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Silver Diamine Fluoride for Arresting Dental Caries in Children: A Systematic Review

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ABSTRACT: Silver diamine fluoride (SDF) is increasingly used to arrest cavitated caries in children, but trials differ in comparators, concentrations, and application schedules. Eligible studies were published through December 2024. PubMed/MEDLINE, Scopus, Embase, Web of Science, and the Cochrane Central Register of Controlled Trials were searched for English-language studies of children with active cavitated carious lesions treated with topical SDF and reporting caries arrest. Risk of bias was assessed with RoB 2 and certainty of evidence with GRADE; clinical heterogeneity precluded meta-analysis, so results were synthesized narratively. Twelve trials reported as randomized (approximately 3,900 children aged 1 to 10 years; follow-up 14 days to 30 months) were included. Annual or semiannual SDF arrested more lesions than the 5% sodium fluoride varnish regimens used in the two trials. Thirty-eight percent SDF also improved arrest versus placebo or no treatment. Results against glass ionomer-based treatments varied. One trial reported more clinical failures with SDF than with conventional restoration. Thirty-eight percent SDF was more effective than 12% SDF in two trials, and more frequent application increased arrest in the interval trials. Black staining was the principal reported adverse effect. Two trials had low overall risk of bias, eight raised some concerns, and two were at high risk. Certainty was moderate for most comparisons, low versus no treatment and for clinical failure versus conventional restoration, and very low versus glass ionomer-based treatments. SDF is a minimally invasive option for arresting cavitated caries in primary teeth. Longer follow-up and child-level reporting are needed.

1. INTRODUCTION

Dental caries is one of the most common chronic diseases worldwide, and untreated decay of the primary teeth remains a leading contributor to the global burden of oral disease [1]. Early childhood caries (ECC) starts early and accumulates quickly:

pooled global estimates indicate that roughly one in six children is affected at age one, more than half by age four, and nearly two in three by age five [2]. In some low- and middle-income settings, the prevalence among five-year-olds has reached about 90% [3]. In Southeast Asia, ECC among children aged 5 to 6 years remains highly prevalent and largely untreated [4].

Left untreated, cavitated lesions cause pain, infection, difficulty eating and sleeping, and poorer growth and quality of life, and they place a heavy load on families and health systems [2]. In many communities most decayed primary teeth are never restored, because conventional care requires equipment, trained personnel, and a degree of cooperation that toddlers and preschoolers often cannot offer, and because dental services are scarce or unaffordable [1, 4].

These barriers have shifted attention toward minimally invasive strategies that stop lesion progression without removing tooth structure, of which professionally applied topical fluorides are the best-known example [5]. Silver diamine fluoride (SDF), an alkaline solution of silver and fluoride stabilized with ammonia, has attracted the most interest because it is painless, inexpensive, quick to apply, and can be delivered outside conventional dental settings [6]. Its main drawback is black staining of arrested lesions, which some parents find unacceptable [6].

The biological rationale is well described. Silver ions have broad antibacterial activity against cariogenic biofilm, fluoride promotes remineralization and the formation of fluorapatite, and the combination inhibits enzymes that degrade the collagen of demineralized dentin, which hardens the lesion and slows its progression [7].

Clinical adoption has been rapid. SDF has been used off-label for caries arrest in the United States, where a widely cited protocol set out its rationale, indications, and consent process [8], and clinical recommendations for children and adolescents, including those with special health care needs, were subsequently published [9]. A national survey found that pediatric dentistry training programs adopted SDF quickly and supported incorporating it into curricula [10].

Systematic reviews and meta-analyses indicate that SDF arrests a substantial proportion of cavitated lesions in primary teeth and compares favorably with several alternatives [11], and an umbrella review reached broadly supportive conclusions [12]. Nevertheless, the primary trials differ widely in SDF concentration, application frequency, comparator, follow-up, age of the children, and method of recording arrest, which complicates translation into clinical protocols. Moreover, several relevant trials have been published since the earlier syntheses were completed.

Therefore, this systematic review aimed to synthesize the clinical evidence published between 2009 and December 2024 on the effectiveness of topical SDF for arresting dentin caries in children, to compare outcomes across concentrations, application frequencies, and comparators, and to appraise the risk of bias and the certainty of the evidence that underpins current practice. Specifically, is topical SDF effective for arresting dentin caries in children, and do its concentration, application frequency, and comparator modify the effect?

2. MATERIALS AND METHODS

2.1 Protocol and registration

This systematic review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [13] and the methodological guidance of the Cochrane Handbook [14].

2.2 Eligibility criteria

The review question was structured using the PICOS framework. Studies were eligible if they met the following criteria:

1. **Population:** children aged 12 years or younger (primary or mixed dentition) with active cavitated (dentin) carious lesions.
2. **Intervention:** topical application of silver diamine fluoride at any concentration, frequency, or duration.
3. **Comparator:** placebo, no treatment, fluoride varnish, glass ionomer or other restorative or interim restorative treatment, or a different SDF concentration or regimen.
4. **Outcomes:** primary, caries arrest at the lesion, surface, or child level (lesion hard or smooth on probing, or inactive by validated criteria); secondary, adverse effects, lesion staining, and parental acceptance.
5. **Study design:** randomized controlled trials, cohort studies, case-control studies, cross-sectional studies, and case series.

Studies were excluded if they involved adults or root caries, were in vitro or animal studies, examined SDF solely for prevention of new lesions without reporting arrest, were reviews, editorials, or conference abstracts, were published in a language other than English, or were published outside the period from January 2009 to December 2024. When several reports described the same trial, the report with the primary arrest outcome and longest follow-up was included.

2.3 Information sources and search strategy

PubMed/MEDLINE, Scopus, Embase, Web of Science, and the Cochrane Central Register of Controlled Trials were searched from January 2009 to December 2024, with filters for English language. Reference lists of included studies and relevant reviews were hand-searched. The PubMed strategy combined controlled vocabulary and free-text terms: ("silver diamine fluoride"[tiab] OR "diammine silver fluoride"[tiab] OR "silver fluoride"[tiab] OR "Silver Compounds"[MeSH]) AND ("dental caries"[MeSH] OR caries[tiab] OR "tooth decay"[tiab]) AND (child*[tiab] OR pediatric[tiab] OR paediatric[tiab] OR preschool[tiab] OR "primary teeth"[tiab] OR "deciduous teeth"[tiab]) AND (arrest*[tiab] OR inactiv*[tiab]). The strategy was adapted for each database.

2.4 Study selection and data extraction

Records were deduplicated and screened by title and abstract, and full texts of potentially eligible reports were assessed against the eligibility criteria by two reviewers working independently; disagreements were resolved by consensus or by a third reviewer. Data were extracted using a piloted form: first author, year, country, design, registration, participants (number, age), SDF concentration and regimen, comparator, follow-up, unit of analysis, arrest outcomes, adverse effects, and the authors' conclusions.

2.5 Risk of bias and certainty of evidence

The risk of bias of randomized trials was assessed with the Cochrane RoB 2 tool [15] across five domains (randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result), and the ROBINS-I tool [16] was prespecified for any non-randomized study. Certainty of evidence for each comparison was rated with the GRADE approach [17] as high, moderate, low, or very low, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias.

2.6 Data synthesis

A random-effects meta-analysis of risk ratios for dichotomous arrest outcomes, with heterogeneity quantified by the I^2 statistic, was planned for comparisons in which at least two trials used the same comparator, outcome, and time point and reported extractable counts. Where this was not feasible, results were synthesized narratively and tabulated by comparison, concentration, and application frequency.

Ethical approval was not required because this review analyzed published data only.

3. RESULTS

3.1 Study selection and characteristics of the included trials

The search identified 1,025 records from bibliographic databases and none from trial registers. Before screening, 296 duplicates and 5 records marked ineligible by automation were removed. Of 724 records screened by title and abstract, 647 were excluded and 77 reports were sought for retrieval. All 77 reports were retrieved and assessed in full text. Of these, 65 were excluded: 12 for an ineligible population, 26 for lack of relevant caries-arrest data, 9 for publication type, and 18 for other reasons. Twelve trials were included (Figure 1) [13].

The reports first appeared online or in print from 2009 to December 2024. Trials were conducted in Nepal, Brazil, mainland China, Hong Kong, the United States, Thailand, Canada, and Saudi Arabia. The reports covered approximately 3,900 children aged 1 to 10 years with active cavitated dentin lesions in primary teeth, including 680 children in the Fontana interim cohort. Nine trials tested 38% SDF, three tested 30% SDF, and two also tested 12% SDF. Comparators were 5% sodium fluoride varnish, glass ionomer-based treatment, conventional restorative treatment, placebo, no treatment, a lower SDF concentration, or a different application interval (Table 1).

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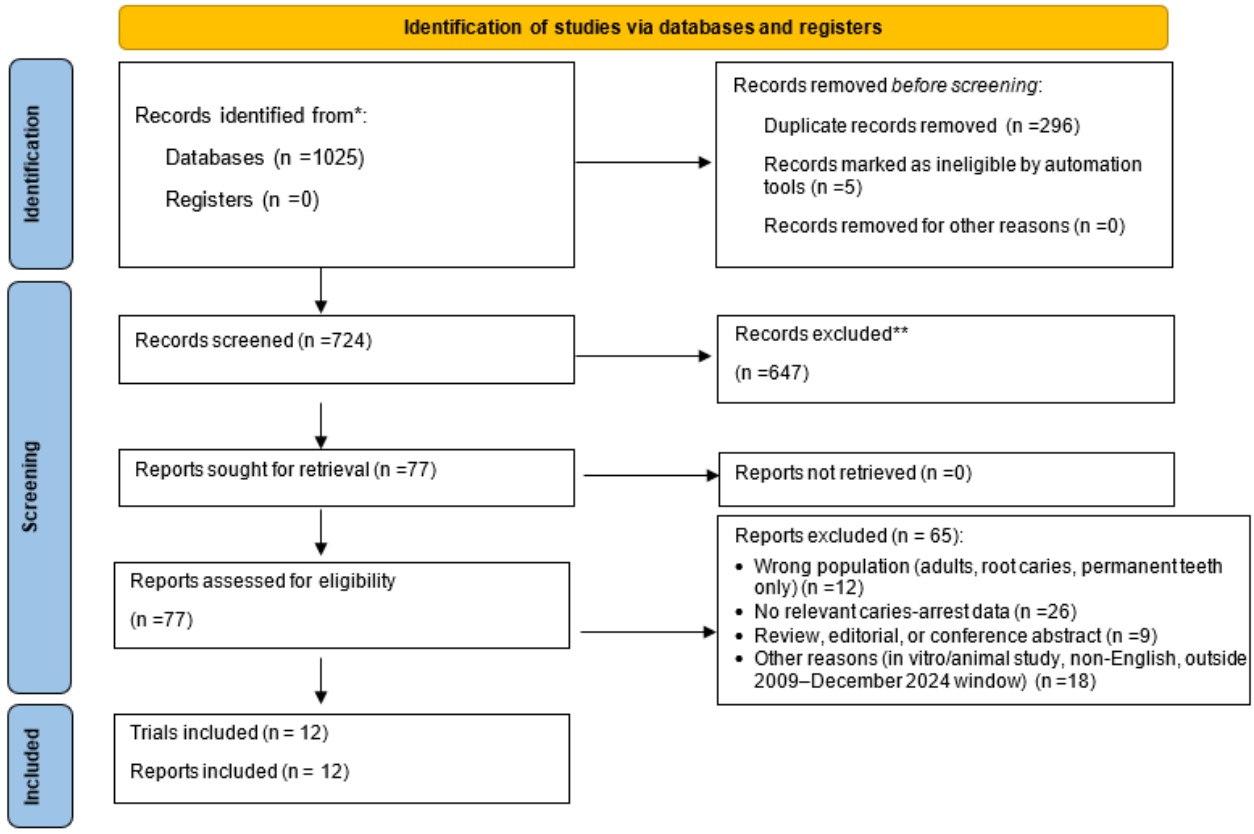

Figure 1. PRISMA 2020 flow diagram for stud'y selection. Of 77 full-text reports assessed, 65 were excluded and 12 trials were included. Source: Page et al. [13]. For more information, visit http://www.prisma-statement.org/

Table 1. Characteristics of the included randomized controlled trials

Study	Country / setting	Design / registration	Participants	SDF regimen	Comparator(s)	Follow-up
dos Santos et al. [24]	Brazil; schoolchildren at risk	Reported cluster RCT	91 children aged 5–6 years	30% SDF	Interim restorative treatment (glass ionomer)	12 months
Zhi et al. [23]	China (Guangzhou); 6 kindergartens	Parallel-group RCT; HK Clinical Trial Register UW07-083	212 (71/69/72); 3-4 y; 719 lesions	38% SDF annually or every 6 months	Flowable high-fluoride glass ionomer, annually	24 months (181 children, 85%, analyzed)
Duangthip et al. [18]	Hong Kong; kindergartens	Parallel-group RCT	371; 3-4 y; 309 (83%) analyzed, 1,877 lesions	30% SDF annually (3 applications) or 3 weekly applications at baseline	5% NaF varnish, 3 weekly applications	30 months

Study	Country / setting	Design / registration	Participants	SDF regimen	Comparator(s)	Follow-up
Fung et al. [27]	Hong Kong; 37 kindergartens	Parallel-group RCT; NCT02385474	888 (222 per arm); 3-4 y; 799 (90%) analyzed	12% or 38% SDF, annually or every 6 months	Lower concentration and lower frequency arms	30 months
Milgrom et al. [21]	USA (Oregon); 3 Head Start programs	Double-blind placebo-controlled RCT; NCT02536040	66 preschool children	38% SDF, single application	Placebo (blue-tinted water)	14-21 days
Mabangkhru et al. [19]	Thailand (Chiang Mai); 19 child development centers	Parallel-group RCT; TCTR20180624001	302 (153/149); 1-3 y; 2,249 surfaces; 263 (87.1%) at 12 mo	38% SDF every 6 months	5% NaF varnish every 6 months	12 months
Schroth et al. [28]	Canada (Winnipeg); community dental clinics	Open-label parallel-group RCT; NCT04054635	84 (28 per arm); mean age 44.4 months; 505 lesions followed	38% SDF plus 5% NaF varnish at 2 visits, 1, 4, or 6 months apart	Different application intervals (no non-SDF comparator)	Final study visit after second application
Yee et al. [22]	Nepal (Kathmandu); kindergartens and primary schools	Four-arm parallel RCT	976; 3–9 y	Single application of 38% SDF, with or without tannic acid	12% SDF or no treatment	6, 12 and 24 months
Vollú et al. [25]	Brazil (Rio de Janeiro); pediatric dental clinic	Parallel-group RCT; NCT03063307	68 randomized; ages 2–5 y; 56 assessed at 12 months	Single application of 30% SDF	ART with glass ionomer cement	3, 6 and 12 months
Fontana et al. [20]	United States; multicenter	Phase III, masked placebo-controlled RCT; NCT03649659	680 in interim cohort; 12–71 months; 599 attended the 6-month exam	38% SDF at baseline; arrest assessed before reapplication	Blue-tinted water placebo	6 months (interim report)
Abdellatif et al. [26]	Saudi Arabia; university pediatric dental clinics	Parallel-group RCT	90 randomized; 79 treated (237 primary teeth); 3–8 y; 53 assessed at 12 months	38% SDF at baseline and 6 months	ART with glass ionomer cement	6 and 12 months

Study	Country / setting	Design / registration	Participants	SDF regimen	Comparator(s)	Follow-up
Cleary et al. [29]	United States (Michigan); two clinical sites	Parallel-group RCT; NCT02601833	98 randomized; ages 2–10 y; 69 assessed at 12 months	38% SDF at baseline and 6 months; both arms received fluoride varnish	Conventional restorative treatment plus fluoride varnish	6 and 12 months

SDF, silver diamine fluoride; NaF, sodium fluoride; RCT, randomized controlled trial; ICDAS, International Caries Detection and Assessment System.

3.2 Caries arrest outcomes

Arrest was assessed by visual-tactile examination and reported at the lesion, surface, or child level, and cluster-adjusted counts were not available for every trial (Table 2). Both trials comparing annual or semiannual SDF with sodium fluoride varnish favored those SDF regimens [18, 19], while both placebo-controlled trials favored 38% SDF [20, 21]. A single 38% application also improved arrest versus no treatment through 24 months [22]. Results against glass ionomer-based treatment diverged: arrest was similar with annual SDF and annual flowable glass ionomer in one trial [23], whereas SDF outperformed interim restorative treatment in another [24]. In the Vollú trial, arrest at 12 months was 88.7% with SDF and 95.6% with atraumatic restorative treatment (ART) [25]. Abdellatif et al. [26] also observed high arrest rates with both regimens among reassessed cavitated lesions, with substantial loss to follow-up. Both concentration trials favored 38% over 12% SDF [22, 27]. Semiannual application outperformed annual application in two trials [23, 27], and a Canadian trial found near-complete arrest with applications one or four months apart and lower arrest at six months [28]. Cleary et al. [29] reported hard lesions in 57% of the SDF arm at six months and 74% at 12 months. At 12 months, minor and major clinical failures were more frequent with SDF than with conventional restoration. Lesion hardness and composite clinical failure were analyzed as separate outcomes.

Table 2. Quantified caries arrest outcomes

Study	Unit of analysis	Time point	Arrest results by group	Effect estimate (95% CI)	Favors
dos Santos et al. [24]	Primary tooth (169 SDF and 153 IRT teeth at 12 months)	12 months	30% SDF: 66.9% arrested Interim restorative treatment: 38.6% arrested	Difference significant ($P < 0.05$)	SDF
Zhi et al. [23]	Lesion	24 months	SDF annual: 79.2% SDF every 6 months: 90.7% Glass ionomer annual: 81.8% Overall difference $P = 0.007$	SDF 6-monthly vs annual: OR 2.98 (1.35-6.69) Glass ionomer vs annual SDF: OR 1.13 (0.52-2.45)	SDF 6-monthly; SDF annual ≈ glass ionomer
Duangthip et al. [18]	Lesion (cavitated, ICDAS 5-6)	30 months	30% SDF annual: 48% 30% SDF weekly ×3: 33% 5% NaF varnish weekly ×3: 34% $P < 0.001$	Annual SDF higher than both weekly protocols ($P < 0.001$)	Annual SDF

Study	Unit of analysis	Time point	Arrest results by group	Effect estimate (95% CI)	Favors
Fung et al. [27]	Surface	30 months	12% SDF annual: 55.2% (512/927) 12% SDF 6-monthly: 58.6% (578/987) 38% SDF annual: 66.9% (650/971) 38% SDF 6-monthly: 75.7% (685/905) P < 0.001	38% vs 12%: OR 1.98 (1.51-2.60)	38% SDF; more frequent in poor hygiene
Milgrom et al. [21]	Lesion (mean fraction per child)	14-21 days	SDF: 0.72 (95% CI 0.55-0.84) Placebo: 0.05 (95% CI 0.00-0.16)	Risk of arrest significantly higher with SDF	SDF
Mabangkhru et al. [19]	Surface	6 and 12 months	12 months: SDF 35.7% (397/1,111) vs NaF varnish 20.9% (238/1,138) 6 months: 20.5% (228/1,111) vs 12.3% (140/1,138) P < 0.001	12 months, adjusted OR 2.04 (1.41-2.96)	SDF
Schroth et al. [28]	Lesion	Final visit	1-month interval: 98% (192/196) 4-month interval: 95.8% (159/166) 6-month interval: 72% P < 0.001	Longer interval associated with lower arrest	Shorter intervals
Yee et al. [22]	Mean arrested primary tooth surfaces per child	24 months	38% SDF: 2.1; 38% SDF with tannic acid: 2.2. No demonstrated benefit for 12% SDF versus no treatment.	P < 0.01 for the reported 24-month comparison	38% SDF
Vollú et al. [25]	Primary molar lesion	3, 6 and 12 months	3 months: SDF 65/65 (100%), ART 50/52 (96.2%). 6 months: SDF 57/64 (89.1%), ART 44/48 (91.7%). 12 months: SDF 55/62 (88.7%), ART 43/45 (95.6%).	Reported mean difference at 12 months: −0.07.	No clear difference at 12 months
Fontana et al. [20]	Lesion (within-child clustering accounted for)	6 months	38% SDF: 54% (95% CI 47–61%); placebo: 21% (95% CI 16–26%).	P < 0.001 (original visit window)	38% SDF

Study	Unit of analysis	Time point	Arrest results by group	Effect estimate (95% CI)	Favors
Abdellatif et al. [26]	Primary tooth lesion (baseline ICDAS 5–6)	6 and 12 months	6 months: SDF 63/63 (100%), ART 87/91 (95.6%). 12 months: SDF 53/54 (98.1%), ART 80/85 (94.1%).	Descriptive counts summed from original Table 6.	High arrest in both arms
Cleary et al. [29]	One primary tooth lesion per child	6 and 12 months	Hard lesions in the SDF arm: 57% at 6 months and 74% at 12 months. At 12 months, minor failures were 65% with SDF vs 23% with restoration, and major failures were 13% vs 3%.	Hardness reported for the SDF arm. Clinical failure was a separate composite outcome.	Restoration for clinical failure

OR, odds ratio. Values are as reported by the original authors; reported percentages and odds ratios may differ in whether they account for clustering.

3.3 Safety and acceptability

Adverse effects were minor, and black staining of arrested lesions was the only consistent finding. Serious adverse events were not reported in three trials [19, 21, 23], and a fourth found no major long-term adverse effects apart from staining [27]. Parental satisfaction with the child's dental appearance did not deteriorate after SDF treatment [19] and was similar across arms in another trial [23] (Table 3). Fontana et al. [20] reported no safety concerns at the interim decision, and the Vollú trial found no statistically significant differences in adverse effects or aesthetic perception [25]. In Cleary et al. [29], parental satisfaction and acceptability were similar between groups, while children in the restoration arm rated tooth appearance more favorably at 12 months.

Table 3. Key findings, safety, and authors' conclusions

Study	Key findings	Safety and acceptability	Authors' conclusions
dos Santos et al. [24]	SDF arrested more lesions than interim restorative treatment after 1 year.	The 12-month report gives no adverse-event or acceptability results.	SDF may justify a paradigm shift for treating caries in underprivileged schoolchildren.
Zhi et al. [23]	Annual SDF and annual flowable glass ionomer arrested a similar share of lesions; 6-monthly SDF arrested more. Anterior teeth and buccal/lingual surfaces arrested more readily.	No adverse effects on teeth or soft tissue. Nearly all SDF-arrested lesions were black; most glass ionomer-arrested lesions were yellow-brown. Parental satisfaction similar across groups (about 45% satisfied).	Annual SDF or glass ionomer can arrest dentin caries; increasing SDF frequency to every 6 months increases arrest.

Study	Key findings	Safety and acceptability	Authors' conclusions
Duangthip et al. [18]	Annual SDF was more effective than three weekly applications of SDF or NaF varnish at baseline for cavitated lesions; time to arrest was shorter in both SDF groups than with varnish.	Dark staining: 65% and 57% in the annual and weekly SDF groups vs about 33% with NaF. No major side effects reported. Parental satisfaction with oral health was similar across groups at 24 months.	Annual SDF is more effective than three weekly applications of NaF varnish or SDF at baseline.
Fung et al. [27]	38% SDF was more effective than 12% SDF; frequency interacted with oral hygiene, with semiannual application compensating for high plaque scores. Occlusal, posterior, large, and plaque-covered lesions arrested less often.	Apart from black staining, no major long-term or permanent adverse effects.	38% SDF is more effective than 12%; in children with poor oral hygiene, semiannual application is more effective than annual.
Milgrom et al. [21]	SDF arrested most treated lesions versus almost none with placebo; no clinically important change in plaque bacterial composition or resistance gene expression in the analyzed subset.	Four parent-reported adverse events per arm, with no statistically significant between-group difference.	Topical 38% SDF is effective and safe for arresting cavities in preschool children.
Mabangkhru et al. [19]	SDF arrested more surfaces than NaF varnish at 6 and 12 months; plaque on lesions, posterior teeth, milk feeding, and frequent snacking reduced arrest.	No major adverse effects or systemic illness; parental satisfaction with dental appearance unchanged from baseline and similar between arms.	Semiannual 38% SDF is more effective than NaF varnish in young children with high caries risk.
Schroth et al. [28]	Arrest was nearly complete with 1- and 4-month intervals and lower with 6-month intervals.	Registry (NCT04054635): 0/28 serious adverse events in each arm and no nonserious events reported at the 5% threshold. Caregivers answered questions on tooth appearance, but the article gives no acceptability results.	Two applications of 38% SDF with NaF varnish 1 or 4 months apart were comparable and very effective; 6-month intervals were less effective.
Yee et al. [22]	A single 38% application improved arrest through 24 months. Tannic acid added no benefit.	Tooth vitality and loss were assessed. Parental acceptability was not reported.	A single 38% application can be used when restorative treatment is unavailable.
Vollú et al. [25]	Arrest was high in both arms at 12 months. Treatment was faster with SDF.	Caregiver-reported adverse events or appearance concerns affected 5/34 children receiving SDF and 3/33 receiving ART (P = 0.709).	SDF may be a faster, less invasive alternative to ART.
Fontana et al. [20]	At six months, 38% SDF arrested more lesions than placebo. Prespecified efficacy stopping criteria were met.	No safety concerns reported at the interim stopping decision; detailed adverse-event results were not presented in this report.	38% SDF arrested active cavitated lesions in young children with severe early childhood caries.

Study	Key findings	Safety and acceptability	Authors' conclusions
Abdellatif et al. [26]	Both groups had high arrest among reassessed cavitated lesions. Median treatment time was 3.3 minutes with SDF and 14.4 minutes with ART.	Pain and sensitivity were assessed, but their results were not reported.	The authors reported comparable arrest and shorter treatment time with SDF.
Cleary et al. [29]	Hardness increased between visits in the SDF arm. Composite clinical failures were more frequent with SDF at 12 months.	Parental satisfaction and acceptability did not differ significantly. Children in the restoration arm rated tooth appearance more favorably at 12 months.	The authors recommended monitoring SDF-treated teeth in children at high caries risk.

3.4 Risk of bias and certainty of the evidence

Two trials were judged at low overall risk of bias, eight raised some concerns, and the Abdellatif and Vollú trials were at high risk because of substantial missing outcome data and the possibility of differential outcome assessment (Table 5). Certainty was moderate for SDF versus sodium fluoride varnish or placebo, 38% versus 12% SDF, and more versus less frequent application. It was low versus no treatment and very low versus glass ionomer-based treatments (Table 4). Evidence on clinical failure versus conventional restorative treatment was of low certainty (Table 4).

Table 4. GRADE summary of the certainty of evidence

Comparison (outcome)	Studies (children)	Risk of bias	Inconsistency	Indirectness	Imprecision	Certainty	Comments
SDF vs 5% NaF varnish (arrest)	2 RCTs (673 children)	Serious (some concerns)	Not serious	Not serious	Not serious	Moderate ⨁⨁⨁◯	Consistent direction; different SDF concentrations
SDF vs glass ionomer-based treatments (arrest)	4 trials (461 children)	Serious	Serious	Not serious	Serious	Very low ⨁◯◯◯	Variable effects, substantial attrition in two ART comparisons, and imprecise estimates
38% SDF vs placebo (arrest)	2 trials (746 children in reported cohorts)	Serious	Not serious	Not serious	Not serious	Moderate ⨁⨁⨁◯	Both trials favored SDF. The six-month trial was reported at a planned interim analysis.
38% vs 12% SDF (arrest)	2 trials (1,864 children across all arms)	Serious	Not serious	Not serious	Not serious	Moderate ⨁⨁⨁◯	Both favored 38%; allocation concealment and attrition concerns in Yee et al. [22]

Comparison (outcome)	Studies (children)	Risk of bias	Inconsistency	Indirectness	Imprecision	Certainty	Comments
More vs less frequent application (arrest)	3 RCTs (1,184 children)	Serious (some concerns)	Not serious	Not serious	Not serious	Moderate ⨁⨁⨁◯	Consistent direction across trials
38% SDF vs no treatment (arrest)	1 trial (976 children across all arms)	Serious	Not applicable	Not serious	Serious	Low ⨁⨁◯◯	Substantial attrition. The report did not provide a confidence interval for the relevant contrast.
SDF vs conventional restoration (clinical failure)	1 trial (98 children; 69 assessed at 12 months)	Serious	Not applicable	Not serious	Serious	Low ⨁⨁◯◯	Unmasked assessment and few events for major failure. No parallel lesion-hardness estimate for restoration.

⨁⨁⨁◯ moderate; ⨁⨁◯◯ low; ⨁◯◯◯ very low. Domain judgments apply to the outcome specified for each comparison.

Table 5. Risk-of-bias assessment of the included randomized trials (Cochrane RoB 2)

Study	D1	D2	D3	D4	D5	Overall	Main basis
dos Santos et al. [24]	Some concerns	Low	Some concerns	Some concerns	Some concerns	Some concerns	Randomization and allocation concealment were poorly described. Arrest criteria differed by arm.
Zhi et al. [23]	Some concerns	Low	Some concerns	Low	Low	Some concerns	Concealment not described; 15% attrition
Duangthip et al. [18]	Some concerns	Low	Some concerns	Low	Low	Some concerns	17% attrition (62/371) at 30 months, with similar rates across arms (19%, 16%, 15%).
Fung et al. [27]	Low	Low	Low	Low	Low	Low	Stratified, coded bottles, blinded examiner
Milgrom et al. [21]	Some concerns	Low	Low	Low	Low	Some concerns	Computer-generated block randomization and coded bottles. The report does not describe how the sequence was concealed before enrollment.

Study	D1	D2	D3	D4	D5	Overall	Main basis
Mabangkhru et al. [19]	Low	Low	Low	Low	Low	Low	Opaque sealed envelopes; blinded examiner
Schroth et al. [28]	Some concerns	Some concerns	Some concerns	Some concerns	Low	Some concerns	Open-label trial. Examiners knew the assigned regimen and lesion status.
Yee et al. [22]	Some concerns	Low	Some concerns	Some concerns	Some concerns	Some concerns	Unclear concealment, substantial attrition, and visible staining in the no-treatment comparison.
Vollú et al. [25]	Low	Low	High	Some concerns	Some concerns	High	Unequal loss to follow-up at 12 months. Different materials may reveal assignment, and registration was retrospective.
Fontana et al. [20]	Low	Low	Some concerns	Some concerns	Low	Some concerns	12% attrition in the interim cohort. Visible staining could reveal assignment despite masking.
Abdellatif et al. [26]	Low	Some concerns	High	Some concerns	Some concerns	High	37/90 children lacked 12-month data. Treatment was visible and arrest definitions differed by arm.
Cleary et al. [29]	Some concerns	Low	Some concerns	Some concerns	Low	Some concerns	Envelope safeguards unclear, 29/98 children missing at 12 months, and treatment visible to assessors.

D1, randomization process; D2, deviations from intended interventions; D3, missing outcome data; D4, measurement of the outcome; D5, selection of the reported result. Green, low risk; yellow, some concerns. Red, high risk.

3.5 Evidence synthesis

Because comparators, concentrations, units of analysis (lesion, surface, or child), and follow-up times differed, and cluster-adjusted counts were not consistently available, pooling in a meta-analysis was judged inappropriate and the evidence was synthesized narratively.

4. DISCUSSION

4.1 Interpretation and comparison with previous evidence

Early childhood caries remains a major, largely untreated problem, and SDF has become one of the most widely discussed non-restorative responses to it [12]. Taken together, the randomized trials in this review indicate that topical SDF reliably arrests a large share of cavitated dentin lesions in primary teeth, and that the size of the benefit depends on the comparator, the concentration, how often the agent is reapplied, the child's age and oral hygiene, and the location of the lesion.

Annual or semiannual SDF yielded higher arrest rates than the sodium fluoride varnish regimens tested. Three weekly applications of SDF and varnish at baseline yielded similar 30-month arrest rates. This agrees with the earlier landmark trial in Chinese preschool children by Chu et al. [30], which also favored SDF over varnish. The advantage is biologically plausible because SDF delivers silver and a far higher fluoride load than varnish, so it combines bactericidal action with remineralization, while varnish acts mainly through fluoride alone.

Findings against glass ionomer-based treatment were less uniform. When a flowable high-fluoride glass ionomer was painted onto cavities and compared with SDF, both arrested lesions to a similar degree, whereas a trial using interim restorative treatment in schoolchildren favored SDF. The difference may reflect the weak retention of thin glass ionomer layers in unprepared cavities and differences in how lesions covered by material were classified, rather than a true conflict in efficacy. The Abdellatif and Vollú trials observed high arrest rates with both SDF and ART at 12 months, although attrition limits interpretation. Placebo-controlled trials favored SDF at 14–21 days and six months. The six-month result came from a prespecified interim analysis [20].

The placebo comparisons support arrest after a single application at both an early assessment and a six-month visit [20, 21]. Because these were separate trials with different populations and outcome summaries, their arrest rates cannot be used to estimate how much the effect changes over time. The restorative comparisons address a different question. Retention of a restoration can contribute to the definition of success, whereas SDF arrest is assessed on the exposed lesion. This distinction, together with substantial loss to follow-up in two comparisons, limits claims of equivalence between the approaches [23, 24, 25, 26]. In the conventional restoration comparison, lesion hardness and clinical failure address different aspects of treatment success. The clinical failure findings should therefore be considered alongside, rather than combined with, the lesion-hardness results [29].

Application frequency emerged as an important modifier of effect. Semiannual application produced higher arrest than annual application, and the interaction with oral hygiene suggests that frequent reapplication matters most when plaque control is poor. The same logic is supported by the Canadian trial, in which closely spaced applications arrested nearly all lesions while a longer interval was less effective. Repeated application replenishes the reservoir of silver and fluoride on the lesion surface, which is continually challenged by plaque and dietary acids, and it is consistent with the sustained arrest seen with six-monthly application in schoolchildren followed for three years by Llodra et al. [31].

The Canadian trial evaluated SDF alongside sodium fluoride varnish and assessed the groups on schedules that differed in elapsed follow-up time [28]. Its findings therefore apply most directly to the combined regimens studied. They provide limited grounds for choosing a single reapplication interval for SDF alone across clinical settings.

Concentration also mattered. Higher-concentration SDF was more effective than the lower concentration. Yee et al. [22] found that a single application of 38% SDF improved arrest through 24 months, whereas 12% SDF did not show a benefit over no treatment. Patient and lesion characteristics shaped outcomes as well. Lesions on anterior and smooth surfaces arrested more readily than those on occlusal surfaces of posterior teeth, where plaque is harder to remove, and the presence of plaque on the lesion was a strong negative predictor, in line with the earlier 18-month report from Hong Kong by Duangthip et al. [32]. The comparatively lower arrest rates in the trial of children aged one to three years may reflect more severe disease, frequent night-time milk feeding and snacking, and the practical difficulty of applying treatment to very young, uncooperative children.

Several mechanisms explain how SDF arrests lesions. Silver ions disrupt bacterial cell walls and enzymes and are active against the cariogenic biofilm, fluoride favors the formation of fluorapatite that resists acid dissolution, and the alkaline solution raises local pH. In addition, SDF inhibits the matrix metalloproteinases and cysteine cathepsins that degrade demineralized dentin collagen, as demonstrated by Mei et al. [33, 34], which helps preserve the organic matrix and produces the hard, darkened surface characteristic of an arrested lesion [7].

These conclusions are consistent with earlier syntheses. A systematic review of clinical trials in children by Gao et al. [35] reported high arrest rates with SDF, and the meta-analysis and umbrella review cited in the introduction reached supportive conclusions [11, 12]. The present review adds more recent trials, makes concentration, frequency, and comparator explicit, and applies formal risk-of-bias and certainty appraisal, which tempers confidence for some comparisons.

Safety and acceptability are central to clinical use. Staining was the principal reported adverse effect. Safety reporting varied across trials. A detailed analysis of adverse effects in a large Hong Kong cohort by Duangthip et al. [36] found no acute systemic illness or major adverse event, and pharmacokinetic work by Vasquez et al. [37] indicated that serum levels after application remain far below toxic thresholds. Parental acceptance of staining varies, and Crystal et al. [38] showed that acceptance depends on the tooth involved and on counseling, which is consistent with the stable parental satisfaction observed in the included trials once parents were informed in advance.

The safety findings also depend on how events were collected. Milgrom et al. [21] recorded parent-reported events in both arms, whereas the interim Fontana report [20] noted no safety concerns at the stopping decision and deferred detailed adverse-event reporting. These reports provide limited information on uncommon harms. Caregiver satisfaction and treatment acceptability also differ across settings and may depend on the visibility of the treated tooth [19, 23, 38].

4.2 Strengths, limitations, and implications

This review has limitations. Only English-language studies were included, the number of trials is modest, and all were randomized trials, so conclusions about real-world effectiveness are indirect. Arrest was judged by visual-tactile examination, which is subjective and may be affected by the dark staining of SDF-treated lesions. Many trials analyzed lesions or surfaces rather than children, and lesions within the same mouth are correlated, as described by Masood et al. [39], so some reported precision may be overstated. Differences in comparators and outcome units prevented meta-analysis, and follow-up of some trials was short. Strengths include a prespecified protocol, a comprehensive multi-database search, and explicit appraisal of certainty. Future research should use child-level reporting, longer follow-up, standardized arrest criteria, and head-to-head comparison of concentrations and intervals, ideally including older children and permanent teeth.

To improve comparability, future trials should prespecify how to classify lesions that are restored, extracted, or exfoliate during follow-up, and report the denominators at each visit. Reporting both the proportion of lesions arrested and the proportion of children with all treated lesions arrested would clarify how lesion-level findings translate into outcomes for individual children [39].

5. CONCLUSIONS

Topical silver diamine fluoride (SDF) helps arrest cavitated caries in children's primary teeth. The included trials found higher arrest rates with 38% than with 12% SDF and with semiannual than with annual application in direct comparisons. Evidence comparing SDF with glass ionomer-based treatments remains very uncertain. One trial found more clinical failures with SDF than with conventional restoration, supporting follow-up to monitor treated teeth [29]. When SDF is considered, clinicians should discuss the expected dark staining with caregivers and reassess whether treated lesions have arrested at follow-up. Future trials should report child-level outcomes and follow lesions for longer.

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AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICS STATEMENT

This study is a systematic review of previously published, de-identified data and did not involve new human or animal subjects; formal ethics approval was therefore not required.

DATA AVAILABILITY STATEMENT

The data extraction tables supporting this review are available from the corresponding author upon reasonable request. All included studies are publicly available in the cited peer-reviewed sources.

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