactile inspection	NSSF showed better aesthetic, no metallic taste and no ulceration compared to SDF.
Al- Nerabieah Z, et al./2020(61)	119	2.8%	3-5	6	Nyvad criteria (unknown level)	Visual- tactile inspection	Higher caries arrest rate for anterior teeth and single surface lesion with NSF and SDF. However, better aesthetic was observed with NSF.
Gao SS, et al./ 2020(62)	1070	25,8%	3-4	30	dmfs index	Visual- tactile inspection	Caries arrest was negatively associated with new development of dmfs ($p < 0.001$) The mean new dmfs, Silver nitrate+ NaF: 0.82 ± 1.45 SDF: 0.89 ± 1.60
Abdellatif HM, et al./2021(63)	79	1.9%	3-8	12	ICDAS (4, 5, 6)	Visual- tactile inspection	NA
Turton B, et al./ 2021(64)	421	10.2%	≤ 12	12	ICDAS (3/4 or 5/6)	Visual- tactile inspection	Advanced lesions (ICDAS 5/6) treated with potassium iodide (KI) had a higher risk of pulpal involvement KI (31.8%) No KI (13.2%) Even though KI presents better aesthetic,

							lowered caries arrest odds.
Prakash DKM, et al./ 2022(65)	34	0.8%	6-9	12	ICDAS (5)	Visual-tactile inspection & radiography	NA
Phoghanyu dh A, et al./ 2022(66)	290	7.0%	1-3	18	ICDAS (2 or 3)	Visual-tactile inspection	Caries arrest was significantly higher in non-cavitated (ICDAS 2) vs. cavitated (ICDAS 3) lesions. Factors influencing caries arrest outcome: tooth position, surface, enamel extension lesion and brushing habits with fluorinated toothpaste.
Yassin R, et al./ 2023(67)	165	3.9%	≤ 4	6	ICDAS (3/4) or (5/6)	Visual-tactile inspection	Higher arrest rate in moderate (ICDAS 3/4) than extensive (ICDAS 5/6) lesions.
Vaid P, et al./ 2023(68)	50	1.2%	3-5	6	ICDAS (4, 5)	Visual inspection & radiography	NA
Ghareep SMEE, et al./ 2023(69)	30	0.72%	4-7	9	Nyvad criteria (level 3)	Visual-tactile inspection	SDF-KI had worse aesthetic outcomes than NSF.
Abdellatif EB, et al./ 2023(70)	220	5.3%	≤ 4	6	ICDAS (3/4) or (5/6)	Visual-tactile inspection	SDF+ NaF was significantly more effective for moderate lesions (ICDAS 3/4), but not for advanced ones (ICDAS 5/6).

Jain A, et al. / 2023(71)	285	6.9%	3-6	12	ICDAS (0)	Visual-tactile inspection	Caries-free rates: Placebo: 46.4% NaF: 52.2% SDF: 72%. SDF showed significant superiority as preventing caries measure.
Zheng FM, et al./ 2023(72)	688	16.6%	3-4	12	dmft/dmfs index	Visual-tactile inspection	Not significant difference between SDF and NaF in caries increment SDF: 26.8% NaF: 24.9%
Hamza BE, et al./ 2024(73)	135	3,26%	3-5	12	ICDAS (5 or 6)	Visual-tactile inspection & radiography	NA
Quritum M, et al/ 2024(74)	360	8.7%	≤ 4	12	ICDAS (3/4) & (5/6)	Visual-tactile inspection	NA
ElGhandour RK, et al./ 2024(75)	100	2.4%	2-5	12	ICDAS (5 or 6)	Visual-tactile inspection	NA
Juárez-López MLA, et al./ 2024(76)	40	0.9%	6-7	12	ICDAS (unknown score)	DIAGNOdent pen	NA
Total	4136						

NA: not applicable

ICDAS: International Caries Detection and Assessment System

dmfs: mean decayed, missing and filled surfaces

SDF: silver diamine fluoride

NSSF: Nano-silver incorporated sodium fluoride

NSF: nano silver fluoride

AgNO₃: silver nitrate solution

KI: potassium iodide

AgF: Aqueous silver fluoride solution

5% NaF: 5% sodium fluoride varnish

GIC: glass ionomer cement

Table 2 Caries arrestment rate (%)

Author/ year	Weight (%)	38% SDF effectiveness (%)	Comparator/s (%)	Effective conclusion
Tirupathi S, et al./ 2019(60)	1.2%	SDF (71.05%)	NSSF (77%)	Similar
Al-Nerabieah Z, et al./2020(61)	2.8%	SDF (79.5%)	NSF (67.2%)	Similar
Gao SS, et al./2020(62)	25.8%	SDF (68.9%)	25% AgNO ₃ + 5% NaF (70.6%)	Similar
Abdellatif HM, et al./2021(63)	1.9%	SDF (99%)	GIC (94%)	Similar
Turton B, et al./ 2021(64)	10.2%	SDF (77.3%) SDF-KI (65.4%)	AgF (75.3%) AgF-KI (51.2%)	Similar: SDF vs. AgF Superior: SDF vs. SDF-KI/ AgF-KI
Prakash DKM, et al./ 2022(65)	0.8%	SDF-KI (77.4%)	5% NaF (41.9%)	Superior
Phoghanyudh A, et al./ 2022(66)	7.0%	SDF (59.1%)	5% NaF (58.8%)	Similar
Yassin R, et al./ 2023(67)	3.9%	SDF (63.7%)	5% NaF (58.1%)	Similar
Vaid P et al./ 2023(68)	1.2%	SDF (92.5%)	GIC (60.86%)	Superior
Ghareep SMEE, et al./ 2023(69)	0.72%	SDF-KI (73.1%)	NSF (84.6%)	Similar
Abdellatif EB et al./ 2023(70)	5.3%	SDF (73.2%)	SDF+ 5% NaF (77.7%)	Inferior
Hamza BE et al./ 2024 (73)	3.26%	SDF (73.4%)	GIC (75.6%) UCT (53.4%)	SDF inferior effect to GIC SDF superior to UCT
Quritum M, et al/ 2024(74)	8.7%	SDF (56.3%)	NSF (71.3%)	Inferior
ElGhandour RK, et al./2024(75)	2.4%	SDF (94.4%)	GIC (34.3%)	Superior
Juárez-López MLA, et al./2024(76)	0.9%	SDF-KI (79%)	SNP-FV (74%)	Similar

SDF: silver diamine fluoride; KI (potassium iodide)

NSSF: Nano-silver incorporated sodium fluoride; NSF: nano silver fluoride

SNP-FV: silver nano particles + difluorosilane varnish

25% AgNO₃: silver nitrate solution

AgF: Aqueous silver fluoride solution

5% NaF: sodium fluoride varnish

GIC: glass ionomer cement

UCT: ultraconservative treatment

Table 3 Summary of effective conclusion of the studies used for caries arrestment rate

Effective conclusion	Superior	Similar	Inferior
	Turton B, et al./ 2021(64)	Tirupathi S, et al./ 2019(60)	Abdellatif EB, et al./ 2023(70)
	Prakash DKM, et al./ 2022(65)	Al-Nerabieah Z, et al./2020(61)	Quritum M, et al/ 2024(74)
	Vaid P, et al./ 2023(68)	Gao SS, et al./ 2020(62)	Hamza BE, et al./ 2024(73)
	Hamza BE, et al./ 2024(73)	Abdellatif HM, et al./2021(63)	
	ElGhandour RK, et al./ 2024(75)	Turton B, et al./ 2021(64)	
		Phoghanyudh A, et al./ 2022(66)	
		Yassin R, et al./ 2023(67)	
		Juárez-López MLA, et al./ 2024(76)	
		Ghareep SMEE, et al./ 2023(69)	
Total weight (%)	17,86%	54,42%	17,26%

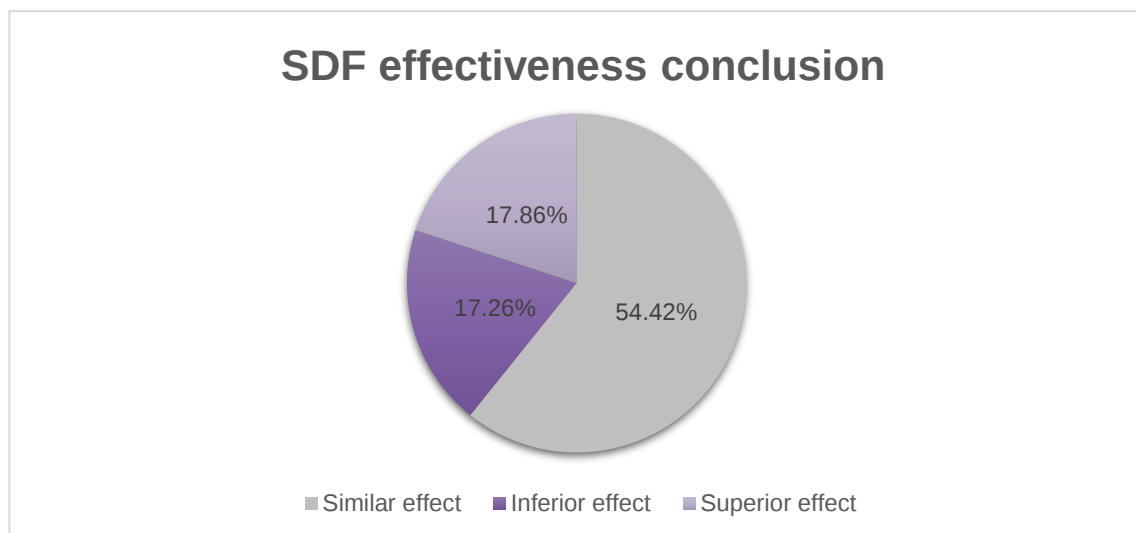


Figure 7 Summary of the effectiveness conclusion of 15 studies selected for the analysis of overall caries arrestment assessment.

Table 4. Prevention of early-stage Caries (ICDAS 0-3)

Author/ year	38% SDF caries arrest
Jain A, et al. / 2023(71)	Sound (ICDAS 0) 72%
Phoghanyudh A, et al./ 2022(66)	Initial (ICDAS 2) 68.2%
Phoghanyudh A, et al./ 2022(66)	Moderate (ICDAS 3) 41.2%

Table 5 Arresting progression in advanced Caries (ICDAS 4-6)

Author/ year	38% SDF caries arrest
Abdellatif HM, et al/ 2021(63)	Moderate (ICDAS 4) 34.1% Extensive (ICDAS 5) 53.7% Extensive (ICDAS 6) 12.2%
Turton B, et al./ 2021(64)	SDF Moderate (ICDAS 3-4) 80.8% Extensive (ICDAS 5-6) 66.9% SDF-KI Moderate (ICDAS 3-4) 65.2% Extensive (ICDAS 5-6) 66.5%
Prakash DKM, et al/ 2022(65)	SDF-KI Extensive (ICDAS 5) 77.4%
Yassin R, et al./ 2023(67)	Moderate (ICDAS 3-4) 72.9% Extensive (ICDAS 5-6) 60.3%
Vaid P, et al./ 2023(68)	Moderate (ICDAS 4) & Extensive (ICDAS 5) 92.5%
Abdellatif EB, et al./ 2023(70)	38% SDF Moderate (ICDAS 3-4) 74.3% Extensive (ICDAS 5-6) 72.8% 38% SDF+ 5%NaF Moderate (ICDAS 3-4) 88.9% Extensive (ICDAS 5-6) 73.9%
Hamza BE, et al./ 2024(73)	Extensive (ICDAS 5-6) 84.6%
ElGhandour RK, et al./ 2024(75)	Extensive (ICDAS 5-6) 93.7%

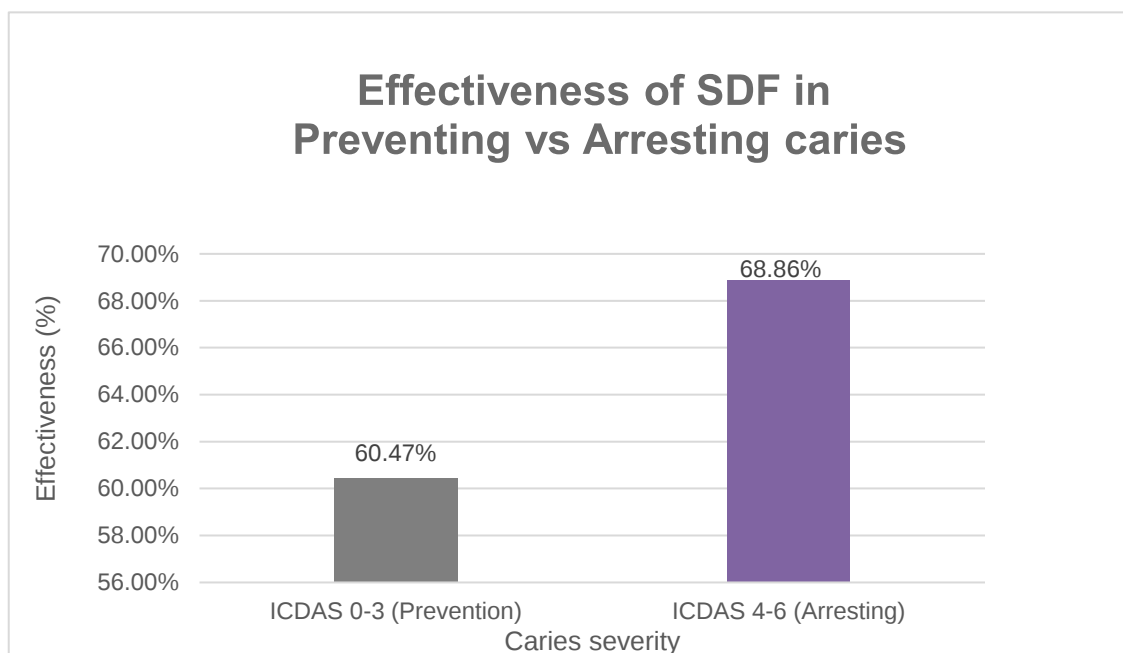


Figure 8 Efficacy of SDF in caries prevention compared to arresting. Summary of Table 4.

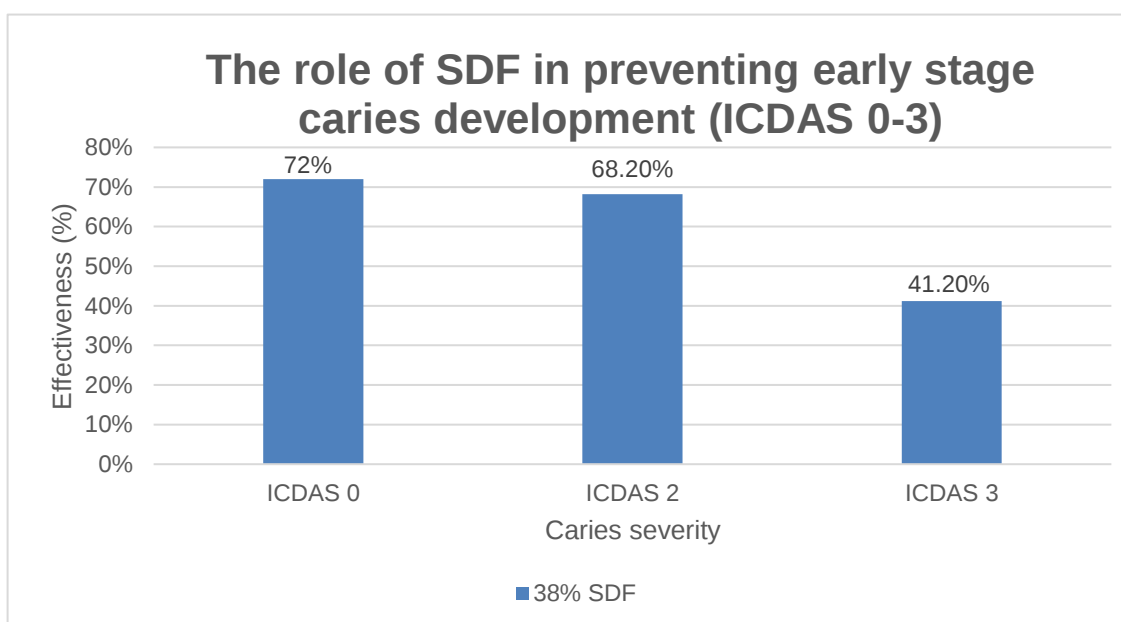


Figure 9 Effectiveness of SDF in preventing early-stage caries (ICDAS 0-3). Data used form Table 4.

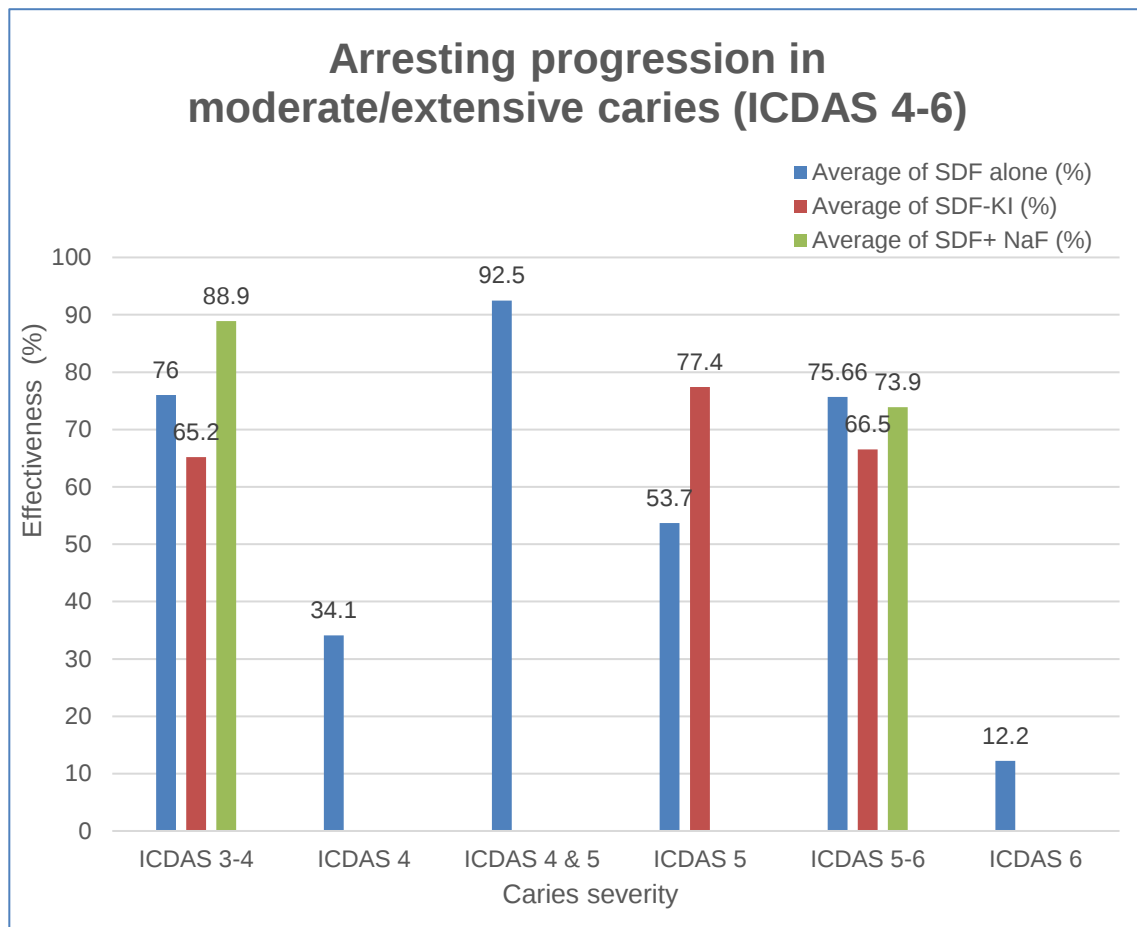


Figure 10 Progression in moderate/extensive caries (ICDAS 4-6). Data used from Table 5.

5. DISCUSSION

5.1 Assessing the effectiveness of 38% Silver diamine fluoride in caries prevention and arrest in primary dentition.

Through this documentary review, we concluded that 38% silver diamine fluoride (SDF) effectively arrests caries in children under 12 years of age with primary dentition, either outperforming or matching effectiveness when compared to other atraumatic preventive treatment. Five clinical trials (17,86%) favored SDF over glass ionomer cement (GIC), 5% sodium fluoride varnish (NaF), SDF with potassium iodide (KI) and ultraconservative treatment (UCT) (64,65,68,73,75). Meanwhile, nine clinical trials (54,42%) found SDF had comparable results against caries, specifically when compared to GIC, nano silver fluoride (NSF), 5% NaF and other silver-based products (60–64,66,67,69,76). On the contrary, three clinical trials (17,26%) indicated SDF showed inferior performance than NSF, GIC and SDF combined with 5% NaF (70,73,74). However, the overall SDF's effectiveness in arresting caries ranged from 56-99%, underscoring its efficiency in pediatrics treatment. These findings align with a previous systematic review, Alqualeef et al 2024, who noted SDF arrest rate between 25-99%, reinforcing its reliability as a caries management tool (77).

Additionally, we found SDF showed promising preventive potential, performing similarly or slightly better than 5% NaF in three trials. For instance, Jain A et al 2023 found that SDF exhibited a 76% success rate in preventing sound surface lesion, compared to 5% NaF (52%) and placebo (46%) (71). Similarly, Phoghanyudh A et al. 2022 observed better outcomes in non-cavitated enamel caries than in cavitated enamel caries, supporting its preventive potential. However, the author noted factors such as lesion location, size, dietary habits and brushing frequency significantly influence SDF effectiveness (66). In contrast, the clinical trial of Zheng FM et al. 2020, reported no significant difference between SDF (27%) and 5% NaF (25%) in caries increment (72). On the other hand, parental concerns regarding SDF-induced black staining may discourage its use when 5% NaF is an alternative. Despite an average of 60,47% effectiveness in preventing ICDAS 0-3 caries, the limited number of studies prevents a definitive conclusion in the documentary review.

Improving SDFs acceptance may require addressing its staining effects. Studies by Tirupathi S et al. 2019, Al-Nerebieah Z et al. 2020, Ghareep SMEE et al. 2023 and Juárez-López MLA et al. 2024 suggest that NSF derivatives offer comparable effectiveness to SDF while providing better aesthetic and fewer side effects. Future research should explore whether these innovations enhance caries prevention without causing discoloration (60,61,69,76).

On average, this review observed a 68,86% effectiveness rate for SDF in arresting moderate/extensive caries. Given the high value placed on aesthetics by parents and pediatric patients, alternative formulations such as SDF-KI have been explored. However, limitations were observed in cases of extensive caries (ICDAS 5-6). Turton B et al. 2021 found that patients' treatment with SDF-KI (32%) had a higher risk of pulp involvement than those treated with SDF alone (13%) (64). Conversely, Prakash DKM et al, 2022 found that SDF-KI was significantly more effective in arresting extensive (ICDAS 5) lesions compared to 5% NaF (65). These findings suggest that although SDF does not consistently outperform fluoride varnish in all cases, its unique additional antimicrobial and remineralizing properties make it a valuable option, particularly in high caries risk populations (10).

Notably studies by Abdellatif HM et al. 2021, Turton B et al 2021, Yassin R et al. 2023, Hamza BE et al 2023 and ElGhandour RK et al. 2024 demonstrated that SDF alone is more effective in arresting moderate caries than extensive caries lesions (63,64,67,73,75). Interestingly, Abdellatif EB et al 2023 reported that combining SDF with 5% NaF improved caries arrest in moderate lesions more effectively than in extensive cases (70). These findings suggest using SDF alone or in combination with 5% NaF, while avoiding SDF-KI for extensive lesions. This may help minimize the risk of pulpitis in children who cannot undergo immediate restorative treatment.

Dental caries is a major public health concern in children, affecting oral health and quality of life (1). Traditional treatments are challenging, especially for those with behavioral difficulties or limited access to care (40). SDF provides a minimally invasive alternative with preventive and caries-arresting benefits (30). The findings of this documentary review support 38% SDF as a valuable tool in pediatric dentistry. Its effectiveness makes it a promising option for modern dental care.

5.2 Limitations

SDF effectively arrests dental caries, specifically in moderate lesions, but its preventive role is debated due to limited studies available. Future research should focus on this aspect and standardize comparators and lesion assessment methods for consistency. A standardized systematic review with fixed comparators would enhance result homogeneity. Prioritizing the International Caries Detection and Assessment System (ICDAS) could improve a reproducible diagnosis and long-term evaluation.

6. CONCLUSIONS

6.1 Conclusion for Primary objective

The findings of the documentary research suggest that 38% silver diamine fluoride (SDF) is an effective treatment for arresting dental caries in pediatric patients with primary dentition. While its preventive effectiveness varied across the studies, SDF generally demonstrated superior or comparable performance to their minimally invasive treatments, including fluoride varnish, glass ionomer cement and nano silver fluoride. However, its effectiveness can be influenced by lesion severity, tooth location and oral hygiene habits. The results confirm that SDF is a valuable tool in minimally invasive dentistry, particularly for caries arrest, though its superiority over other preventive treatments remains inconclusive.

6.2 Overall effectiveness of 38% SDF for caries arresting

The overall effectiveness of 38% of SDF in arresting dental caries was found to range from 56.3 to 99%, indicating a strong potential for stopping the progression of existing lesions. Compared to other treatments, including 5% NaF varnish, GIC, NSF, the SDF showed either superior or comparable caries arrest rates. However, adjuncts such as potassium iodide (KI) have been explored to improve aesthetics, but studies suggest that KI may reduce the effectiveness of caries arrest and increase the risk of pulpal complications. Consequently, SDF remains a highly effective option for caries arrest, particularly in moderate lesions, though more research is needed to optimize its application.

6.3 The role of 38% SDF in early caries prevention and secondary prevention for moderate and extensive lesions.

This documentary research indicates that SDF has a promising role in preventing early stages caries and halting the progression of more severe lesions. Studies show that SDF provides better prevention than placebo and NaF varnish, with preventive effectiveness averaging around 60.47%. For secondary prevention, SDF demonstrates an average arrest rate of 68.86%, particularly in moderate lesions. The highest caries arrest rate was observed in cases where SDF was combined with NaF, whereas extensive lesions treated with SDF-KI showed increased risk of pulpal complications. These findings reinforce the utility of SDF in both preventive and secondary caries management, though further research is needed to refine treatment protocols based on lesion severity and patient factors.

7. SUSTAINABILITY

The use of 38% silver diamine fluoride aligns with sustainable dentistry by offering a cost-effective, minimally invasive solution for caries management. Silver diamine fluoride effectiveness in arresting and preventing dental caries reduces the need for resource intensive treatment such as restoration and extraction in young children. Thereby, minimizing the material waste and clinical intervention working time. Additionally, silver diamine fluoride application requires fewer dental visits, lowering the environmental impact associated with frequent patient travel and clinic resource consumption. Future research should focus on optimizing silver diamine fluoride protocols to further enhance its long- term efficacy and sustainability in a global preventive dental care.

8. REFERENCES

1. Anil S, Anand PS. Early Childhood Caries: Prevalence, Risk Factors, and Prevention. *Front Pediatr*. 2017;5:157. DOI: 10.3389/fped.2017.00157.
2. Carli C, Seymen F. Silver Diamine Fluoride in Pediatric Dentistry. *Eur J Res Dent*. 2023;7(1):47–53. DOI: 10.29228/erd.44.
3. Sheiham A, Williams DM, Weyant RJ, Glick M, Naidoo S, Eiselé JL, et al. Billions with oral disease. *J Am Dent Assoc*. 2015;146(12):861–4. DOI: 10.1016/j.adaj.2015.09.019.
4. Nuvvula S, Mallineni SK. Silver Diamine Fluoride in Pediatric Dentistry. *J South Asian Assoc Pediatr Dent*. 2019;2(2):73–80. DOI: 10.5005/jp-journals-10077-3024.
5. Thakur S, Arora A, Dheer A. Alternative methods for caries removal: A narrative review. *J Dent Spec*. 2024;12(2):108–114. DOI: 10.18231/j.jds.2024.020.
6. Hansen R, Shirtcliff RM, Ludwig S, Dysert J, Allen G, Milgrom P. Changes in Silver Diamine Fluoride Use and Dental Care Costs: A Longitudinal Study. *Am Acad Pediatr Dent*. 2019;41(1):35-44.
7. Thomas ML, Magher K, Mugayar L, Davila M, Tomar SL, MI T. Silver Diamine Fluoride Helps Prevent Emergency Visits in Children w ith Early Childhood Caries. *Pediatr Dent*. 2020;42(3):217–220.
8. Slayton RL, Urquhart O, Araujo MWB, Fontana M, Guzmán-Armstrong S, Nascimento MM, et al. Evidence-based clinical practice guideline on nonrestorative treatments for carious lesions. *J Am Dent Assoc*. 2018;149(10):837–849. DOI: 10.1016/j.adaj.2018.07.002.
9. Natarajan D. Silver Modified Atraumatic Restorative Technique: A Way Towards “SMART” Pediatric Dentistry During the COVID-19 Pandemic. *Front Dent*. 2022;19:12. DOI: 10.18502/fid.v19i12.9215.
10. Mei ML, Lo ECM, Chu CH. Arresting Dentine Caries with Silver Diamine Fluoride: What’s Behind It? *J Dent Res*. 2018;97(7):751–758. DOI: 10.1177/0022034518774783.
11. Zheng FM, Yan IG, Duangthip D, Gao SS, Lo ECM, Chu CH. Silver diamine fluoride therapy for dental care. *Jpn Dent Sci Rev*. 2022;58:249–57. DOI: 10.1016/j.jdsr.2022.08.001.
12. Jabin Z, Vishnupriya V, Agarwal N, Nasim I. SILVER DIAMINE FLUORIDE: A POTENT CARIES ARRESTING AND PREVENTING AGENT. *International Journal of Clinical Dentistry* [Internet]. 2022 Jan [cited 2025 Apr 15];15(1):115-126. Available from: <https://search.ebscohost.com/login.aspx?direct=true&db=edselc&AN=edselc.2-52.0-85128385683&lang=es&site=eds-live&scope=site>
13. Kongsomjit M, Punyanirun K, Tasachan W, Hamba H, Tagami J, Trairatvorakul C, et al. Material of choice for non-invasive treatment of dentin caries: An in vitro study using natural carious lesions. *Int J Dent Hyg*. 2024;22(3):689–695. DOI: 10.1111/idh.12765.

14. Illustration of 38% silver diamine fluoride product representing their concentration of its different composition [Digital image self-created with Adobe Illustrator]. Adobe Illustrator. [Created 2025 Apr 1; cited 2025 Apr 15].
15. Eye Dropper Bottle Mockups - Mockup Free [Internet]. [cited 2025 Apr 1]. Available from: <https://mockupfree.net/eye-dropper-bottle-mockups>.
16. Hafiz Z, Allam R, Almazyad B, Bedaiwi A, Alotaibi A, Almubrad A. Effectiveness of Silver Diamine Fluoride in Arresting Caries in Primary and Early Mixed Dentition: A Systematic Review. *Children*. 2022;9(9):1289. DOI: 10.3390/children9091289.
17. Muntean A, Mzoughi SM, Pacurar M, Candrea S, Inchingolo AD, Inchingolo AM, et al. Silver Diamine Fluoride in Pediatric Dentistry: Effectiveness in Preventing and Arresting Dental Caries—A Systematic Review. *Children*. 2024;11(4):499. DOI: 10.3390/children11040499.
18. Crystal YO, Marghalani AA, Ureles SD, Wright JT, Sulyanto R, Divaris K, et al. Use of Silver Diamine Fluoride for Dental Caries Management in Children and Adolescents, Including Those With Special Health Care Needs. *J Calif Dent Assoc*. 2017;39(5):E135–E145. DOI: 10.1080/19424396.2018.12221981.
19. Phantumvanit P, Makino Y, Ogawa H, Rugg-Gunn A, Moynihan P, Petersen PE, et al. WHO Global Consultation on Public Health Intervention against Early Childhood Caries. *Community Dent Oral Epidemiol*. 2018;46(3):280–287. DOI: 10.1111/cdoe.12362.
20. Hu S, Meyer B, Duggal M. A silver renaissance in dentistry. *Eur Arch Paediatr Dent Off J Eur Acad Paediatr Dent*. 2018;19(4):221–227. DOI: 10.1007/s40368-018-0363-7.
21. Gao SS, Amarquaye G, Arrow P, Bansal K, Bedi R, Campus G, et al. Global Oral Health Policies and Guidelines: Using Silver Diamine Fluoride for Caries Control. *Front Oral Health*. 2021;2:685557. DOI: 10.3389/froh.2021.685557.
22. Kaewkamchai S, Thanyasrisung P, Sukarawan W, Samaranayake L, Tuygunov N, Songsiripradubboon S. Efficacy of silver diamine fluoride (SDF) in arresting dentin caries against inter-kingdom biofilms of *Streptococcus mutans* and *Candida albicans*. Hwang G, editor. *PLOS ONE*. 2024;19(9):e0308656. DOI: 10.1371/journal.pone.0308656.
23. Timms L. Everyone else is using it, so why isn't the UK? Silver diamine fluoride for children and young people. *Community Dent Health*. 2020;37:143–149. DOI: 10.1922/CDH_00008Timms0
24. Abdellatif AM, Hamza BE, Attia NM, Hegazy SA. Arresting Active Carious Lesions Using Minimal Intervention Dentistry among a Group of Preschool Children: A Randomized Controlled Clinical Trial. *Int J Clin Pediatr Dent*. 2024;17(9):1018–1024. DOI: 10.5005/jp-journals-10005-2927.
25. Illustration of examples of countries employing silver diamine fluoride. [Digital image self-created with Pareto Software, LLC]. SimpleMaps.com. [Internet]. [Created 2025 Apr 1; cited 2025 Apr 15]. Available from: <https://simplemaps.com/custom/world/BColUL72>
26. Burgess JO, Vaghela PM. Silver Diamine Fluoride: A Successful Anticarious Solution with Limits. *Adv Dent Res*. 2018;29(1):131–134. DOI: 10.1177/0022034517740123.

27. Duggal M, Gizani S, Albadri S, Krämer N, Stratigaki E, Tong HJ, et al. Best clinical practice guidance for treating deep carious lesions in primary teeth: an EAPD policy document. *Eur Arch Paediatr Dent*. 2022;23(5):659–666. DOI: 10.1007/s40368-022-00718-6.
28. El-Damanny HM, Rahman B, Sheela S, Ngo HC. Dentinal Tubule Occlusion and Dentin Permeability Efficacy of Silver Diamine Fluoride Solutions. *Int J Dent Hyg*. 2024;23(2):1–8. DOI: 10.1111/idh.12854.
29. Jagtap V, Padawe D, Takate V, Dighe K, Rath G, Wankhade A. Silver diamine fluoride – ‘The silver bullet’ in pediatric dentistry: An overview of past, present and prospects. *Int Dent J Stud Res*. 2024;11(4):146–153. DOI: 10.18231/j.idjsr.2023.032.
30. Crystal YO, Niederman R. Silver Diamine Fluoride Treatment Considerations in Children’s Caries Management Brief Communication and Commentary. *Pediatr Dent*. 2016;38(7):466–471.
31. Wakshlak RBK, Pedahzur R, Avnir D. Antibacterial activity of silver-killed bacteria: the ‘zombies’ effect. *Sci Rep*. 2015;5(1):9555. DOI: 10.1038/srep09555.
32. Altarjami MM, Sadayo TZA, Alsulami SR, Saeed A, TariqQurban R, Altukhays HA, et al. The Role Of Fluoride In Preventing Dental Caries: A Contemporary Review. *Migrat. Lett*. [Internet]. 2023 Jul [cited 2025 Apr 15];20(S1):2950-2958. Available from: <https://migrationletters.com/index.php/ml/article/view/9043>
33. Zhao IS, Gao SS, Hiraishi N, Burrow MF, Duangthip D, Mei ML, et al. Mechanisms of silver diamine fluoride on arresting caries: a literature review. *Int Dent J*. 2018;68:67–76. DOI: 10.1111/idj.12320.
34. Cifuentes-Jiménez CC, Bolaños-Carmona MV, Enrich-Essvein T, González-López S, Álvarez-Lloret P. Evaluation of the remineralizing capacity of silver diamine fluoride on demineralized dentin under pH-cycling conditions. *J Appl Oral Sci*. 2023;31:e20220306. DOI: 10.1590/1678-7757-2022-0306.
35. Hamama H, Yiu C, Burrow M. Effect of silver diamine fluoride and potassium iodide on residual bacteria in dentinal tubules. *Aust Dent J*. 2015;60(1):80–87. DOI: 10.1111/adj.12276.
36. Horst JA, Ellenikiotis H, Milgrom PL. UCSF Protocol for Caries Arrest Using Silver Diamine Fluoride: Rationale, Indications and Consent. *J Calif Dent Assoc*. 2016;44(1):16–28. DOI: 10.1080/19424396.2016.12220962.
37. Manuschai J, Talungchit S, Naorungroj S. Penetration of Silver Diamine Fluoride in Deep Carious Lesions of Human Permanent Teeth: An In Vitro Study. Pagano S, editor. *Int J Dent*. 2021;2021:1–9. DOI: 10.1155/2021/3059129.
38. Kiesow A, Menzel M, Lippert F, Tanzer JM, Milgrom P. Dentin tubule occlusion by a 38% silver diamine fluoride gel: an in vitro investigation. *BDJ Open*. 2022;8(1):1. DOI: 10.1038/s41405-022-00095-8.
39. Seto J, Horst JA, Parkinson DY, Frachella JC, DeRisi JL. Enhanced Tooth Structure via Silver Microwires Following Treatment with 38% Silver Diamine Fluoride. *Am Acad Pediatr Dent*. 2020;42(3):226–231.

40. Crystal YO, Niederman R. Evidence-Based Dentistry Update on Silver Diamine Fluoride. *Dent Clin North Am.* 2019;63(1):45–68. DOI: 10.1016/j.cden.2018.08.011.
41. Shah S, Bhaskar V, Venkatraghavan K, Choudhary P, M. G, Trivedi K. Silver Diamine Fluoride: A Review and Current Applications. *J Adv Oral Res.* 2014;5(1):25–35. DOI: 10.1177/2229411220140106.
42. Horst JA. Silver Fluoride as a Treatment for Dental Caries. *Adv Dent Res.* 2018;29(1):135–140. DOI: 10.1177/0022034517743750.
43. Sun IG, Duangthip D, Chai HH, Luo BW, Lo ECM, Chu CH. Postoperative instructions for silver diamine fluoride therapy: A scoping review of current evidence and practice. *J Dent.* 2024;145:105029. DOI: 10.1016/j.jdent.2024.105029.
44. Potgieter N, Noordien N, Mulder R, Peck C, Groisman S. Parental acceptance of silver fluoride as a treatment option for carious lesions among South African children with special health care needs. *Front Oral Health.* 2023;4:1294227. DOI: 10.3389/froh.2023.1294227.
45. Potgieter N, Pereira V, Elias R, Charone S, Groisman S. Remineralization and inactivation of carious lesions treated with silver fluoride in Brazilian children with special healthcare needs. *Front Oral Health.* 2024;5:1345156. DOI: 10.3389/froh.2024.1345156.
46. Knapp R, Marshman Z, Rodd H. Treatment of dental caries under general anaesthetic in children. *BDJ Team.* 2017;4(7):17116. DOI: 10.1038/bdjteam.2017.116.
47. Potgieter N, Pereira V, Elias R, Charone S, Groisman S. Acceptance of the use of silver fluoride among Brazilian parents of children with special health care needs. *Front Oral Health.* 2024;5:1377949. DOI: 10.3389/froh.2024.1377949.
48. Chan AKY, Tsang YC, Jiang CM, Leung KCM, Lo ECM, Chu CH. Treating hypersensitivity in older adults with silver diamine fluoride: A randomised clinical trial. *J Dent.* 2023;136:104616. DOI: 10.1016/j.jdent.2023.104616.
49. Chan AKY, Tsang YC, Yu OY, Lo ECM, Leung KCM, Chu CH. Clinical evidence for silver diamine fluoride to reduce dentine hypersensitivity: A systematic review. *J Dent.* 2024;142:104868. DOI: 10.1016/j.jdent.2024.104868.
50. Castillo JL, Rivera S, Aparicio T, Lazo R, Aw TC, Mancl LL, et al. The Short-term Effects of Diammine Silver Fluoride on Tooth Sensitivity: a Randomized Controlled Trial. *J Dent Res.* 2011;90(2):203–208. DOI: 10.1177/0022034510388516.
51. Savitha K, Manoharan P, Balaji J, Ezhumalai G, Pradeep Raja B, Roy S. Effect of silver diamine fluoride, potassium nitrate, and glutaraldehyde in reducing the post vital tooth preparation hypersensitivity: A randomized controlled trial. *J Indian Prosthodont Soc.* 2022;22(2):143. DOI: 10.4103/jips.jips_254_21.
52. Ballikaya E, Ünverdi GE, Cehreli ZC. Management of initial carious lesions of hypomineralized molars (MIH) with silver diamine fluoride or silver-modified atraumatic restorative treatment (SMART): 1-year results of a prospective, randomized clinical trial. *Clin Oral Investig.* 2022;26(2):2197–2205. DOI: 10.1007/s00784-021-04236-5.
53. Saad AE, Alhosainy AY, Abdellatif AM. “Evaluation of Silver Diamine Fluoride Modified Atraumatic Restorative Treatment (SMART) on hypomineralized first permanent molar”- a

- randomized controlled clinical study. *BMC Oral Health*. 2024;24(1):1182. DOI: 10.1186/s12903-024-04860-z.
54. Bal C, Sozuoz MA, Sari MBD, Aksoy M. 1-year Results of Molar Incisor Hypomineralization-affected Cases Treated with Silver Modified Atraumatic Restorative Treatment: A Retrospective Study. *Int J Clin Pediatr Dent*. 2024;17(6):683–689. DOI: 10.5005/jp-journals-10005-2910.
 55. Shokravi M, Khani-Varzgan F, Asghari-Jafarabadi M, Erfanparast L, Shokrvash B. The Impact of Child Dental Caries and the Associated Factors on Child and Family Quality of Life. Saccucci M, editor. *Int J Dent*. 2023;2023(1):1–8. DOI: 10.1155/2023/4335796
 56. Duangthip D, Fung MHT, Wong MCM, Chu CH, Lo ECM. Adverse Effects of Silver Diamine Fluoride Treatment among Preschool Children. *J Dent Res*. 2018;97(4):395–401. DOI: 10.1177/0022034517746678.
 57. Kaur M, Anderson P, Shahid S, Davis GR, Mills D, Wong FSL. Effects of silver diamine fluoride with/without potassium iodide on enamel and dentin carious lesions in primary teeth. *Front Oral Health*. 2024;5:1465956. DOI: 10.3389/froh.2024.1465956.
 58. Karaduran B, Çelik S, Gök MK, Koruyucu M. cpotential of Silver Diamine Fluoride, Potassium Iodide, Nanosilver Fluoride: an in vitro study. *BMC Oral Health*. 2024;24(1):699. DOI: 10.1186/s12903-024-04370-y.
 59. 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. *Syst Rev*. 2021;10(1):89. DOI: 10.1136/bmj.n71.
 60. Tirupathi S, Svsg N, Rajasekhar S, Nuvvula S. Comparative cariostatic efficacy of a novel Nano-silver fluoride varnish with 38% silver diamine fluoride varnish a double-blind randomized clinical trial. *J Clin Exp Dent*. 2019;11(2):e105–e112. DOI: 10.4317/jced.54995.
 61. Al-Nerabieah Z, Arrag E, Rajab A. Cariostatic efficacy and children acceptance of nano-silver fluoride versus silver diamine fluoride: a randomized controlled clinical trial. *J Stomatol*. 2020;73(3):100–106. DOI: 10.5114/jos.2020.96939.
 62. Gao SS, Chen KJ, Duangthip D, Wong MCM, Lo ECM, Chu CH. Arresting early childhood caries using silver and fluoride products – A randomised trial. *J Dent*. 2020;103:103522. DOI: 10.1016/j.jdent.2020.103522.
 63. Abdellatif HM, Ali AM, Baghdady SI, ElKateb MA. Caries arrest effectiveness of silver diamine fluoride compared to alternative restorative technique: randomized clinical trial. *Eur Arch Paediatr Dent*. 2021;22(4):575–585. DOI: 10.1007/s40368-020-00592-0.
 64. Turton B, Horn R, Durward C. Caries arrest and lesion appearance using two different silver fluoride therapies on primary teeth with and without potassium iodide: 12-month results. *Clin Exp Dent Res*. 2021;7(4):609–619. DOI: 10.1002/cre2.367.
 65. Prakash DKM, Vinay C, Uloopi K, RojaRamya KS, Penmatsa C, Chandana N. Evaluation of caries arresting potential of silver diamine fluoride and sodium fluoride varnish in primary molars: A randomized controlled trial. *J Indian Soc Pedod Prev Dent*. 2022;40(4):377–382. DOI: 10.4103/jisppd.jisppd_239_22.

66. Phonghanyudh A, Duangthip D, Mabangkhu S, Jirattanasopha V. Is Silver Diamine Fluoride Effective in Arresting Enamel Caries? A Randomized Clinical Trial. *Int J Environ Res Public Health*. 2022;19(15):8992. DOI: 10.3390/ijerph19158992.
67. Yassin R, Amer H, Tantawi ME. Effectiveness of silver diamine fluoride versus sodium fluoride varnish combined with mother's motivational interviewing for arresting early childhood caries: a randomized clinical trial. *BMC Oral Health*. 2023;23:710. DOI: 10.1186/s12903-023-03456-3.
68. Vaid P, Gupta A, Dogra S, Garg S, Tandon S, Rai R. Evaluation of 38% Silver Diamine Fluoride vs High Viscosity Glass Ionomer Cement for Management of Dentinal Caries in Primary Molars. *World J Dent*. 2023;14(6):486–491. DOI: 10.5005/jp-journals-10015-2250.
69. Ghareep SMEE, Elhendawy FAA, Khatab AM, Amer WHS. Nano silver fluoride versus silver diamine fluoride with potassium iodide on carious dentine of primary teeth. *Tanta Dent J*. 2023;20(4):365–370. DOI: 10.4103/tdj.tdj_31_23.
70. Abdellatif EB, El Kashlan MK, El Tantawi M. Silver diamine fluoride with sodium fluoride varnish versus silver diamine fluoride in arresting early childhood caries: a 6-months follow up of a randomized field trial. *BMC Oral Health*. 2023;23:875. DOI: 10.1186/s12903-023-03597-5.
71. Jain A, Deshpande A, Tailor B, Shah YS, Jaiswal V. Effectiveness of Silver Diamine Fluoride and Sodium Fluoride Varnish in Preventing New Carious Lesion in Preschoolers: A Randomized Clinical Trial. *Int J Clin Pediatr Dent*. 2023;16(1):1–8. DOI: 10.5005/jp-journals-10005-2488.
72. Zheng FM, Yan IG, Duangthip D, Lo ECM, Gao SS, Chu CH. Caries Prevention Using Silver Diamine Fluoride: A 12-Month Clinical Trial. *Int Dent J*. 2023;73(5):667–673. DOI: 10.1016/j.identj.2022.12.005.
73. Hamza BE, Abdellatif AM, Attia NM, Hegazy SA. Arresting Active Carious Lesions Using Minimal Intervention Dentistry among a Group of Preschool Children: A Randomized Controlled Clinical Trial. *Int J Clin Pediatr Dent*. 2024;17(9):1018–1024. DOI: 10.5005/jp-journals-10005-2927.
74. Quritum M, Abdella A, Amer H, El Desouky LM, El Tantawi M. Effectiveness of nanosilver fluoride and silver diamine fluoride in arresting early childhood caries: a randomized controlled clinical trial. *BMC Oral Health*. 2024;24:701. DOI: 10.1186/s12903-024-04406-3.
75. ElGhandour RK, ElTekeya MMH, Sharaf AA. Effectiveness of silver diamine fluoride in arresting early childhood caries: a randomised controlled clinical trial. *Eur J Paediatr Dent*. 2024;23(3):202–207. DOI: 10.23804/ejpd.2024.2052.
76. Juárez-López MLA, Marín-Miranda M, Palma-Pardines R, Retana-Ugalde R. The Effectiveness of Remineralization with Compound Silver Nanoparticles and Fluoride Varnish in Carious Lesions in Primary Teeth: A Randomized Split-Mouth Clinical Trial. *Dent J*. 2024;12(10):318. DOI: 10.3390/dj12100318.
77. Alqalaleef SS, Alnakhli RA, Ezzat Y, AlQadi HI, Aljilani AD, Natto ZS. The role of silver diamine fluoride as dental caries preventive and arresting agent: a systematic review and meta-analysis. *Front Oral Health*. 2024;5:1492762. DOI: 10.3389/froh.2024.1492762.