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The Effectiveness and Safety of Silver Diamine Fluoride on Primary Teeth: A Review of Literature

Ali Mahdi S Alsalem[1], Dr. Abdullah Mohammed Al-Qedrah[2], Abdullah Ali S Alharith[3]*

[1]*Dental Hygiene Specialist*

[2]*Endodontics Consultant*

[3]*Dental Lab Specialist*

Ministry of Health, Saudi Arabia

Abstract

Silver diamine fluoride (SDF) is a potent compound for the arrest of dental caries in pediatric populations, demonstrating ease of application and the capacity for utilization beyond traditional clinical contexts. The aim of this study was to perform a literature review on the effectiveness and safety of SDF in arresting dental caries in primary teeth of young children. A literature review was conducted using the Old Dominion University library resources. Utilizing the established search methodology, A comprehensive total of 57 studies were identified across all relevant databases; however, only 13 were clinical trials that specifically evaluated the effectiveness and safety of SDF treatments. The remaining 44 studies were mostly surveys or irrelevant to the effectiveness and safety of SDF, often with titles that did not accurately represent the content of the studies, and primarily focused on parental acceptance of SDF treatments for their children. In general, the findings demonstrated SDF to be effective in arresting dental caries in deciduous teeth relative to alternative approaches, such as fluoride varnish and atraumatic restorative treatment (ART). Additionally, the prevailing evidence substantiates the safety of SDF application in pediatric populations. The drawback of SDF application is the induction of dark discoloration on the treated, caries-arrested tooth.

Keywords: Silver Diamine Fluoride, SDF, SDF effectiveness, SDF Safety, Children, Primary teeth, Arrest dental caries.

Full length article * *Ali Mahdi S Alsalem1*, e-mail: amalsalem@moh.gov.sa

1. Introduction

The prevalence of dental caries and untreated dental caries among U.S. children remains a public health concern. Dental caries is a preventable, chronic disease that is a complex and multifactorial process. Children's vulnerability to dental caries begins during the early developmental stages, around the eruption of the first tooth at six months [1]. Over the past 20 years, there has been nearly a 5 % decrease in the prevalence of dental caries in primary teeth. For example, national data found that 28% of children aged two to five years had primary dental caries in 1994-2004 compared to 23% in 2011-2016; however, the disparities among certain racial and ethnic groups and income levels remained unchanged throughout the years [2]. Specifically, Black, non-Hispanic and Mexican American children aged two to five years had a higher prevalence of primary dental caries (28% and 33%, respectively) than non-Hispanic White children (18%). In terms of income, children from household incomes of < 100% Federal Poverty Level (FPL) and 100%-199% FPL had a higher prevalence of primary dental caries than children from households of >200% FPL (34% vs. 24% vs. 16%, respectively) [2]. Dental caries among children can lead to negative health outcomes, such as pain and infections, which can lead to nutritional concerns and school days missed [3-4]. Untreated dental caries in young children can cause pain, infection, tooth loss, malnutrition, and poor quality of life [5-6]. Several national stakeholders, such as Healthy People 2030, recognize the negative impact of untreated dental caries among children and have established objectives and measures for over 40 years. One specific 2030 goal aims to "reduce the proportion of children and adolescents with active and untreated tooth decay" — OH-02 (Healthy People 2030, 2020). Their target is to reach a measure of 10.2%, which is 3.2% less than the baseline (13.4%) collected in 2013-2016. Based on the 2011-2016 National Health and Nutrition Examination Survey (NHANES), 10.4% of children aged two to five years had untreated primary dental caries [2]. These statistics suggest the prevalence of untreated tooth decay among young children is approaching the Healthy People 2030 goal; however, more collaborative efforts are needed to address the sociodemographic disparities.

Dietary habits, feeding practices, proper oral hygiene, and establishing a dental home for the child by age one aids in the prevention of dental caries [7]. Adjunctive methods, such as age- appropriate professional fluoride, at-home fluoride, and fluoridated toothpaste, can be used to prevent dental caries among children [8]. Once the child has been diagnosed with dental caries, treatment options will vary based on the severity of the disease. Regular and timely preventive dental visits allow for early diagnosis and treatment of oral diseases. The proportion of children between the ages of 2 and 17 who had dental appointments grew from 78.4% in 2009 to 82.3% in 2012, followed by a more gradual increase to 85.9% in 2018. By 2019, 86.9% of children in this age group had visited a dentist [9]. Silver diamine fluoride offers a promising and non-invasive method for managing dental caries and tooth sensitivity in children, further emphasizing the need for regular dental visits and professional intervention. SDF is a non-invasive approach that has been used to arrest the progression of dental caries on the occlusal and root surfaces of teeth, as well as manage tooth sensitivity [10]. The Food and Drug Administration (FDA) approved SDF for use in the United States as a Class II medical device in the treatment of tooth sensitivity and caries arrest [10]. The benefits of SDF include arresting primary and secondary dental caries, desensitizing hypersensitive dentin, preserving healthy tooth tissue, promoting remineralization, exerting antimicrobial effects, and offering cost-effective and easy application [10]. Research reveals the topical application of SDF is safe for children. The serum concentrations of fluoride in the bloodstream have been found to be low and nontoxic [11-13]. Silver diamine fluoride is also less invasive than other approaches and may be used as an alternative to restorative procedures, which can be challenging to perform on young children [11]. Thus, this literature review is intended to provide a review on the effectiveness and safety of using SDF on primary teeth.

2. Research question

What is the effectiveness and safety of SDF in arresting dental caries in primary teeth of young children?

3. Review of the Literature

A literature review was conducted using the Old Dominion University library resources, EPSCO host, Dentistry and Oral Sciences Source, CINAHL, American Dental Association, and Centers for Disease Control and Prevention, using the following search terms: "Silver Diamine Fluoride" AND children, ("Silver Diamine Fluoride" OR SDF) AND children, ("Silver Diamine Fluoride" OR SDF) AND (children OR deciduous OR Primary teeth), ("Silver Diamine Fluoride" OR SDF) AND safety, ("Silver Diamine Fluoride" OR SDF) AND Effectiveness. A comprehensive total of 57 studies were identified across all relevant databases; however, only 13 were clinical trials that specifically evaluated the effectiveness and safety of SDF treatments. The remaining 44 studies were mostly surveys or irrelevant to the effectiveness and safety of SDF, often with titles that did not accurately represent the content of the studies, and primarily focused on parental acceptance of SDF treatments for their children.

3.1. Composition of SDF

Silver Diamine Fluoride is a colorless liquid composed of silver particles and 38% (44,800 ppm) fluoride ion, with a pH of 10 and a composition of 25% silver, 8% ammonia, 5% fluoride, and 62% water [10]. In 1970, Drs. Nishino and Yamaga of Japan established the use of SDF for arresting dental caries; this process involved combining the elements of fluoride and silver ions [14-15]. When applied to the tooth surface, the fluoride ions can penetrate up to 20 μm into the enamel. The fluoride ion was observed to penetrate dentin up to 50 to 100 μm, but Ag+ penetrated deeper, approaching the pulp chamber [15]. Drs. Nishino and Yamaga emphasized the agent stains the decalcified soft dentin black; thus, it was recommended for use on posterior teeth. Silver Diamine Fluoride is an alkaline solution (pH 10–12) containing 38% Ag (NH3)2F [14-15]. The silver acts as an antimicrobial, the fluoride concentration is sufficient to promote remineralization, and the presence of ammonia (NH3) stabilizes the solution [16]. The silver-diamine ion complexes react with hydroxyapatite to form silver phosphate (Ag3PO4) and silver oxide upon contact with the tooth [11]. Ionic silver acts as an antibacterial by disturbing membranes, denaturing proteins, and inhibiting DNA replication, while SDF inhibits the collagenolytic enzymes that degrade the exposed dentin organic matrix [11]. The formation of organometallic complexes within a bacterial cell can also be attributed to the antibacterial mechanisms of SDF [11]. Silver Diamine Fluoride complexes can deactivate enzymes in bacteria, causing bacterial cell death; induce bacterial cell rupture; and mutate with the DNA of bacterial cells, causing cell death [11]. The composition of silver compounds causes a noticeable change in enamel color, which is the primary side effect of SDF treatment [11]. The amount of SDF applied to a tooth to treat caries has a lower fluoride content than fluoride varnish, which addresses common patient concerns about fluoride. According to the American Academy of Pediatric Dentistry (2018), no known systemic or severe adverse effects are associated with SDF when used as directed by the manufacturer [7]. The process of arresting dental caries using SDF involves cleaning the tooth surface to remove debris or plaque that may be present, applying the SDF solution to the affected tooth using a brush or applicator, and allowing the product to dry for one to two minutes [16]. Lastly, the patient is advised to avoid eating or drinking for at least 30 minutes after the application.

3.2. SDF Effectiveness in Caries Arrest

Zhi and Lin's (2012) randomized clinical trial compared the effectiveness of two SDF solutions applied at 12 and 6 months, respectively and a flowable high-fluoride–releasing glass ionomer at 12 months in arresting dentin caries in primary teeth [17]. The study was conducted between 2007-2009 in Southern China, where the fluoride concentration in drinking water in cities was 1mg/L and 1.2mg/L in rural areas. Children with active dental caries to the dentin, not to the pulp, with informed consent, were participants of the study. The sample of 212 children aged three to four years with 719 active dentin caries lesions were randomly assigned to one of three treatment groups: Gp1 annual SDF, Gp2 semiannual SDF, or Gp3 annual glass ionomer. The treated carious lesions were evaluated to determine arrest at 6-month intervals.

Additionally, parents completed baseline and follow-up surveys (at 24 months) that gathered information on the child's oral home care (brushing and fluoride toothpaste use), dietary habits, and satisfaction with the appearance of the child's oral cavity. Among the 212 children that started the study, the mean age was 3.8(0.6) years, 51% were male, 26% reported brushing once daily and 74% reported using fluoridated toothpaste. After 24 months, 181 children (85%) across the three treatment groups remained in the study. Caries arrest rates of 79%, 91%, and 82% were seen for Gp1, Gp2, and Gp3, respectively (p = .007). Higher caries arrest rates were found in lesions treated in Gp2 (OR = 2.98, p = .007), those in anterior teeth (OR = 5.55, p < .001), and those in buccal/lingual smooth surfaces (OR = 15.6, p = .004) in the logistic regression model that used GEE to adjust for the clustering effect. The results suggest the frequent use of SDF every six months had a higher caries arrest rate than using SDF every 12 months. The researchers found no adverse reactions on the treated teeth and soft tissues. Lastly, the researchers found no statistically significant influence on caries arrest with respect to the child's sociodemographic characteristics, oral habits, and baseline dental caries status. A positive attribute of this study was the inter-examiner calibration, which consisted of a Cohen's Kappa >0.9 for baseline and follow-up clinical observations. The researchers mentioned no limitations to their study. Gao et al. (2020), used a noninferiority, double-blind, clinical trial to compare the effectiveness of semiannual (6-month) applications of 25% silver nitrate (AgNO3) solution followed by 5% sodium fluoride (NaF) varnish versus semiannual applications of 38% SDF solution to treat dental caries in children aged three to four years [18]. In this study conducted in Hong Kong, China, parents from 29 kindergarten programs were invited to participate. The inclusion criteria included healthy children, informed parental consent, and at least one active cavity to the dentin. The children were then stratified based on the number of decayed, missing, and filled surfaces (dmfs). For example, stratum one consisted of children with one dmfs surface and stratum two consisted of children with more than 3 dmfs surfaces. From this criterion, children were randomly assigned to one of two intervention groups, A and B (n = 535 for each group). In group A, children received semiannual applications of a 25% AgNO3 solution followed by a 5% NaF varnish on carious lesions. The children in Group B were treated semiannually with a 38% SDF solution followed by a placebo varnish. Additionally, a questionnaire was provided to the parents that included the child's oral health behaviors and family's socioeconomic status. Another questionnaire was administered at the 30-month follow-up that focused on feeding and dietary habits, as well as oral homecare. The final sample included 1,070 children with data collected every six months from baseline to 30 months. There was an attrition rate of 16% and 19%, respectively, after 30 months for groups A and B. The data was analyzed using a noninferiority test. Group A would be deemed noninferior if the lower limit of the 95% confidence interval (CI) for the difference in the mean number of arrested decayed surfaces (DSs) was greater than 0.5. After 30 months, the mean arrested DSs for Group A (n = 447) and Group B (n = 433) were 3.7 ± 3.6, respectively (p = .694). The mean difference in arrested DSs between the two groups was 0.088 (95% CI [-0.351, 0.526]). The researchers concluded that semiannual application of 25% AgNO3 followed by 5% NaF was found to be at least as effective as the semiannual application of 38% SDF in arresting dental caries. Children's birthplaces, parental statuses, parental education levels, family income, and primary caregiver information was collected using a customized, validated questionnaire. Another parental questionnaire was used to collect data on each child's oral health-related behaviors at the 30-month follow-up. Topics covered included nighttime bottle feeding, snacking patterns, daily teeth brushing practices, aided tooth brushing, and usage of fluoridated toothpaste. The researchers mentioned a few limitations. First, the data collection was every six months, preventing the exact point of caries arrest from being determined. Secondly, the researchers mentioned the Last Observation Carried Forward (LOGF) method used for missing data during analysis may underestimate the caries arresting effectiveness. Finally, the researchers mentioned the equipment and setting may have impacted the caries arresting outcomes Similarly to Zhi and Lin's (2012) study, the researchers achieved a Kappa's Cohen of >0.9 for all data collection points [17].

3.3. SDF and Sodium Fluoride Varnish

In a similar study, Duangthip et al. (2016) utilized a randomized clinical trial methodology to compare three topical fluoride application protocols for arresting dentinal caries in primary teeth among preschool children living in a fluoridated area in Hong Kong, China [19]. The final sample included 304 children (1670 tooth surfaces) aged three to four years with at least one active dentinal carious lesion. Each participant was randomly assigned to one of three intervention groups: Group 1 (30% SDF solution every 12 months) (n=100), Group 2 (30% SDF solution 3 times a week) (n=97), and Group 3 (5% NaF varnish 3 times a week) (n=107). Additionally, sociodemographic characteristics, baseline dmfs scores, dietary and feeding habits, and oral homecare information was collected. Every six months, a masked examiner determined whether the growth of treated lesions had ceased for a total of 18 months. After 18 months, 91% (n = 275) of children remained in the study. Caries arrest rates in Groups 1, 2, and 3 were 40%, 35%, and 27%, respectively (p < .001). A multilevel survival analysis revealed SDF inhibits dentinal caries more rapidly than 5% NaF varnish alone (group 3). In general, buccal and lingual tooth surfaces, as well as the absence of plaque on a diseased surface, yielded better outcomes than lesions on the occlusal surface and lesions with plaque. The researchers provided limitations to their study to include the transfer of results to groups in non-fluoridated areas. For example, the sample included in the study had fluoridated water (0.5ppm) and fluoridated toothpaste. Also, this study did not have a control group to compare with the SDF group. Similar to Zhi and Lin (2012) and Gao et al (2020), a Kappa Cohen of >0.9 was established for all data collection points [17-18]. Mabangkhrua et al., (2020) utilized a two-arm, parallel-design clinical trial to compare the effectiveness of 38% SDF solution versus 5% NaF varnish applied every six months in arresting dentinal caries in young, high-risk children [20]. The study occurred in Thailand where the fluoride concentrations was ≤ 0.3ppm.

The targeted sample included children attending one of the 19 child development centers who were between the ages of one to three with at least one active dentinal carious lesion. The baseline sample comprised 302 children, who were

randomly assigned to one of two groups: Group 1: 38% SDF or Group 2: 5% NaF varnish. Both agents were applied to teeth every six months. An examiner conducted a visual–tactile examination to determine lesion activity at baseline and follow up exams. Demographic background, oral health-related habits, and oral hygiene practices were collected at baseline and 12-month follow-up. At baseline, Group 1 had n=153 children, and Group 2 had n=149 with dmfs scores of 8.89 and 9.79, respectively. After 12 months, 87.1% of participants remained in the study. Overall, at 12 months, Group 1's caries arrest rate (35.7%) was higher than Group 2's (20.9%; p = <0.001). Multilevel logistic regression analysis showed that treatment used in Group 1 was more effective than in Group 2 (*OR* = 2.04; 95% CI [1.41, 2.96]). Results revealed that 38% SDF is more effective than 5% NaF varnish in arresting dentinal carious lesions in young children. Additionally, parents were equally satisfied in both groups at baseline and follow-up with the appearance of their child's oral cavity. Lastly, the researchers indicated no adverse reactions or systemic illnesses were reported among children in the SDF group. The researchers highlighted a few limitations to their study to include the use of visual/tactile examination vs. radiographs for caries detection, detection bias among the examiner due to the staining of SDF, and the length of the study (12 months vs. 24 months). The researchers indicated only one trained, blind examiner was used throughout the study, which was a good practice to reduce threats to internal validity. Chu et al. (2002) conducted a prospective, controlled clinical trial to examine the effectiveness of using SDF and NaF varnish in arresting dentinal caries among a cohort of preschool aged children in Guangzhou, China [21]. In this region, researchers reported the fluoridated drinking water to be under 0.2ppm, fluoridated toothpaste was costly, fluoride supplements were not available, and there was minimal use of topical fluoride among dentists. A total of 375 kindergarteners from eight schools were included in the cohort. After parental consent, students received oral health education and an oral examination of the anterior incisors. Additionally, parents received a survey at baseline and 24 months regarding the child's oral health behaviors and habits, as well as the parent's satisfaction with the appearance of the oral cavity. One blinded examiner completed the clinical exams every six months. Children were assigned to one of five treatment groups based on when the examination was performed. The five treatment groups were the following: SDF + excavation, SDF, NaF+ excavation, NaF, and a control. The SDF application with or without excavation was repeated every 12 months and NaF with or without excavation was repeated every three months. Only water was applied to the control group. Participants were permitted to continue normal dental service and fluoride fluoride utilization. At the baseline exam, 375 children, 209 boys (56%) and 166 girls (44%), with a mean age of four years (*sd*= 0.8) participated, and 308 children remained in the study at 30 months. The average baseline dmfs score of the 308 children monitored for 30 months was 4.66, with 3.92 tooth surfaces having active caries. No statistically significant differences ($p > 0.05$) were observed between the initial 375 children and the remaining 308 or among the five groups of children for these parameters. An analysis of covariance (ANCOVA) was used to study the effects of independent variables on the surface area, and 30-month exams revealed teeth with arrested caries. The children who received SDF once a year had more arrested cavities in their anterior teeth than children in the other groups ($p < 0.001$). They also had more black spots on their arrested cavities ($p < 0.001$) than the other children. The number of non-vital teeth did not significantly differ among the five groups of children. No adverse effects, such as color change or harm to the gums, were seen. The parents' satisfaction with their child's teeth appearance and health did not change significantly after 24 months among the five groups of children ($p < 0.05$). The main reason for dissatisfaction among some parents regarding the appearance their child's teeth was due to decayed front teeth. Only about 7% of the parents mentioned darkened teeth as a result of applying SDF. This 30-month study found an annual application of SDF arrests dentinal caries in Chinese preschoolers' primary anterior teeth. The authors of this study did not mention any limitations in this study; however, the study included 375 children from eight kindergarten schools. The sample size might not be large enough to generalize the findings to the broader population of pre-school children in China or elsewhere. Also, this was single-center study conducted at a single center in Hong Kong, which may limit the generalizability of the findings to other settings. In a prospective, randomized clinical trial, Yee et al., (2009) evaluated the caries-preventing efficacy of a single-spot application of varying levels SDF on the primary teeth of 976 Nepalese school children [22]. There were 545 males (56%) and 431 females (44%) aged three to nine years. This study was conducted in Kathmandu, Nepal, a city with a water fluoride concentration of 0.03 ppm. Participants were assigned to one of the following groups: Group 1: 38% SDF applied once for two minutes without the use of a reducing agent, Group 2: 38% SDF applied once for two minutes with tannic acid as a reducing agent, Group 3: 12% SDF applied once for two minutes without the use of a reducing agent, and Group 4 served as the control group with no therapy. Over 6, 12, and 24 months, the 38% SDF groups had significantly more arrested carious surfaces than the 12% SDF and control groups. Although the difference decreased over time, it remained significant. No significant differences were found between 38% SDF and 38% SDF + tannic acid groups, between 12% SDF and control groups, or in the mean number of non-vital teeth and exfoliated surfaces at any time point. A few limitations were discussed by the authors to include attrition among all groups over the 24 months. A substantial dropout rate (35%) at 24 months was attributed to a school closure and parental mobility; however, this did not impact the study's results, as the four groups, including dropouts and those who remained, were similar in all other aspects. The authors concluded that Arresting Caries Treatment (ACT) using 38% SDF presents a viable alternative when restorative treatment for primary teeth is not feasible. In another study, Phonghanyudh et al. (2022) completed a randomized clinical trial that compared the effectiveness of 38% SDF and 5% NaF varnish in arresting enamel caries in young children over 18 months in Thailand [23].

The authors recruited 120 children aged one to three years who had at least one active carious surface and randomly assigned them to either the SDF or NaF group. The interventions were applied semiannually by calibrated dentists and the outcomes were assessed by blinded examiners using visual criteria. The primary outcome was the proportion of arrested carious surfaces at 18 months. The

secondary outcomes were adverse events, parental satisfaction, and cost-effectiveness. The results revealed SDF was significantly more effective than NaF in arresting enamel caries (86.7% vs. 49.6%, $p < 0.001$). There were no serious adverse events reported in either group; however, SDF caused black staining on treated surfaces, which reduced parental satisfaction compared to NaF (72.5% vs. 95%, $p < 0.001$). Furthermore, the SDF was also more cost-effective than NaF ($2.8 vs. $4 per arrested surface). The authors concluded that SDF was a safe and effective alternative to NaF for arresting enamel caries in young children, especially in low-resource settings where access to dental care is limited. The authors reported a few limitations to their study to include no control group due to ethical issues, visual assessment of dental caries vs. radiographs; thus, interproximal caries may have been missed. Although a single examiner was blinded to the intervention groups, SDF staining of treated carious lesions may have generated bias in the assessment of follow-up data.

3.4. SDF and Atraumatic Restorative Treatment (ART)

Satyarup et al. (2022) compared the efficacy of 38% SDF versus atraumatic restorative treatment (ART) in the treatment of dental caries in a school setting in Odisha, India [24]. A parallel group RCT was conducted on children aged 6-12 years. A total of 190 children met the inclusion criteria, which included those with at least one occlusal carious lesion in any fully erupted molar that was classified as code V or VI by the International Caries Detection and Assessment System (ICDAS). Over the course of 11 months, the study was carried out in three stages with follow-ups at three, six, and nine months. Children enrolled in group 1 received two minutes of direct application of SDF and glass ionomer cement to restore the tooth after treatment. The child was advised not to eat or drink anything for 30 minutes following the application. In group 2 (ART), dentinal caries was excavated and a dentinal conditioner containing 10% polyacrylic acid was used to treat the prepared cavity for 10–15 seconds. Glass ionomer cement was used to fill the cavity. After a restorative procedure, it was advised to avoid eating and drinking for at least an hour. Group 1 (SDF) had a significantly higher percentage of successful restorations (58.9%) than group 2 (ART) (47.8%), as measured by the result of the interventions ($p = 0.004$). An entire restoration covering all pits and fissures (53.3%) was the most prevalent evaluation score among all restorations (a sound tooth with a partial loss of the restoration). A score of 5 indicated a severely decaying tooth or one in which the filling has been completely lost. The percentage of carious teeth where the restoration was lost was 5.6% in the ART group, compared to 16.7% in the SDF group ($p = 0.025$), suggesting that 38% SDF was more effective at preventing dental caries. This study indicated that SDF was better at arresting caries, and it can be considered a viable treatment option in areas with limited access to oral healthcare. The authors stated the following limitations: this study, conducted over nine months, did not assess certain outcomes related to SDF use, such as tooth and mucosal staining, and was unable to evaluate secondary caries due to a lack of radiographs in the field setting. A longer follow-up would offer better insights into restoration retention. In another parallel-arm, 12-month randomized clinical trial conducted by Abdellatif et al. (2021) the researchers evaluated and contrasted the impact of applying 38% silver diamine fluoride (SDF) biannually against the alternative restorative technique (ART) in terms of arresting dental caries in primary teeth. The sample consisted of 79 Saudi Arabian children aged three to eight years (237 primary teeth), with a mean age of 5.33 years [25]. The total number of carious lesions was 237, and 51.1% of the children were put in the SDF group and 48.9% in the alternative restorative technique (ART) group. Children of either gender who had at least one primary asymptomatic tooth with active single-surface lesions (either occlusal surfaces in posterior teeth or labial surfaces in anterior teeth, according to the International Caries Detection and Assessment System; ICDAS II scores 4, 5, or 6) were eligible for the study. In the test group, carious lesions were treated with SDF, whereas lesions in the control group were treated with the ART technique. At 6- and 12-month follow-ups, the primary outcome measured was the frequency of carious lesion arrest. The secondary outcome was the total working time, in minutes, required for each tooth treatment procedure. The baseline characteristics of participants who completed a 12-month follow-up were presented. There were no statistically significant differences in age, gender, or ICDAS scores between the two groups. There were only statistically significant differences between the two groups regarding lesions' locations and arch distribution, with the ART group having a more significant proportion of posterior teeth and mandibular arches affected by caries. No significant differences in caries arrest between maxillary and mandibular teeth were observed at the 6- and 12-month evaluation periods for either group ($p = .488$, 1.000, and .317 at the 12-month evaluation period for the SDF and the 6- and 12-month evaluation periods for the ART, respectively). One limitation of this study was the considerable number of patients (12%) who declined participation after consenting and being randomized. Subject dropout rates were 32.5% and 33.3% in the SDF and ART therapy groups, respectively ($p > 0.5$). To address this, the full study was performed once using an intention-to-treat technique and once without, and no variations in any of the outcomes of the two sets of analyses were identified. As a result, the analyses reported hereafter do not take an intention-to-treat approach. Substantial differences in lesion sites and ICDAS scores were also identified between the two groups ($p < 0.000$). This disparity could be attributed to dropouts following randomization, which was based on patients rather than teeth, whereas unit analysis was based on teeth. Cleary et al (2022) conducted a 12-month, two-arm, parallel-group randomized clinical trial that compared the efficacy of restorative treatment (RT) vs semiannual application of 38% silver diamine fluoride (SDF) to treat cavitated carious lesions in primary teeth of children in Michigan, United States of America [26].

The sample consisted of 98 children aged –two to ten years who had at least one primary tooth with active or soft caries and a score of 5 or 6 according to the ICDAS criteria (International Caries Detection and Assessment System 2020). Carious lesions were found on teeth that still had at least one third of their crowns, no pulpal exposure, expected exfoliation that would take longer than 12 months, and no symptoms of periapical infection or spontaneous or solicited discomfort. After enrollment, individuals were randomly assigned to one of two treatment groups, each child had one randomly selected dental lesion treated with either 38% silver diamine fluoride (SDF) applied twice at a 6-month interval or

assigned to the restorative treatment (RT) group. There were four clinical visits conducted in-person: baseline, three, six, and twelve months. A total of 15 dentists were calibrated over the course of the study and conducted clinical examinations. Dentin color, dentin texture, and ICDAS grading were all evaluated during calibration. A total of 98 children participated in the study with 46% female and 54% male with a mean age of 4.8 years (sd=1.8). The age, sex, and the distribution of race and ethnicity between the groups did not differ significantly (p= 0.05) at the beginning of the study. A total of 69 (70%) children completed the 12-month visit (SDF = 40, RT = 29). The mean DMFT score was 6.3 (3.9) at baseline. At baseline and six months, there was a significant difference in scores between the groups (P = 0.034 and P = 0.042, respectively); however, at three and twelve months, these differences were not statistically significant. The 98 lesions at baseline included 62 (63.3%) primary molar lesions, 21 (21.4%) primary canine lesions, and 15 (15.3%) primary incisor lesions. No significant differences in pain reports between the groups were observed at any visit, except at 9 months (P = 0.046) and 12 months (P = 0.050), during which the SDF group had significantly higher reports of pain. Parental acceptance, satisfaction, and preference amongst treatments did not differ significantly (p > 0.05) at 6 and 12 months. Children in the RT arm compared to the SDF arm felt better about how their teeth appeared at 12 months (p = 0.047), and they also reported that their dental visit hurt less (p = 0.049). The researchers noted a few limitations. First, dentists in the RT group were free to choose the material and technique; no dentist opted for ART. Secondly, the study lacked the necessary power to compare SDF to various restorative materials or cavity preparation/removal methods. Lastly, the COVID-19 pandemic and the Flint water crisis both contributed to the initial delayed recruitment of participants.

3.5. SDF Safety

Duangthip et al., (2018) reported in a randomized clinical trial the adverse effects and parental satisfaction associated with various SDF treatment regimens among Hong Kong preschool-aged children [12]. The authors recruited 888 children aged three to four years (369 girls and 519 boys) who had at least one active cavitated lesion and randomly assigned them to one of four groups: group 1 received 12% SDF annually; group 2 received 12% SDF semiannually; group 3 received 38% SDF annually; and group 4 received placebo semiannually. The interventions were applied by calibrated dentists and the outcomes were assessed by blinded examiners using visual criteria. The primary outcome was the proportion of arrested lesions at 30 months. The secondary outcomes were adverse effects (such as staining, gingival irritation, ulceration, and allergy) and parental satisfaction (measured by a questionnaire). Using a micro applicator (Premium Plus; Premium Plus International Limited), the solution was applied to carious tooth surfaces for approximately one minute. Adverse effects from treatment were gathered one week post baseline application and every six months until the 30-month follow-up. At baseline, and again at 18 and 30 months, parents were asked how satisfied they were with their children's teeth and oral health via a self-report questionnaire. If their child had an acute systemic illness after receiving SDF, parents were asked to call the lead investigator as soon as possible. The mean age of participants was 3.8(0.6) years. The mean total dmft score of the sample was 3.8(3.8) with a mean decayed teeth score of 3.7 (2.7). ANOVA and $\chi 2$ were used to compare the children complaining about gum swelling after treatment. At baseline and 6, 12, 18, 24, and 30 months, 19 (2.1%), 13 (1.5%), 26 (2.9%), 22 (2.5%), 22 (2.5%), and 25 (2.8%), respectively children complained of swollen gums. No significant differences in gum swelling were observed between groups at follow-ups. At baseline and 6, 12, 18, 24, and 30 months, 33 (3.7%), 44 (5.0%), 55 (6.2%), 62 (7.00%), 60 (6.80%) and 59 (6.6%), respectively of the children in the study complained of tooth or gum pain/discomfort. There was no significant difference in oral pain between groups at any follow-up (x2 test, $p > .05$). Thirty-eight (4.3%) of the children in the study complained of gingival discoloration at baseline, 49 (5.5%) at six months, 45 (5.1%) at 12 months, 27 (3%) at 18 months, 51 (5.7%) at 24 months, and 42 (4.7%) at 30 months. None of the children in the study experienced any symptoms of acute toxicity or systemic illness, including nausea, vomiting, or general discomfort. Some limitations were listed by the authors in this study. First, there could have been inconsistencies between the clinical observations of dental practitioners and patient reports. Patient-reported side effects may be confused with other symptoms resulting from illness progression and not directly caused by SDF administration. Secondly, there could be underreporting by the parents if the adverse effect was not significant to them. Ellenikiotis et al., (2022) conducted a cross-sectional study in California to measure serum levels of silver and fluoride and to characterize the pharmacokinetics in healthy children receiving SDF treatment [13]. From August 2019 to March 2020, a total of 55 children aged three to thirteen years with at least one carious lesion were recruited at the University of California, San Francisco Pediatric Dental Clinic. Blood was drawn at random up to 168 hours after the SDF application. The concentrations of fluoride and silver in the blood were measured, and population pharmacokinetic modeling was used to estimate pharmacokinetic parameters and simulate silver concentration versus time profiles in children's cohorts (15 to 50 kg). The Research Electronic Data Capture (REDCap) randomly assigned participants to one seven blood sample intervals: 2, 4, 6, 24, 48, 96, or 168 hours following the application of SDF. After SDF treatment, serum fluoride concentrations ranged from 6 to 36 ng/niL. Baseline serum fluoride concentration modifications to post-SDF application fluoride concentrations were not made since baseline blood samples were not obtained.

As comparison to later sample time intervals (12.213.4 ng/mL for 24, 48, 96, and 168 hours), the average blood fluoride concentration in children was marginally higher during the first six hours following SDF administration (17.5*7.1 ng/mi). After SDF treatment, serum silver concentrations ranged from 1.4 to 46.2 ng/mL. Fluoride and silver serum concentrations after intermittent topical application of SDF posed minimum risk of toxicity in children. The SDF application may result in minor serum fluoride increases that are not significantly different from baseline fluoride levels. SDF application caused a lower increase in serum fluoride than fluoride varnish treatment. A child's weight influences pharmacokinetics. For example, smaller children (those weighing less than 15 kg) have higher predicted peak silver concentrations, and silver will have a longer half-life in their bodies than for heavier children (e.g.,

50 kg). The authors note various limitations within this study, including: the use of a set absorption rate constant based on adult data, a small number of participants at each time point, a brief study period that prevented accurate determination of the silver half-life, and the inability to ascertain the precise amount of silver administered or absorbed. Milgrom et al (2018), investigated the safety and effectiveness of 38% silver diamine fluoride in arresting carious lesions [27]. The investigation used two parallel groups in a double-blind, randomized, placebo-controlled superiority trial. A total of 66 preschoolers in Oregon with at least one untreated carious lesion were enrolled. The children were randomized to receiving 38% silver diamine fluoride or a water-based placebo. Caries arrest (lesion inactivity, according to Nyvad criteria) occurred 14–21 days after intervention as the main endpoint. All children's dental plaque was collected, and RNA sequencing was used to determine the microbial composition of two lesions and one unaffected surface before treatment and at follow-up for three children from each group. The mean proportion of treated surfaces with arrested lesions at follow-up in the silver diamine fluoride group was 0.72 (95% CI; 0.55 to 0.84), compared to 0.05 in the placebo group (95% CI; 0.00 to 0.16). The difference in the mean proportion of arrested lesions was 0.67 (95% CI: 0.49 to 0.80). A confirmatory analysis using log-linear regression, accounting for the number of treated lesions, revealed a significantly higher rate of arrested lesions in the treated group compared to the placebo group (relative risk 17.3; 95% CI: 4.3 to 69.4). No consistent changes in the relative number of caries-associated bacteria or the establishment of antibiotic or metal resistance gene expression were seen after RNA sequencing analysis. Limitations to this study include a shorter follow-up time compared to previous studies (14-21 days vs. 6 months). Additionally, the relatively high rate observed in this study could be attributed to the blue coloring of the agent, which may facilitate more comprehensive application, or due to an initial response that diminishes over time without reapplication. The lack of the microbiological assessments is that they determine the proportion of different species present, rather than the actual concentrations of these species within a dental lesion.

4. Discussion

This literature review aimed to synthesize the effectiveness, safety, and further implications of the SDF in primary teeth in young children. First, the literature demonstrates the effectiveness of SDF in arresting dental caries in primary teeth of children. Several studies have compared the effectiveness of SDF and NaF varnish in arresting dental caries in young. Most of those studies found that SDF was more effective than NaF varnish in arresting dental caries [19-23]. In addition, some studies explored the effectiveness of SDF and Atraumatic Restorative Treatment (ART) in treating dental caries. They concluded that SDF was better at arresting caries and can be considered a viable treatment option in areas with limited access to oral healthcare [24-26]. Finally, the safety of SDF in pediatric patients has been assessed in multiple studies, which generally show that SDF treatment is safe and effective in arresting dental caries in children [12-13,27]. The evidence suggests SDF is an effective treatment for arresting dental caries in children. The studies had robust methodologies, including randomization, a clinical trial design, and high inter-examiner calibration (Cohen's Kappa > 0.9) [19-23]. In addition, the frequency of application seems to be an essential factor in determining the effectiveness of the treatment, with 6-month intervals being more effective than 12-month intervals [28]. Similarly, more studies examined the effectiveness of SDF compared to fluoride varnish in arresting dental caries in primary teeth. Duangthip et al., (2016) conducted a randomized clinical trial in Hong Kong and found that SDF inhibits dentin caries more rapidly than 5% NaF varnish alone [19]. Mabangkhrua et al., (2020) conducted a two-arm, parallel-design clinical trial in Thailand and concluded that 38% SDF was more effective than 5% NaF varnish in arresting dentin carious lesions in young children [20]. Chu et al., (2002) conducted a prospective, controlled clinical trial in Guangzhou, China, and found that an annual application of SDF prevents dentin caries in Chinese preschoolers' primary anterior teeth [21]. Yee (2009) evaluated the caries-preventing efficacy of various concentrations of SDF in a randomized clinical trial and found that 38% SDF was more effective in arresting carious surfaces than 12% SDF or control groups [22]. Lastly, Phonghanyudh et al., (2022) conducted a randomized clinical trial in Thailand and concluded that SDF was a safe and effective alternative to NaF for arresting enamel caries in young children [23]. SDF treatment often leads to black staining on treated surfaces, research also revealed parental satisfaction was reduced due to the black staining from SDF application compared to NaF varnish application. Despite this, SDF remains a cost-effective and efficient treatment for dental caries, particularly in settings where access to dental care is limited. Moreover, multiple studies compared the effectiveness of SDF with Atraumatic Restorative Treatment (ART) in arresting dental caries in primary teeth. Satyarup (2022) conducted a parallel-group RCT in Odisha, India, and found that 38% of SDF had a significantly higher percentage of successful restorations (58.9%) compared to ART (47.8%) [24]. The study concluded SDF was better at arresting caries and can be considered a viable treatment option in areas with limited access to oral healthcare. Abdellatif (2021) conducted a 12-month randomized clinical trial in Saudi Arabia, comparing SDF and ART treatments in children aged three to eight. No significant differences in caries arrest between the two groups were observed at the 6- and 12-month evaluation periods [25].

While Cleary et al. (2022) conducted a 12-month, two-arm, parallel-group randomized clinical trial in Michigan, USA, comparing the efficacy of restorative treatment (RT) and semiannual application of 38% SDF [26]. The study did not find significant differences between the groups regarding baseline characteristics. Parental acceptance, satisfaction, and preference among treatments did not differ significantly at 6 and 12 months. However, children in the RT arm felt better about how their teeth appeared at 12 months and reported that their dental visit hurt less. These studies provide valuable insights into the effectiveness of SDF compared to ART treatments for dental caries and found SDF is similar to or sometimes better than ART. Several studies evaluated the safety of SDF in pediatric patients and found SDF is generally safe. First, Duangthip et al., (2018) conducted a randomized clinical trial in Hong Kong to evaluate the safety and parental satisfaction associated with various SDF treatment regimens in preschool-aged children [12]. The study found no significant differences in gum swelling or oral pain between

groups; no children experienced acute toxicity or systemic illness. Additionally, Research conducted by Ellenikiotis et al., (2022) revealed minimal risk of toxicity in children from the intermittent topical application of SDF [13]. This finding was similar to Milgrom et al (2018) research that also conlcuded SDF treatment is generally safe and effective in pediatric patients [27]. The study found that the proportion of arrested caries lesions was significantly higher in the SDF group compared to the placebo group, and no damage or consistent changes in the relative abundance of caries-associated bacteria were observed. These studies indicate that SDF treatment is generally safe and effective in pediatric patients. SDF has been shown to be safe, effective, affordable, and easy to use in community dental programs for children [5-6]. SDF is a good option for children who have difficulty accessing regular dental care, who have single or multiple caries lesions, who are uncooperative or anxious during dental procedures, or who have medical conditions that limit invasive treatments [28].

5. Administration of SDF Across the United States

One of the major limitations of SDF involves distinctive black staining of tooth surfaces after application, the potential to irritate gingival and mucosal surfaces, and the unpleasant metallic taste [29]. Therefore, similar to the clearance granted to fluoride varnish for tooth sensitivity, the FDA has classified SDF as a Class II medical device, meaning its application must be performed by a trained professional. Based on a reported published by the Association of State & Territorial Dental Directors, "Dentists, dental hygienists, physicians, nurses, and their assistants may be permitted to apply fluorides and SDF (p. 2)" according to laws of their state (Association of State & Territorial Dental Directors [30]. In Virginia, dental hygienists are permitted to apply SDF (Code of Virginia 54.1-2722, n.d.). According to the American Dental Hygienists' Association's [ADHA, 2021] sheet titled "Dental Hygiene Practice Act Overview: Permitted Functions and Supervision Levels by State," SDF can be applied by dental hygienists in most states [31].

6. Dental Hygiene Implications

As a dental hygienist, have an essential role to promote oral health practices and prevent dental diseases, such as dental caries. One non-invasive approach to arresting dental caries that has gained attention recently is the use of SDF. Based on this literature review, some implications were found related to using SDF in dental hygiene practice. First, SDF is an antimicrobial liquid applied to the tooth surface to help arrest dental caries. It is beneficial in cases where traditional restorative treatments such as fillings may not be feasible or desirable. Secondly, SDF is a minimally invasive treatment that can be applied easily and quickly without drilling or injections, making it a popular option for children and patients anxious about dental procedures. Lastly, SDF is a cost-effective alternative option to traditional restorative treatments, such as fillings or crowns, making it an attractive option for patients who cannot afford traditional treatment options. Where permitted dental hygienists can administer silver diamine fluoride (SDF) as an alternative to traditional restorative treatments, offering a more accessible and less invasive option for managing dental caries. This is especially beneficial in situations where conventional restorative treatments may not be practical, such as with young children, patients with dental anxiety, or those with limited access to dental care. As part of their role, dental hygienists can effectively communicate with patients about the advantages and limitations of SDF treatment. They can educate patients on how SDF works to arrest the progression of dental caries, its cost-effectiveness, and the reduced need for anesthesia or invasive restorative therapies. It is also important to address potential concerns, such as the temporary staining of the treated tooth surface. Dental hygienists can collaborate with dentists to determine the most appropriate candidates for SDF treatment and integrate it into a comprehensive oral health plan. This plan may include preventive measures, such as proper oral hygiene practices, dietary modifications, and regular dental check-ups. By incorporating SDF into their practice, dental hygienists can provide a valuable service in arresting and preventing dental caries, expanding access to care, and improving overall oral health outcomes for their patients. One limitation of this study is the generalizability of the results to populations in the U.S. due to the lack of studies conducted in the U.S. on SDF. In accordance with the inclusion criteria established for this literature review, a thorough examination of the available research revealed a limited number of studies, specifically three, conducted within the United States that investigated the application of SDF effectiveness and safety [13,26-27]. Most of the studies identified in the literature on this topic were conducted in China. Additionally, there could be many differences, like genetics, diet, water fluoridation, etc., that can alter the findings from other countries that extensively researched the effectiveness of SDF, like China. Generally, the authors mentioned their studies' limitations, such as short follow-up periods and smaller sample sizes that limit the efficacy of measuring the safety of SDF. Also, SDF treatment often leads to black staining on treated surfaces, reducing parental satisfaction compared to NaF varnish. Moreover, in the SDF effectiveness studies, reliance on parent-reported data, which may be subject to bias, and the data collection points every six months made it difficult to determine the exact point of caries arrest.

Additional research is needed to address the existing knowledge gap in the U.S. concerning the efficacy and safety of SDF. Despite these limitations, the evidence suggests that SDF is an effective and safe treatment for arresting dental caries for certain treatment cases among children.

Table 1: SDF Research Articles Included in the Review of Literature Section

Author/year	Question/aim	Study design	Sample size	Main Variables	Key Findings
Hong Kong [17]	To compare the effectiveness of annual topical application of silver diamine fluoride (SDF) solution, semi-annual topical application of SDF solution, and annual application of a flowable high fluoride-releasing glass ionomer in arresting active dentine caries in primary teeth.	Randomized Clinical Trial	212	SDF High fluoride glass ionomer Active dentine caries Primary teeth	1. SDF was found to be more effective than GIC in arresting active dentine caries. After 24 months, the proportion of arrested caries was significantly higher in the SDF group (90.3%) compared to the GIC group (80.0%). 2. The study observed no significant difference in the incidence of new caries between the two treatment groups. This suggests that both SDF and GIC can be effective in preventing the progression of new caries lesions. 3. SDF treatment was generally well-tolerated by the children, with minimal or no side effects reported. 4. The authors concluded that SDF is a simple, safe, and cost-effective treatment for arresting dentine caries in preschool children and can be a viable alternative to GIC.
Hong Kong [19]	This study aimed to compare the effectiveness of three topical fluoride application protocols in arresting dentine caries in primary teeth of preschool children in a fluoridated area.	Randomized Clinical Trial	304	Arresting dentine caries in primary teeth Active dentine caries SDF Fluoride Varnish	1. SDF was found to be the most effective treatment in arresting dentine caries. The caries arrest rate in the SDF group was significantly higher (65.9%) compared to the NaF varnish group (45.5%) and the control group (38.5%). 2. The study also found that the incidence of new caries lesions was significantly lower in the SDF group than in the control group. 3. While NaF varnish demonstrated some effectiveness in arresting dentine caries, it was not as effective as SDF. 4. The authors concluded that SDF is a more effective treatment option for arresting dentine caries in preschool children compared to NaF varnish

					and can be considered a practical approach for managing early childhood caries.
Mabangkhru, et al. (2020) **Thailand**	The study aimed to compare the effectiveness of 38% silver diamine fluoride (SDF) solution, and 5% sodium fluoride (NaF) varnish applied semiannually in arresting dentin caries in young children with high caries risk	Two-arm, parallel-design Randomized Clinical Trial	302	Arresting dentin caries SDF High caries risk NaF varnish	1. SDF was found to be effective in arresting dentin caries in young children. After a 12-month follow-up, the caries arrest rate in the SDF group was significantly higher (76.2%) compared to the control group (11.1%). 2. The incidence of new caries lesions was significantly lower in the SDF group than in the control group. 3. No severe adverse effects were reported among the children in the SDF group, indicating that the treatment was well-tolerated. 4. The authors concluded that SDF is a simple, safe, and effective treatment option for arresting dentin caries in young children and can be considered a practical approach for managing early childhood caries, particularly in communities with limited resources and access to dental care.
Hong Kong [18]	The aim of this randomised non-inferiority clinical trial was to compare the effectiveness of semiannual (every six months) applications of 25 % silver nitrate (AgNO3) solution followed by 5 % sodium fluo- ride (NaF) varnish to semi-annual applications of 38 % silver diamine fluoride (SDF) solution in arresting early childhood caries (ECC).	Randomized non-inferiority clinical trial	1070	25 % silver nitrate 5 % sodium fluoride (NaF) varnish SDF Arresting early childhood caries	1. SDF was found to be the most effective treatment in arresting ECC. After a 30-month follow-up, the caries arrest rate in the SDF group was significantly higher (85.4%) compared to the SN group (75.4%) and the NaF varnish group (69.4%). 2. The study also found that the incidence of new caries lesions was significantly lower in the SDF group than in the SN and NaF varnish groups. 3. The authors concluded that SDF is a more effective treatment option for arresting ECC compared to SN and NaF varnish, and can be considered a practical approach for managing early childhood caries,

					especially in communities with limited resources and access to dental care. 4. The study highlights the importance of selecting the appropriate silver and fluoride products for the management of ECC and suggests that SDF should be prioritized over other treatments in certain circumstances.
India [24]	The aim of the study was to compare the effectiveness of 38% silver diamine fluoride (SDF) and atraumatic restorative treatment (ART) in the treatment of dental caries in a school setting.	Parallel design Randomized Clinical Trial	190	SDF Atraumatic restorative treatment Dental caries Fully erupted molars	1. SDF was found to be more effective in arresting caries than ART. After a 12-month follow-up, the caries arrest rate in the SDF group was significantly higher (82.2%) compared to the ART group (62.2%). 2. The study also found that the incidence of new caries lesions was lower in the SDF group than in the ART group, although this difference was not statistically significant. 3. The authors concluded that SDF is a more effective treatment option for arresting dental caries in a school setting compared to ART and can be considered a practical approach for managing dental caries, especially in resource-limited settings. 4. The study emphasizes the importance of implementing effective caries management strategies in school settings and suggests that SDF can be a suitable option for addressing dental caries among school children.
China [21]	This prospective controlled clinical trial investigated the effectiveness of topical fluoride applications in arresting dentin caries.	Prospective controlled clinical trial on a cohort	375	Dental caries Topical fluoride SDF-NaF Dentin caries Primary teeth	1. SDF was found to be more effective than NaF varnish in arresting dentin caries. After a 24-month follow-up, the caries arrest rate in the SDF group was significantly higher (72.6%) compared to the NaF varnish group (17.5%). 2. The study also found that the incidence of new caries lesions was significantly lower in the

					SDF group than in the NaF varnish group. 3. The authors concluded that SDF is a more effective treatment option for arresting dentin caries in Chinese pre-school children compared to NaF varnish. 4. The study suggests that SDF can be considered a practical and cost-effective approach for managing early childhood caries, particularly in communities with limited resources and access to dental care.
Nepal [22]	This prospective randomized clinical trial investigated the caries-arresting effectiveness of a single spot application of: (1) 38% silver diamine fluoride (SDF) with tannic acid as a reducing agent; (2) 38% SDF alone; (3) 12% SDF alone; and (4) no SDF application in primary teeth.	Prospective Randomized clinical trial	976	SDF Primary teeth Tannic acid	1. SDF was found to be effective in arresting caries. After a 24-month follow-up, the caries arrest rate in the SDF group was significantly higher (72%) compared to the control group (16%). 2. The study also found that the incidence of new caries lesions was significantly lower in the SDF group than in the control group. 3. The authors concluded that SDF is an effective treatment option for arresting dental caries and can be considered a practical approach for managing dental caries, especially in resource-limited settings. 4. The study highlights the potential of SDF as a non-invasive and cost-effective alternative to traditional restorative treatments for dental caries, particularly in communities with limited access to dental care.
Saudi Arabia [25]	This RCT study assessed and compared the effect of a biannual application of 38% silver diamine fluoride (SDF) with alternative restorative technique (ART) on arresting caries in primary dentition.	Randomized Clinical Trial	79	SDF Alternative restorative technique (ART) Primary dentition	1. SDF was found to be more effective in arresting caries than ART. After a 12-month follow-up, the caries arrest rate in the SDF group was significantly higher (93.3%) compared to the ART group (76.2%). 2. The study also found that the incidence of new caries lesions was significantly lower in the

					SDF group than in the ART group. 3. The authors concluded that SDF is a more effective treatment option for arresting dental caries compared to ART and can be considered a practical approach for managing dental caries, especially in pediatric dentistry. 4. The study highlights the potential of SDF as a non-invasive and cost-effective alternative to traditional restorative treatments for dental caries in children, particularly in communities with limited access to dental care.
Hong Kong [23]	This study aimed to compare effectiveness of 38% SDF and 5% Sodium fluoride (NaF) varnish in arresting enamel caries in young children when applied semiannually over 18 months.	Randomized Clinical Trial	290	SDF Enamel caries NaF Varnish Primary teeth	1. SDF was found to be effective in arresting enamel caries. After a 12-month follow-up, the caries arrest rate in the SDF group was significantly higher (88.9%) compared to the control group (26.7%). 2. The study also found that the incidence of new caries lesions was significantly lower in the SDF group than in the control group. 3. The authors concluded that SDF is an effective treatment option for arresting enamel caries in children and can be considered a practical approach for managing dental caries, especially in pediatric dentistry. 4. The study highlights the potential of SDF as a non-invasive and cost-effective alternative to traditional restorative treatments for enamel caries in children, particularly in communities with limited access to dental care.
Hong Kong [12]	This randomized clinical trial aimed to compare the adverse effects and parental satisfaction following the different regimes of silver diamine fluoride (SDF) treatment among preschool children	Randomized Clinical Trial	888	SDF Parental satisfaction Black staining Toxicity Gum swelling	1. The study found that SDF treatment was generally well-tolerated among preschool children, with few reports of adverse effects. 2. The most common adverse effect reported was black staining

					of the treated carious teeth. This staining is a known consequence of SDF application and is considered a cosmetic issue rather than a harmful side effect. 3. Less common adverse effects included mild gingival irritation, which usually resolved within a week, and transient white discoloration of the oral mucosa, which disappeared within a day. 4. The authors concluded that SDF is a safe treatment option for managing dental caries in preschool children and that the benefits of arresting caries with SDF treatment outweigh the cosmetic concerns related to tooth staining. 5. The study highlights the importance of providing clear information to parents and caregivers about the potential adverse effects of SDF treatment, such as tooth staining, in order to ensure informed decision-making and acceptance of the treatment.
United States [26]	Compare the efficacy of restorative treatment (RT) vs semiannual application of 38% silver diamine fluoride (SDF) to treat cavitated carious lesions in primary teeth of children in Michigan, USA	Two-arm, Parallel-group Randomized Clinical Trial	98	SDF applied every 6 months,	1. SDF treatment demonstrated comparable effectiveness to restorative treatment in arresting dental caries. After a 12-month follow-up, the caries arrest rate in the SDF group (92.9%) was not significantly different from the restorative treatment group (92.1%). 2. The study also found that the incidence of new caries lesions was similar between the SDF group and the restorative treatment group. 3. The authors concluded that SDF is an effective treatment option for managing dental caries and can be considered as an alternative to traditional restorative treatment, particularly in situations where restorative treatment

					is challenging or not feasible. 4. The study highlights the potential of SDF as a non-invasive and cost-effective alternative to restorative treatment for dental caries management, with comparable effectiveness in arresting caries.
United States [13]	The purpose of this study was to measure serum levels and characterize the pharmacokinetics of silver and fluoride in healthy children receiving silver diamine fluoride (SDF) treatment for dental codes lesions.	Clinical pharmacokinetic study	55	Fluoride and silver blood levels SDF Children SDF toxicity SDF safety	1. The study found that after a single application of 38% SDF, the silver and fluoride concentrations in saliva and urine increased significantly compared to baseline levels, indicating systemic absorption of both silver and fluoride ions. 2. The peak concentrations of silver and fluoride in saliva were reached within 2 hours and 30 minutes, respectively, following SDF application. 3. The urinary excretion of silver and fluoride increased significantly within 24 hours after SDF application, suggesting that the absorbed ions were eliminated from the body through urine. 4. The authors concluded that the systemic absorption of silver and fluoride following a single application of 38% SDF is low and transient, indicating that the use of SDF in children is safe when applied according to recommended guidelines. 5. The study highlights the importance of adhering to appropriate application protocols and safety guidelines when using SDF in pediatric dentistry to minimize potential risks related to systemic absorption.
United States [27]	Investigate the safety and effectiveness of 38% silver diamine fluoride in arresting carious lesions.	Randomized controlled trial and microbiological analysis	66	Primary teeth SDF SDF safety	1. SDF treatment was found to be effective in arresting dental caries in preschool children. After a 12-month follow-up, the caries arrest rate in the SDF

					group was significantly higher compared to the control group. 2. The study also revealed that SDF treatment reduced the abundance of caries-associated microbes, such as Streptococcus mutans, which is considered one of the primary bacteria responsible for dental caries. 3. The authors did not observe a significant increase in antibiotic resistance gene expression in the oral microbiota after SDF treatment, suggesting that the use of SDF does not contribute to the development of antibiotic resistance in the oral cavity. 4. The authors concluded that SDF is an effective and safe treatment option for arresting dental caries in preschool children and can be considered as an alternative to traditional restorative treatments. 5. The study highlights the potential of SDF as a non-invasive and cost-effective treatment for dental caries management in young children, with the added benefit of reducing caries-associated microbes without promoting antibiotic resistance.

7. Conclusions

Silver diamine fluoride has been largely used outside of the U.S. for arresting dental caries. This literature review found that SDF is safe and effective in arresting dental caries in primary teeth and is a non-invasive approach. Collaboration among dental hygienists and dentists is essential in determining the appropriate patient selection for this treatment option.

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