

Effectiveness of Silver Diamine Fluoride in Preventing and Arresting Dental Caries in Young Children: A Scoping Review

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Abstract

Aim: To assess the effectiveness of silver diamine fluoride (SDF) in preventing and arresting dental caries in paediatric dentistry.

Background: Dental caries presents a worldwide health issue that results in significant pain and infection among numerous children. Nevertheless, it is more common among children from lower socio-economic backgrounds, and cavitated carious lesions in children are predominantly left untreated. Numerous clinical studies have demonstrated that the advancement of dental caries in young children is easily arrested through the application of SDF solution.

Methodology: This scoping review examined 20 randomized clinical trials from various countries, published between 1990 and 2024, concentrating on the efficacy of SDF in preventing or halting dental caries in young children. This review employed clearly defined inclusion and exclusion criteria to guarantee the relevance and quality of the chosen studies.

Results: Findings indicate that, the application of SDF is a successful and effective approach for arresting the caries process in dentin and enamel in primary teeth as well as the permanent first molars in children. Also, it provides a feasible, economical, and minimally invasive treatment alternative, which is especially appropriate for families and communities with limited resources. However, aesthetic concerns, such as black staining of lesions, remain a drawback.

Conclusion: SDF demonstrated superior effectiveness in preventing and arresting dental caries in children especially when applied two times a year. The reviewed clinical trials yielded a comprehensive understanding of SDF, that can influence public health policy and suggesting shift towards minimally invasive treatment in young children.

Keywords: Silver Diamine Fluoride (SDF), children, dental caries, arrested caries, prevent, paediatric dentistry

Introduction

Dental caries occurs through a natural process wherein bacteria in the polymicrobial biofilm induce pH changes, resulting in enamel degradation and the formation of a visible lesion in absence of proper care.¹ Dental plaque forms on the pellicle immediately following the mechanical exfoliation of the biofilm.² The dental plaque upon clinically intact enamel surfaces in children comprises primarily *streptococci* and *lactobacilli*. Upon the consumption of sugary foods and beverages, the commensal plaque microbiota will assimilate these sugars and convert them into acids, predominantly lactic acid. The production of acid results in a pH transition from neutral to acidic.³ Therefore, it has enduring implications for dental, medical, sociological, economic, as well as oral health-related quality of life (QoL).⁴ As a result, caries is the most widespread childhood disease globally, particularly affecting low-income families.⁵

Early childhood caries (ECC) poses a significant public health issue affecting young children. ECC is the most common chronic disease among children globally,⁶ with an incidence reaching 46% and exhibiting a higher incidence in low-income nations.⁵ The incidence of dental caries was reported 40% approximately in the USA amongst children aged 2 to 11 years old.⁷ Also, children with an existing caries lesion have a 5–6 times higher incidence of developing new caries lesions compared to caries-free children. The global prevalence of ECC in children with primary teeth was approximately 1.76 billion in 2012,⁸ which can be expected to be much higher by

now. Children with ECC exhibit a significant risk of dental caries, and it can advance swiftly over a span of 3 to 6 months following tooth eruption.⁹ Children with ECC, especially those who are uncooperative, cognitively delayed, or medically compromised, often require treatment under general anaesthesia, which adds complexity and cost.¹⁰ This treatment can lead to economic, health-related, and relapse complications.¹¹ Consequently, procedures that are safe, effective, acceptable, cost-effective, minimally invasive, and easy to execute are essential for the successful management of cavitated dental lesion in young children.

Mineralization agents, as well as good oral health, have been shown in some studies to slow the progression of early carious lesions. Timely detection and treatment of the primary lesion can mitigate the burden of this condition. Furthermore, the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) advocate using dental sealants and topical fluorides, such as silver diamine fluoride (SDF), as vital interventions in a school-based caries prevention program to mitigate the incidence of caries in children.¹² Fluoride is the most widely utilized mineralizing agent for both the prevention and treatment of dental caries.^{13–15} SDF constitutes a topical fluoride solution with an increased concentration of fluoride and silver, which has recently garnered significant interest from clinicians as well as researchers. The efficacy of caries arrest appears promising owing to synergistic effects of silver, as an antimicrobial agent, as well as fluoride, facilitating remineralization, while ammonia aids in stabilizing the solution's concentrations.¹⁶

Several systematic reviews have pointed out the findings of various randomized clinical trials that have evaluated the effectiveness of SDF in preventing and arresting dental caries particularly in children with varying success rates.¹⁷⁻¹⁹ Likewise, it has been extensively utilized for caries management in communal settings across numerous countries, requiring neither dental instruments nor caries excision.¹⁶ While 38% SDF is highly endorsed for the treatment of dentine caries lesions, its significant disadvantages include permanent black staining of the lesions as well as a metallic taste.²⁰ The effectiveness of SDF in arresting the progression of pre-existing carious lesions is supported by numerous studies. However, based on systematic reviews, there is insufficient evidence to support its efficacy in preventing caries in deciduous molars.²¹ Consequently, research regarding the impact of SDF on the children's oral health related quality of life (QoL) yields inconsistent outcomes, with certain studies indicating improvement while others reported no effect comparing with other sealants.²²

In addition to QoL considerations, parental perception plays a pivotal role in the acceptability and success of SDF programs. A recent cross-sectional study from Iraq highlighted that despite concerns over tooth discoloration, many parents expressed overall support for SDF due to its easy to use and non-invasive nature.²³

Irmaleny et al.²⁴ recently conducted a scoping review of 8 articles to determine the effectiveness of SDF in preventing caries in permanent teeth in Indonesia, while Zhang et al.²⁵ conducted a scoping review on SDF effectiveness in caries management in children in New Zealand. However, other trials demonstrated varying results on SDF effectiveness or arresting the progression of carious lesions in their study population.²⁶ Therefore, there remains a need for a comprehensive review determining SDF effectiveness in primary teeth across different settings. This scoping review aims to provide deep insights into the effectiveness of SDF in preventing or arresting dental caries among young children by comparing clinical trials across different countries.

Methods

Protocol

This scoping review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) instructions.²⁷

Research Questions

1. What is the effect of SDF in preventing or arresting dental caries among young children?
2. How does the application of SDF affect the treatment of dental caries lesions in paediatric dental care?

Search Strategy

The search strategy was designed in order to identify appropriate research articles from a variety of scholarly databases, such as PubMed, Scopus, Web of Science, and Google Scholar, using a systematic approach. Keywords such as "silver diamine fluoride," "dental caries," "prevent," "arrest," "paediatric," and "children" were implemented during the search. The search was refined using Boolean operators: "AND" was employed to

combine terms, and "OR" was used to broaden the search as demonstrated in [Table 1](#).

Eligibility Criteria and Study Selection

This review applied well-defined inclusion and exclusion criteria to ensure the relevance and quality of selected studies.

Inclusion criteria

- Comparative studies that provide data on the effectiveness of SDF.
- SDF studies using randomized controlled clinical trials.
- Articles published in English between 1990 and 2024.

Exclusion criteria

- Studies not using clinical trials in dental caries in children.
- Publications in languages other than English or studies without full-text availability.
- Case reports, editorials, and conference abstracts without significant data.

The titles and abstracts obtained from the initial search were evaluated for relevance. Full-text articles were obtained for additional assessment. Eligibility was assessed by two independent reviewers according to the established inclusion and exclusion criteria, to maintain consistency.

Data Processing and Quality Assessment

Two independent reviewers (A.A. & H.G.) carried out the database search and retrieved pertinent data out of the selected studies. The quality assessment was conducted according to the inclusion criteria for ensuring data reliability. The calculated Cohen's Kappa coefficient ($K = 0.80$) demonstrates an excellent level of agreement between the two reviewers. Disagreements among reviewers were addressed through consultation with a senior reviewer (M.H.K.).

Table 1 **Details on databases, sources and search strategies and outcomes**

| Database | Search strategies | Results |
|----------------|---|---------|
| PubMed | ((silver diamine fluoride) AND (dental caries)) AND (prevent OR Arrest) AND (paediatric OR pediatric OR children) | 333 |
| Scopus | TITLE-ABS-KEY ("silver diamine fluoride") AND TITLE-ABS-KEY ("dental caries") AND TITLE-ABS-KEY (prevent* OR arrest*) AND TITLE-ABS-KEY (pediatric OR paediatric OR children) | 238 |
| Web of Science | "silver diamine fluoride" (All Fields) and "dental caries" (All Fields) and prevent* OR arrest* and paediatric OR pediatric OR children | 191 |
| Google Scholar | "Silver diamine fluoride" AND ("dental caries" OR "caries") AND (prevent OR arrest) AND (paediatric OR pediatric OR children) | 752 |
| Total | | 1514 |

PICOS Requirements

- 1. Population:** Randomized clinical trials focused on children of various age groups from different countries with active dental caries undergoing SDF treatment.
- 2. Intervention:** Interventions related to treatment with SDF involving cleaning and application by rubbing of 38% SDF solution on to the carious tissues in children by trained dental nurses or dental professionals.
- 3. Comparison:** Studies comparing the effect of SDF treatment in treating dental caries with respect to other preventive measures in children.
- 4. Outcome:** The primary outcomes of interest included caries arrest rates, parents' satisfaction.
- 5. Study Design:** Randomized controlled clinical trials were considered, provided they were published in English.

Results

Study Selection

A total of 1,514 studies were identified from online databases: PubMed ($n = 333$), Scopus ($n = 238$), Web of Science ($n = 191$), and Google Scholar ($n = 752$). No further articles were found through hand searching. Following the removal of 905 duplicate studies, 609 records were retained for title and abstract screening. After a thorough assessment, 550 studies were excluded for failing to meet the inclusion criteria, resulting in 59 records available for full-text review. Thirty-nine studies

were excluded due to misalignment with the reviews' scope or insufficient relevant data regarding the effect of SDF in caries treatment. Subsequently, a total of 20 articles have been reviewed in this study. The PRISMA flow diagram (Figure 1) illustrates the study selection process.

Overview of Included Studies

A total of 20 randomized clinical trial studies were included (Table 2). These studies were conducted across various countries (Hong Kong = 4; USA = 4; Brazil = 3; Egypt = 3; Thailand = 2; China = 1; India = 1; Turkey = 1; Philippines = 1) among different age groups of children. The publication dates ranged from 1990 to 2024. Several studies evaluated the effectiveness of SDF alone, while some reported the effect of SDF in comparison with other mineralized sealants like glass ionomer cements, sodium fluoride varnish, and nano silver fluoride. Three randomized controlled trials utilized 30% SDF, whereas the other 17 studies employed 38% SDF. One article employed two distinct percentages of SDF: 12% and 38%. Five articles evaluated the efficacy of SDF in comparison to NaF varnish, while the remaining articles evaluated SDF with different topical fluoride products and materials.

Discussion

For prevention of dental caries, it has been highly recommended to prioritize the fluoridation of public water, the use of fluoride-containing toothpaste, the maintenance

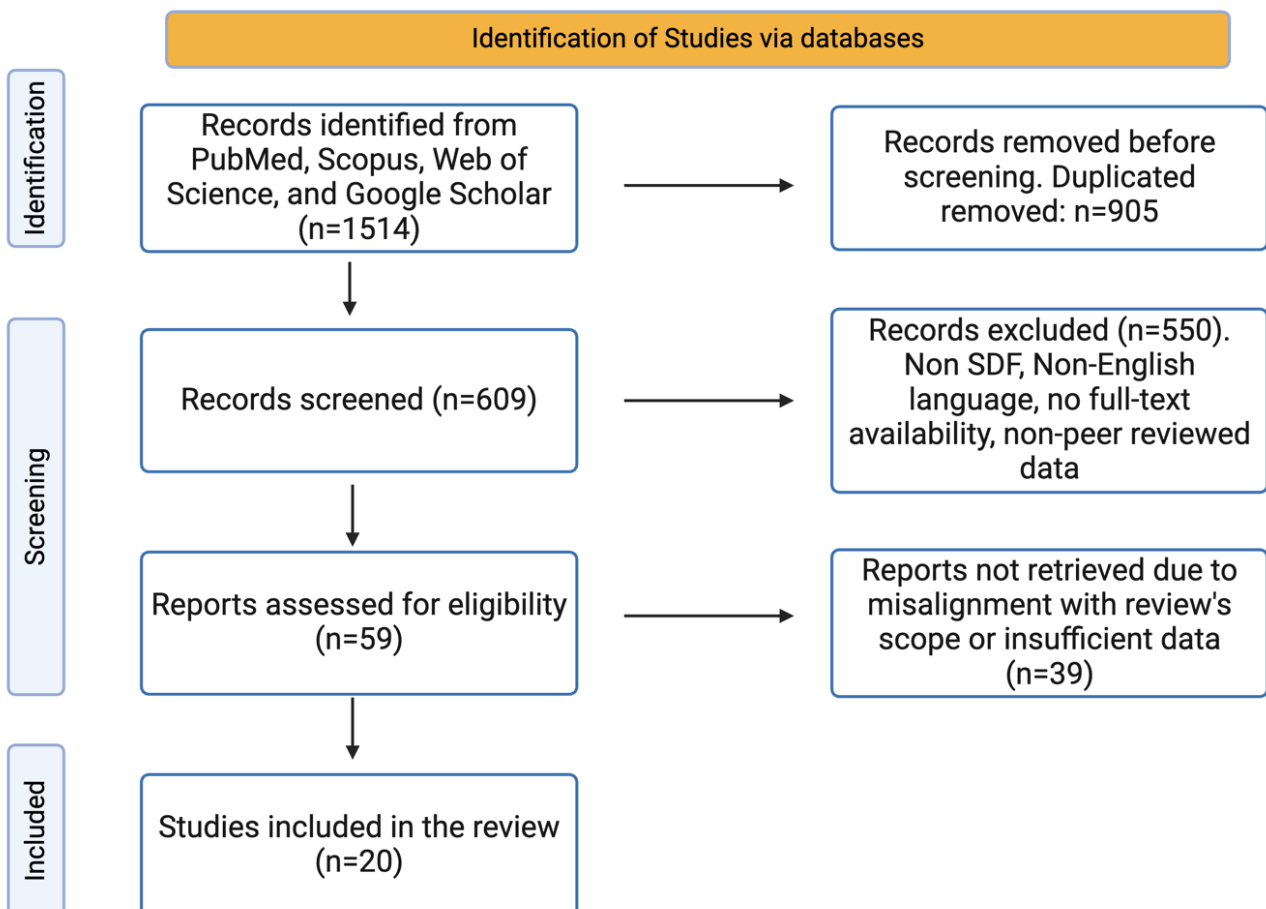


Fig. 1 PRISMA flow diagram demonstrating the selection process of articles retrieved and selected.

Table 2. Characteristics of included clinical trials evaluating the effect of SDF in children

| Study | Country | Study design | Age group | Intervention | Key findings |
|--------------------------------|-----------|---|------------|--|--|
| Ruff et al. (28) | USA | School-Based Randomized Clinical Trial | 5–13 years | Single application of 38% SDF with fluoride varnish (FV). Two years follow up. | Treatment of SDF and fluoride varnish demonstrated noninferiority over a two-year period in the arrest and prevention of dental caries when compared with a glass ionomer sealants. |
| Phonghanyudh et al. (29) | Thailand | Two-arm randomized controlled trial | 1–3 years | Two groups of 38% SDF and 5% NaF. Repeated every six months for 1.5 years. | The semiannual application of 38% SDF and 5% NaF varnish demonstrated comparable efficacy in preventing enamel dental caries in primary teeth. |
| Mabangkhu et al. (30) | Thailand | Two-arm randomized controlled trial | 1–3 years | Two groups consisting of 38% SDF and 5% NaF. Conducted semi-annually. | 38% SDF demonstrates significantly greater efficacy than 5% NaF varnish in halting dentin carious lesions within young children. SDF doesn't impact parental perception of the child's teeth. |
| Zheng et al. (31) | Hong Kong | Parallel-assigned randomized clinical trial | 3–4 years | 38% SDF and 5% sodium FV with one year follow up. | SDF does not demonstrate superiority over FV for preventing caries in primary upper anterior teeth during the 1-year follow-up. Child cooperation as well as parent satisfaction were comparably elevated with SDF and FV. |
| Quritum et al. (32) | Egypt | Two-parallel arms, randomized controlled clinical trial | < 4 years | Two groups with 38% SDF and Nano silver fluoride (NSF). | After six months, both agents significantly enhanced children's oral health-related quality of life (OHQoL), with NSF demonstrating a notably greater effect than SDF. |
| Fontana et al. (33) | USA | Two-parallel arms, randomized controlled clinical trial | 1–6 years | 1:1 allocation of SDF or placebo with treatment during baseline and six months. | Lesions in the SDF group exhibited a 54% arrest rate. SDF demonstrated efficacy in preventing active cavitated lesions within the target population. |
| Quritum et al. (34) | Egypt | Two-parallel arms, randomized controlled clinical trial | < 4 years | 38% SDF was applied onto the lesion at baseline and again after six months, or NSF was applied on the lesion once at baseline. | NSF exhibited superior effectiveness in caries arrest among preschool children, avoiding the occurrence of black staining on teeth and resulting in higher parental satisfaction compared to SDF. |
| Schroth et al. (35) | USA | Parallel-group randomized clinical trial | < 6 years | 38% SDF and 5% sodium FV. Followed for a two, eight, or twelve months intervals. | Two administrations of 38% SDF and 5% NaFV at a month's and four-month intervals have been shown to be comparable and highly effective in preventing ECC. |
| Fung et al. (36) | Hong Kong | Randomized clinical trial | 3–4 years | 12% and 38% SDF applied annually and semi-annually. | SDF at a concentration of 38% demonstrates greater efficacy than 12% in preventing active dental caries in primary teeth. |
| Buldur and Taskaya et al. (37) | Turkey | Single-arm, prospective, non-randomized clinical study | 3–5 years | 38% SDF at baseline and six-month follow up. | The use of 38% SDF successfully halted caries lesions in young children, accompanied by a significant increase in parental acceptance before and after treatment. |
| Mani Prakash et al. (38) | India | Split-mouth randomized controlled trial | 6–9 years | Two groups with 38% SDF + potassium iodide and 5% NaF. Follow up after six and twelve months. | SDF demonstrated greater effectiveness in preventing dental caries in the primary teeth than 5% NaF varnish. |
| Duangthip et al. (39) | Hong Kong | | 3–4 years | 30% SDF and 5% NaF applied. Follow up every 6 months. | Annual SDF solution applications arrest dentine caries lesions in primary teeth more effectively than three weekly NaF varnish or SDF solution applications at baseline. |
| Ali et al. (40) | USA | Two-parallel arms, randomized controlled clinical trial | 3–8 years | Comparing 38% SDF test group vs atraumatic restorative treatment (ART) control group during baseline and six-month follow up. | Parental acceptability for the primary teeth caries treatment by SDF was greater than that of ART treatment. |

(Continued)

Table 2. Characteristics of included clinical trials evaluating the effect of SDF in children—Continued

| Study | Country | Study design | Age group | Intervention | Key findings |
|-----------------------------|-------------|--|------------|---|--|
| Zhi et al. (41) | China | Randomized clinical trial | 3–4 years | 38% SDF and glass ionomer applied at baseline and different durations. | SDF caries arrest can be increased by applying every six months. |
| El Ghandour et al. (42) | Egypt | Randomized clinical trial | 2–5 years | Comparing 38% SDF test group vs ART control group during baseline and six-month follow up | SDF arrested ECC better than ART after 12 months. Oral health-related QoL was slightly better. |
| Vollu et al. (43) | Brazil | Two-parallel arms, randomized controlled clinical trial | 2–5 years | Comparing 38% SDF test group vs ART control group during baseline, three month, six-month, and 12-month follow up | The treatment duration for SDF was shorter than ART, while the outcomes regarding dental caries arrest, adverse effects, and parent acceptability were comparable to those of ART. |
| Mei et al. (44) | Hong Kong | Randomized clinical trial | 4–6 years | 38% SDF applied semi-annually. | A zone with high remineralization, abundant in calcium and phosphate, was identified on the arrested cavitated dentinal lesion in children following the application of SDF. |
| Mattos-Silveira et al. (45) | Brazil | Three-arm parallel, randomized placebo-controlled clinical trial | 3–10 years | 30% SDF applied and evaluated in comparison to dental flossing every three months up to 24 months. | SDF represents the most cost-effective intervention in arresting dental caries. |
| Monse et al. (46) | Philippines | Prospective randomized clinical trial | 6–8 years | Two groups with 38% SDF solution and ART glass-ionomer sealant. | A single application of 38% SDF in primary teeth does not prevent dentinal (D3) caries lesions. Meanwhile, ART sealants significantly prevented onset of caries over 18 months. |
| Dos Santos et al. (47) | Brazil | Randomized clinical trial | 5–6 years | Two groups with interim restorative treatment and 30% SDF. Follow up after 1 year. | The SDF technique demonstrated superior efficacy compared to ART in the treatment of caries in primary teeth. |

of proper oral hygiene, and healthy dietary practices through community education.⁴² Likewise, there are many reports suggesting the use of SDF for prevention and treatment of dental caries. This scoping review assessed the efficacy of SDF in preventing or arresting dental caries in young children. Upon evaluating 59 articles against the inclusion criteria, 20 randomized clinical trials from various countries were incorporated into the current review.

The reviewed clinical trial reports demonstrated a diverse degree of efficacy of SDF in arresting the advancement of dental caries in children. A preliminary randomized controlled trial⁴⁰ evaluated the efficacy of 38% SDF solution in arresting caries compared to atraumatic restorative treatment sealants. The preliminary results regarding the efficacy of SDF in a clinical setting indicated that a single application of 38% SDF in children is not an effective strategy for preventing dentinal (D3) caries lesions. The ART sealants, in contrast to the control group, significantly inhibited the onset of caries. Conversely, a separate trial conducted by Dos Santos et al. evidenced the efficacy of SDF in halting caries progression.⁴³ After one year of treatment, SDF demonstrated superior efficacy in arresting caries compared to interim restorative treatment. Likewise, Zhi et al. (2012) demonstrated that semi-annual application of SDF solution resulted in superior caries arrest rates compared to annual application of SDF.⁴¹ Furthermore, Mattos-Silveira et al. (2014) assessed the efficacy, parental satisfaction, and cost-effectiveness of SDF in comparison to resin infiltration and flossing. However, the result of this

trial remains unpublished.³⁹ Moreover, Mei et al. (2014) affirmed the beneficial effects of SDF application on dentine remineralization.⁴⁴

Duangthip et al. (2016) demonstrated the impact of SDF at various intervention intervals. The annual treatment with the SDF solution resulted in higher caries arrest rates (40%) compared to the weekly consecutive application at baseline (35%).³⁹ A subsequent study by the same researchers compared the efficacy of 30% SDF and 5% NaF varnish in caries management, revealing that 30% SDF was superior to 5% NaF varnish.⁴⁴ Additionally, Fung et al. (2016) assessed the efficacy of two distinct concentrations of SDF (12% and 38%) in primary dentition. The first and second groups received annual and semi-annual applications of 12% SDF, whereas groups 3 and 4 received annual and semi-annual applications of 38% SDF. The study findings indicated that the caries arrest rates were markedly elevated in groups with a 38% SDF concentration. Consequently, 38% SDF was more efficacious in arresting caries than 12% concentration when administered semi-annually.³⁶

A clinical trial in 2019 evaluated the efficacy of SDF, focusing on treatment duration, adverse effects, oral health-related quality of life, and parental perceptions in preschool children aged 2 to 5 years. The SDF test group and ART control groups were evaluated at three, six, and twelve-month follow-ups. Aside from the SDF requiring reduced treatment duration, the remaining findings were similar to those of ART.³⁷ Additionally, another RCT assessed pain perception in conjunction with parents' perceptions regarding SDF and

ART treatments for caries control in primary teeth. Children administered SDF experienced significantly reduced discomfort and pain, alongside enhanced parental satisfaction comparing to the ART group.³⁴

Other trials have explored the growing interest in comparing SDF with NaF, likely due to the former's advantage of not causing black staining of the lesions. Mabangkhu et al. (2020) initially compared the efficacy of 38% SDF and 5% NaF varnish. Semi-annual administration of 38% SDF and 5% sodium fluoride varnish exhibited superior caries arrest rates in preschool children after 12-months. Furthermore, SDF did not adversely affect parental satisfaction regarding their child's dental aesthetics.³⁰ Similarly, another study indicated that the semi-annual application of 38% SDF and 5% NaF exhibited comparable efficacy in arresting enamel caries in children after 18 months.²² A study from India assessed the efficacy of 38% SDF and 5% NaF varnish in arresting caries in primary molars. The results aligned with previous studies, indicating that the SDF group demonstrated greater effectiveness in arresting caries in primary molars compared to NaF varnish.⁴⁵

Ruff et al. (2023) assessed the non-inferiority of SDF relative to FV against glass ionomer sealant in a cohort of 2,998 children aged 5 to 13 years in primary schools throughout New York City.²⁸ After two years of intervention and follow-up, it was reported that SDF demonstrated noninferiority to sealants in caries arrest, achieving 80% arrest rate. A trial conducted in Egypt among children under 4 years with active dental caries assessed the efficacy of SDF compared to NSF. Conversely, this study illustrated that NSF was more effective in arresting caries without leading to black staining of teeth and resulted in higher parental satisfaction compared to SDF. Consequently, positioning NSF as a viable and economical alternative within underprivileged neighbourhoods.²⁸ Furthermore, a recent clinical trial revealed that SDF was effective in arresting active cavitated lesions.²⁷

This scoping review is limited by the inclusion of only English-language articles, and heterogeneity in treatment protocols and outcome measures across trials which may limit comparability.

In summary, SDF showed more effectiveness in arresting caries than other available topical fluoride products and materials in primary dentitions. The application of SDF is simple, less time consuming, and doesn't require extensive operators' skills. However, due to its drawbacks of dark black staining, other alternatives are still under consideration. Numerous studies have documented various strategies to mitigate this drawback and reduce the staining of treated teeth, including the application of potassium iodide after using SDF.⁴⁶ In order to exclude the only negative point with current SDF, development of stainless SDF is highly recommended.

Conclusions

This scoping review underlines the importance of SDF application as a promising and effective treatment for preventing or arresting dental caries in young children. Compared to other recognized fluoride products, SDF demonstrates superior efficacy in arresting caries both in dentin and enamel. The evidence reviewed supports SDF as a highly effective caries management approach in children. These findings may help public health policies in promoting minimally invasive dentistry, particularly in resource-limited settings.

Acknowledgment


None.

Conflict of Interest

None. ■

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