

# A systematic review of silver diamine fluoride: Effectiveness and application in older adults

Amruta D. Hendre<sup>1</sup> | George W. Taylor<sup>1</sup> | Elisa M. Chávez<sup>2</sup> | Susan Hyde<sup>1</sup>

<sup>1</sup>Department of Preventive and Restorative Dental Sciences, University of California, San Francisco School of Dentistry, San Francisco, CA, USA

<sup>2</sup>Department of Diagnostic Sciences, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, CA, USA

## Correspondence

Susan Hyde, Department of Preventive and Restorative Dental Sciences, UCSF School of Dentistry, San Francisco, CA, USA.  
Email: Susan.Hyde@ucsf.edu

**Objective:** This systematic review examines the effectiveness of silver diamine fluoride (SDF) in the management of caries in older adults.

**Background:** Silver diamine fluoride has been extensively researched and proven effective for caries prevention and arrest in children. Limited studies support its effectiveness in adult and older adult populations.

**Materials and methods:** Multiple databases were searched according to specified inclusion-exclusion criteria. Quality assessment used modified Centre for Evidence-Based Medicine worksheets.

**Results:** Three randomised controlled trials were identified that addressed the effectiveness of SDF on root caries in older adults, but none addressed coronal caries. Root caries prevented fraction and arrest rate for SDF were significantly higher than placebo. The prevented fraction for caries prevention for SDF compared to placebo was 71% in a 3-year study and 25% in a 2-year study. The prevented fraction for caries arrest for SDF was 725% greater in a 24-month study and 100% greater than placebo in a 30-month study. No severe adverse effects were observed.

**Conclusion:** This systematic review evaluates the use of SDF for both root caries prevention and arrest in older adults. Existing reports of SDF trials support effectiveness in root caries prevention and arrest, remineralization of deep occlusal lesions and treatment of hypersensitive dentin.

## KEYWORDS

arrest, caries, older adults, prevent, safety, silver diamine fluoride, systematic review

## 1 | INTRODUCTION

In 2030, 19% of the U.S. population will be aged 65 years or older, and 2.3% over age 85.<sup>1</sup> The number of adults aged 65 years and older per 100 working-age adults will increase from 0.22 in 2010 to 0.35 in 2030, indicating a growing burden on the healthcare system.<sup>1</sup> Nationally, 19% of community-dwelling adults in the United States aged 65 and older have untreated coronal caries.<sup>2</sup> The most current estimates for root caries prevalence in U.S. adults aged 65 and older are 14%, with 12% for non-Hispanic Whites and 31% and 30% for Mexican Americans and African Americans, respectively.<sup>3</sup> The rise in the proportion of older adults in the population living with chronic

disease, the longer retention of natural teeth, combined with pre-existing dental restorations and persistent caries experience is poised to create a dental public health crisis.<sup>4</sup>

The World Health Organization (WHO) has included oral health as an important component of their active ageing policy, which promotes healthy living, disease prevention and focusing on improving the quality of life of older adults.<sup>5</sup> In concordance with the WHO global goals for 2020, Healthy People 2020 has included for the first time objectives to reduce the proportion of older adults with untreated coronal and root caries.<sup>6,7</sup> In order to achieve these objectives, it is important to consider how the oral health needs of an older population change with fluctuations in functional status and level of dependency over a

lifetime. The goals for oral health and the factors that influence the provision of care may vary with different stages of dependency.<sup>8</sup>

Silver diamine fluoride (SDF) is an emerging caries preventive treatment option that is inexpensive, safe and easily accessible.<sup>9</sup> Treatment with SDF requires minimal instrumentation and application at less frequent intervals than other caries preventive materials. Current evidence supports SDF use in children.<sup>10,11</sup> However, older adults, especially those with high caries risk and/or with limited to no access to dental services due to economic, social or functional challenges, may benefit from this treatment as well.

## 1.1 | Background of SDF

Silver nitrate was first used to arrest caries in the 19th century. Rapid development to create more effective formulations occurred during the 20th century starting with Howe's ammoniacal silver nitrate, followed by silver fluoride, and later SDF. Since 1970, a solution of 38% SDF has been widely used outside the United States, primarily for caries prevention and arrest in children.<sup>12</sup> The U.S. Food and Drug Administration (FDA) approved the use of SDF as a desensitising agent in 2014. In January 2016, a new Code on Dental Procedures and Nomenclature (CDT) D1354 allowed billing claims for off-label use of SDF as an interim caries arresting medicament.<sup>13,14</sup> Thirty-eight per cent SDF is an alkaline (pH 10) colourless solution, containing 24%-27% silver (Ag), 8.5%-10.5% ammonia (NH<sub>3</sub>) and 5.0%-6.0% fluoride (F).<sup>15</sup>

SDF affects the tooth structure and the caries process. The effect on enamel is primarily due to fluoride, while the effect on dentin is predominantly due to silver.<sup>16,17</sup> Formation of silver phosphate turns SDF-treated carious lesions black.<sup>18</sup> SDF does not affect the bond strength of composite resin to noncarious dentin, but may reduce bond strength to caries-affected dentin.<sup>19,20</sup> SDF is compatible with glass-ionomer cements (GIC) and may increase resistance of GIC and composite restorations to secondary caries.<sup>21,22</sup>

Excavation of caries is not required prior to application. Teeth are air-dried, and SDF is applied to the carious lesions using a microbrush for 1 minute and rinsed.<sup>9</sup> The effect of SDF diminishes over time, therefore follow-up applications are required as the lesion can revert to further carious demineralization in 24 months.<sup>23</sup> The recommended safest maximum dose of SDF per visit is 1 drop/10 Kg.<sup>9</sup>

Although numerous randomised clinical trials have been conducted in children, very few randomised controlled<sup>24-26</sup> trials have been conducted in older populations. The purpose of this report is to provide a systematic review of the evidence regarding the effectiveness of SDF in arresting or preventing root caries in older adults.

## 2 | METHODS

### 2.1 | Search strategy

This systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement (PRISMA).<sup>27</sup>(Figure 1)

#### Databases used:

PubMed, PubMed Clinical Queries, EMBASE, the American Dental Association's Evidence-Based Dentistry Website, Cochrane Library, Web of Science, repository of the Journal of the American Dental Association and Google Scholar.

#### 1) Search terms (MeSH, Brand names, Other terms) for SDF:

"Silver Diamine Fluoride" OR "Diammine Silver Fluoride" OR "Ammonical Silver Fluoride" OR Silver Ammonia Fluoride" OR "Silver Fluoride" OR "Quaternary Ammonium Compounds"(MeSH) OR "Saforide" OR "Riva-Star" OR "Silver Nitrate + Caries"

#### 2) MeSH terms for caries in older adults:

"Elderly + Caries + Silver" OR "Dental Caries + Therapy + Silver" OR "Older Adult + Care Management + Dental" OR "Cariostatic Agents + Therapeutic + Elderly" OR "Dental Atraumatic Restorative Treatment/Methods" OR "Dental Caries + Prevention + Control+ Silver" OR "Dental Caries + Drug Therapy" OR "Aged" OR "Frail" OR "Institutionalized".

FIGURE 1 Search strategy

PubMed, PubMed Clinical Queries, EMBASE, the American Dental Association's Evidence-Based Dentistry Website, Cochrane Library, Web of Science, repository of the Journal of the American Dental Association and Google Scholar were searched for articles published from 1946 to November 2015 with monthly reruns of search terms in PubMed through August 2016.

A literature search was conducted under two broad categories:

- *Silver diamine fluoride*: Under search terms (MeSH, Brand names, Other terms) "Silver Diamine Fluoride" OR "Diammine Silver Fluoride" OR "Ammonical Silver Fluoride" OR Silver Ammonia Fluoride" OR "Silver Fluoride" OR "Quaternary Ammonium Compounds"(MeSH) OR "Saforide" OR "Riva-Star" OR "Silver Nitrate +Caries"
- *Caries in older adults*: Under search terms "Elderly+Caries+Silver" OR "Dental Caries+Therapy+Silver" OR "Older Adult+Care Management+Dental" OR "CariostaticAgents+Therapeutic+Elderly" OR "DentalAtraumatic Restorative Treatment/Methods" OR "Dental Caries+Prevention+Control+Silver" OR "Dental Caries+Drug Therapy" OR "Aged" OR "Frail" OR "Institutionalized."

We continued to update our search through monthly reruns of our search terms in PubMed. The bibliographies of the selected manuscripts were subsequently hand-searched.

#### 2.1.1 | Inclusion criteria

Type of study: randomized controlled trials, cohort studies; Dentition: permanent; Population: adults aged 18 and older, community dwelling,

or institutionalized; Treatment outcomes: caries prevention, arrest, remineralization; Language: English.

### 2.1.2 | Exclusion criteria

Type of report: systematic reviews, meta-analysis, case reports, in vitro studies, comments on articles, reports on caries in older adults that excluded SDF, and narrative reviews; Dentition: studies of primary dentition, exclusively; Population: children and animals; Language: any other than English.

Clinical trials included in this systematic review are registered with the Hong Kong University Clinical Trials Registry (available from: <http://www.hkuctr.com/search>) and the U.S. National Institutes of Health Registry (available from: <https://clinicaltrials.gov>) (clinical trial registration numbers: HKUCTR-343,<sup>24</sup> HKUCTR-1297,<sup>25</sup> HKUCTR-1583<sup>26</sup> and NCT02360124<sup>26</sup>).

### 2.2 | Data extraction

Summary tables were used to organise the study characteristics and results for each study (Table 1). Prevented fraction (PF), number needed to treat (NNT) and relative risk (RR) were calculated by the authors of this review to augment the results reported by Zhang et al and Li et al.<sup>25,26</sup>

### 2.3 | Quality assessment

The critical appraisal worksheet for randomised controlled trials from the Oxford Centre for Evidence-based Medicine (CEBM 2005) provided the framework to assess the quality and risk of bias of the selected articles.<sup>28</sup> All four authors recorded their findings in an assessment table (Table 2) and discussed disagreements until achieving consensus. The appraisal worksheet was slightly modified: Question 3b was added to the therapy appraisal for clinical trials to gauge inter-examiner calibration.

### 2.4 | Clinical recommendations

To thoroughly evaluate the published evidence regarding its safety and effectiveness before making clinical recommendations, the authors also reviewed studies on remineralization by Sinha et al<sup>29</sup> and hypersensitivity and safety by Castillo et al.<sup>30</sup> These studies were conducted in younger adult populations but provided evidence to support extending SDF application for use in coronal caries.

## 3 | RESULTS

The initial search identified 2931 articles. Category #1 "SDF" yielded 509 articles. Search for articles in category #2, "caries in older adults," yielded 2419 articles. An additional 3 articles were subsequently identified. After removing duplicates and applying inclusion and exclusion criteria, 176 abstracts were selected for initial review by all

authors. Eighteen articles were selected for full review. One article, published in May 2016, was identified during a monthly search rerun. Three articles were selected for final inclusion in this systematic review (Figure 2).

Selected RCT's investigated the effect of SDF on root caries compared to other preventive agents or placebo. Measures used to quantify findings of the studies reviewed are shown in Table 1. Our search did not find studies investigating effect of SDF on coronal caries.

## 4 | ASSESSMENT OF CLINICAL TRIALS REVIEWED

Using the quality assessment framework, Zhang et al<sup>25</sup> met all CEBM criteria, while Li et al<sup>26</sup> and Tan et al<sup>24</sup> met 8 of 9 CEBM criteria. All three studies exhibited a low degree of bias. (Tables 1 and 2)

All three RCT's investigated the effect of SDF on root caries and reported a significant effect of SDF on the prevention and/or arrest of root caries.<sup>24-26</sup> Effectiveness of SDF was measured using the following parameters:

- *Number needed to treat (NNT)*: number of patients required to treat in the intervention group(s) in order to prevent a root surface caries lesion from occurring or to prevent a carious root surface from progressing relative to the control group.<sup>10</sup>
- *Prevented fraction (PF)*: reduction in the rate of incident caries surfaces or the increase in the rate of preventing root surface caries from progressing in the intervention group(s) relative to the control group.<sup>10</sup>
- Mean number new carious surfaces and mean number of arrested root surfaces.
- *Relative risk (RR)*: how much more likely new root surface caries will occur, or existing root surface caries will be prevented from progressing in the intervention group(s) relative to the control group.<sup>28</sup>
- *Arrest rate*: percentage of active carious lesions at baseline that subsequently became arrested per time period at 12, 24, 30 months. We calculated PF, NNT and RR for Zhang et al,<sup>25</sup> and Li et al<sup>26</sup> to increase homogeneity of the reported results.

Tan et al investigated the effect of 38% SDF on root caries prevention in institutionalized older adults and found the preventive effect of SDF was comparable to other preventive agents and greater than placebo.<sup>24</sup> The effectiveness of annual application of SDF was compared with four quarterly applications of 5% sodium fluoride varnish (NaF), 1% chlorhexidine varnish (CHX) and placebo. Each group received oral hygiene instruction (OHI). The NNT for preventing new caries was 2.5, 3.1 and 3.2 for SDF, NaF and CHX varnish, respectively. The PF, compared to placebo and OHI, was 71%, 64% and 57% for SDF, NaF and CHX varnish, respectively ( $P < .001$ ).<sup>24</sup>

Zhang et al<sup>25</sup> investigated the effect of SDF on root caries prevention and arrest and concluded annual SDF application is more effective than placebo in arresting and preventing root caries. In that study, community-dwelling older adults were randomly assigned to

**TABLE 1** Summary of randomised clinical trial studies

Author, year, country	Sample size, loss to follow-up	Type of study, duration	Study population, ages, inclusion criteria	Treatment protocols included	Outcomes	Results Number needed to treat (NNT), Prevented fraction (PF), Relative risk (RR), arrest rate Other measures
Tan et al <sup>24</sup> 2010 Hong- Kong	Baseline N=306 loss to follow-up: N=247 (19%) at 1 y N=227 (26%) at 2 y N=203 (34%) at 3 y	RCT 3 y	Elders. mean age 78.8±6.2 y. At least 5 teeth with exposed roots. No serious medical problems. Basic self-care ability. Living in 21 residential and nursing homes.	Grp.1 OHI+water (placebo) q 3 mo. Grp.2 OHI+CHX varnish q 3 mo. Grp.3 OHI+NaF varnish q 3 mo. Grp.4 OHI+annual application of SDF solution.	Development of new caries on the exposed sound root surfaces.	PF/NNT/RR for prevention of new carious surfaces compared to OHI+Placebo OHI+CHX 57%/3.2/0.27 OHI+NaF 64%/3.1/0.26 OHI+SDF 71%/2.5/0.19 Mean number of new root caries surfaces OHI+Placebo 2.5 OHI+CHX 1.1 OHI+NaF 0.9 OHI+SDF 0.7 3 intervention groups had significantly lower mean number of new root caries surfaces than the control group at 3 y (P<.001).
Zhang et al <sup>25</sup> 2013 Hong Kong	Baseline N=266 loss to follow-up: N=227 (15%) at 2 y	RCT 2 y	Elders. Age 60-89 y. At least 5 teeth with exposed roots. No serious medical problems. Basic self-care ability. Community dwelling from 11 elderly centres.	Grp.1 OHI+Water (placebo) q 12 and 24 mo. Grp.2 OHI+SDF q 12 and 24 mo. Grp.3 (OHI+SDF) q 12 and 24 mo+Oral hygiene education programme (OHE) q 6 mo.	Prevention and arrest of new carious surfaces on exposed roots.	PF/NNT/RR for prevention of new carious surfaces compared to OHI+Placebo OHI+SDF 25%/3.3/0.75 OHI+SDF+OHE 47%/1.59/0.53 PF/NNT/RR for arrest of root surface caries compared to OHI+Placebo OHI+SDF-600%/4.17/7.0 OHI+SDF+OHE -725%/3.45/8.25 Mean number of new/arrested root caries surfaces OHI+Placebo 1.33/0.04 OHI+SDF 1.00/0.28 OHI+SDF+OHE 0.70/0.33 OHI+SDF had significantly better effect on prevention (P<.05) and arrest (P<.05) of root caries than OHI alone. Additional improvement in prevention and arrest with adding OHE to OHI+SDF (P<.05).
Author, year, country	Sample size, loss to follow-up	Type of study, duration	Study population, ages, inclusion criteria	Treatment protocols included	Outcomes	Results number needed to treat (NNT), prevented fraction (PF), Relative risk (RR), arrest rate other measures
Li et al <sup>26</sup> 2016 Hong Kong	Baseline N=83 Baseline root surfaces with active caries lesions n=156 Loss to follow-up at 30 mo: N=16 (19%)	RCT 30 Months	Elders. Age 72.2±5.2 y. No serious medical problem. No salivary gland malfunction. No cognitive problems in communication. Basic self-care ability. One or more teeth with active root caries.	Grp.1 OHI+Soda water (placebo) q 12 and 24 mo. Grp.2 OHI+SDF q 12 and 24 mo. Grp.3 OHI+SDF+KI q 12 and 24 mo. Individual OHI+tooth brush+interdental brush+fluoridated tooth paste provided at each exam q 6 mo to all participants.	Arrest rate of carious root surfaces. Assess colour of arrested carious lesions.	Arrest rate at 12/24/30 mo. OHI+Placebo 32.1%/28.6%/45% OHI+SDF 61%/82.1%/90% OHI+SDF+KI 75.9%/85.4%/92.5% PF/NNT/RR for arrest of root surface caries compared to OHI+placebo. SDF+OHI -100%/1.8/2.0 The arrest rate in SDF and SDF+KI groups were statistically significant compared to placebo (P<.001), while there was no statistically significant difference in arrest rates between SDF and SDF+KI groups (P>.05). There was no statistically significant difference between colour distribution of arrested lesions in SDF and SDF+KI groups (P>.05).

CHX, chlorhexidine; F, fluoride; Grp, group; N, number of participants; NaF, sodium fluoride; OHE, oral hygiene education programme; OHI, oral hygiene instructions; q3 months, every 3 months; RCT, randomised controlled trial; RR, relative risk; SDF, silver diamine fluoride; KI, potassium iodide; NNT, number needed to treat; PF, preventive fraction; RR, relative risk.

|| The PF and NNT have negative values for arrested caries because the formulae for PF and NNT are designed to yield positive values when the incidence of the adverse outcome (or event) is higher in the control group than in the intervention group. In the case of arrested caries, the event is a beneficial outcome (arrested caries surfaces) and is actually greater in the intervention group, thus yielding negative values for PF and NNT. Nevertheless, the interpretation for PF and NNT ignores the negative signs and uses the absolute value.

**TABLE 2** Modified centre for evidence-based medicine (CEBM) critical appraisal worksheet summary: randomised clinical trial

Author, year, study type	Q1a: Randomised assignment of subjects	Q1b: Similar groups at baseline	Q2a: Equal treatment of groups	Q2b: Intention-to-treat-analysis.	Q3a: Double-masked (blinded) study design or objective measures for cohort study	Q3b: Examiners calibrated	Results		External validity/applicability	Extent to which CEMB criteria were met
							Large effect Size	Precision of estimate		
Tan et al <sup>26</sup> 2010 Hong Kong RCT	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	This study met 8 of the 9 modified CEBM criteria. Based on the data presented in the study we assume an intention-to-treat analysis was performed.
Zhang et al <sup>27</sup> 2013 Hong Kong RCT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	This study met all the modified CEBM criteria.
Li et al <sup>28</sup> 2016 Hong Kong RCT	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	This study met 8 of the 9 modified CEBM criteria.

three groups who received one of the following: (i) annual application of 38% SDF on root caries and on sound exposed root surfaces with oral hygiene instruction (SDF/OHI); (ii) SDF application and oral hygiene instruction supplemented with tailored biannual oral hygiene education (SDF/OHI+OHE); or (iii) oral hygiene instruction and placebo (OHI+P), the control group.<sup>25</sup>

The mean increments of new root caries surfaces in Zhang et al<sup>25</sup> were 0.70, 1.00 and 1.33, respectively, for the (SDF/OHI+OHE), (SDF/OHI) and (OHI+P) groups ( $P < .05$ ). Our calculated PF (ie 1-RR) was 25% for (SDF/OHI) group and 47% for (SDF/OHI+OHE) group, using the control group as the referent group. For NNT, to prevent one new root caries surface, the (SDF/OHI) and (SDF/OHI+OHE) groups required treating of 3.03 and 1.59 patients, respectively.

The mean number of arrested root caries surfaces for Zhang et al<sup>25</sup> was 0.33 (SDF/OHI+OHE), 0.28 (SDF/OHI) and 0.04 (OHI+P) ( $P < .01$ ). The RR for caries arrest was 7 for (SDF/OHI) and 8.25 for (SDF/OHI+OHE), respectively. This means participants who received (SDF/OHI) or (SDF/OHI+OHE) had a sevenfold or 8.25 greater chance of experiencing caries arrest, respectively, than those who received (OHI+P). The PF for arrested caries was 600% greater in the (SDF/OHI) group and 725% greater in the (SDF/OHI+OHE) than in the (OHI+P) group. The NNT to arrest one carious surface was 4.17 for (SDF/OHI) and 3.45 for (SDF/OHI+OHE).

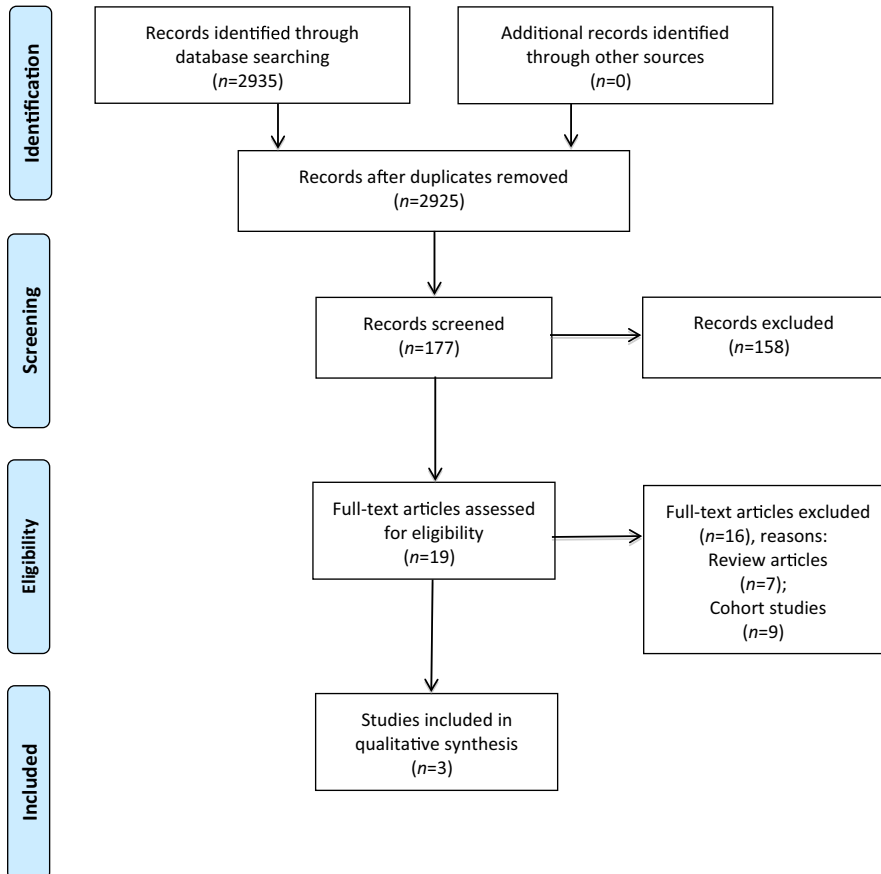
Li et al<sup>26</sup> investigated the effectiveness of SDF in arresting root caries in community-dwelling older adults and assessed the effectiveness of potassium iodide (KI) for reducing the colour of the arrested lesions. SDF was effective in arresting caries, KI had no effect on the arrest rate, and all arrested lesions eventually changed colour to the characteristic black stain. Effectiveness of annual application of 38% SDF was compared with annual application of 38% SDF immediately followed by KI application (SDF+KI), and with annual application of soda water used as placebo. Individualised oral hygiene instructions were provided to all participants at baseline and subsequently every 6 months. The caries arrest rate at the 30-month follow-up was 90% in the SDF group, 93% in the (SDF+KI) group and 45% in the placebo group ( $P < .001$ ).<sup>26</sup>

## 5 | DISCUSSION

Our search for studies on SDF in older populations resulted in only 3 well-conducted randomised clinical trials on root caries.<sup>24-26</sup> None investigated SDF treatment of coronal caries in older adults. We extended our search to include SDF safety, remineralization and desensitization studies in adults' aged 18-65 but found no systematic reviews or meta-analyses of these topics.

All three studies were high quality and had a low degree of bias. While Zhang et al study clearly met all evaluation criteria, the description of the equal treatment of the study groups was unclear in the Tan et al study, and the description of the similarity of the groups at baseline was unclear in the Li et al study.

Taken together, the three clinical trials reviewed support the use of SDF for prevention and arrest of root caries in older adults. The PF



**FIGURE 2** Data selection schematic [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

for prevention was lower in the Zhang et al<sup>25</sup> study than that in the Tan et al<sup>24</sup> study. This difference could be due to differences in study duration, number of SDF applications during the study and health status of the study groups.<sup>25</sup> Although the PF differed, the mean numbers of new caries in both studies were similar. Importantly, only one application of SDF was required to achieve results comparable to four applications of either NaF or CHX varnish.<sup>24</sup> Similar to this systematic review, a meta-analysis of root caries prevention and arrest in older adults by Wierichs et al that reviewed the studies by Tan et al and Zhang et al found fewer new carious root surfaces with a mean difference of  $-0.33$  (95% CI =  $-0.39, -0.28$ ) in SDF-treated teeth than placebo. Additionally, a systematic review of root caries prevention in older adults by Gluzman et al that reviewed the study by Tan et al, reported that SDF reduced incidence of new root surface caries by 72%.<sup>31,32</sup>

SDF effectively arrested root caries in the studies assessing root caries arrest.<sup>25,26</sup> The arrest rate for SDF and SDF-KI groups in the Li et al. study was 2 times (200%) greater than placebo, while Zhang et al reported the arrest rate being 6 times (600%) greater for the SDF group and 7.25 times (725%) greater for the (SDF+OHE) group than placebo. All participants in the Li et al study received individualised OHI, instructions for using manual toothbrush and interdental brush and received fluoride toothpaste during each follow-up examination every 6 months. The difference in arrest rates between Zhang et al and Li et al studies could be due the difference in their placebo groups where in addition to individualised oral hygiene instructions, the placebo group in the Li et al study received one fluoride toothpaste tube and a manual

toothbrush at each visit. For the Zhang et al study, as a part of OHE, the (SDF+OHI+OHE) group was engaged in establishing their oral hygiene goals and were evaluated every 6 months.<sup>25,26</sup>

KI application following SDF application inhibits biofilm formation<sup>33</sup> and improves fluoride uptake from glass-ionomer fillings.<sup>34</sup> The formation of silver iodide in SDF+KI reaction is thought to reduce staining.<sup>34</sup> However, Li et al reported KI application had no effect on reducing the characteristic black stain of SDF ( $P > .05$ ).<sup>26</sup> Carious lesions turned yellow immediately after KI application, but after 30 months, the colour of arrested lesions in the SDF and SDF-KI groups was similar. KI application may delay the staining process but eventually the arrested lesion will darken.

Our search found no studies testing the effect of SDF on coronal caries in older populations. However, SDF studies in children aged 18–36 months dominate the literature and provide evidence supporting the effectiveness of SDF in the prevention and arrest of coronal caries, with results comparable to other caries preventing and arresting agents such as NaF varnish, CHX, sealants and GIC. SDF was significantly more effective than no treatment in children.<sup>10,35–41</sup>

Evidence suggests SDF is effective in reducing pain in hypersensitive dentin in permanent teeth. Castillo et al reported significant reduction in the pain response of hypersensitive teeth, 24 hours after initial SDF application. Sensitivity continued to diminish further during the 7-day study period.<sup>30</sup> Sinha et al demonstrated effectiveness of SDF as a remineralizing agent and possible use as an indirect pulp capping agent in deep carious lesions.<sup>32</sup>

Dental caries is caused by demineralization of tooth structure following loss of calcium and phosphate ions. Hypersensitivity is an early sign of demineralization. Although older adults may not report hypersensitivity, the process of demineralization continues.<sup>42</sup> SDF enhances deposition of calcium and phosphate ions, remineralization of tooth structure and reversal of the disease process. Based on findings from studies in children, as well as from Sinha et al (age group 18-35 years old) and Castillo et al (average age 43-44 years old) studies, SDF could be effective in arresting and preventing coronal caries in older adults.<sup>10,29,30,35-41</sup> SDF application on coronal surfaces may help retention of natural teeth and increase their resistance to many of the risk factors for caries such as xerostomia, poor oral hygiene and low pH that are more prevalent in older adults coping with chronic diseases and functional impairments.<sup>9,43</sup>

Professional application of SDF is considered safe. No serious adverse effects are reported from clinical trials of SDF. A pilot study by Vasquez et al addressed safety and reported that the serum concentrations for fluoride and silver were significantly less than the U.S. Environmental Protection Agency's oral reference dose for daily fluoride exposure and lifetime silver exposure.<sup>44</sup> No significant mucosal changes were noticed.<sup>30,44</sup>

SDF is inexpensive relative to other caries preventive agents. A simulated study about cost-effectiveness of root caries preventive treatment concluded that SDF application is more effective and less costly in high-risk populations.<sup>45</sup>

## 6 | KNOWLEDGE GAP ANALYSIS

There is no established frequency for SDF application; suggested frequencies in children range from annual to biannual to three consecutive weekly applications followed by semi-annual recall applications.<sup>24,25,36,39</sup> Increased frequency is linked to a greater arrest rate over the first 6-12 months in children.<sup>36,39</sup> Annual application of SDF effectively prevents and arrests root caries in older adults who are capable of self-care and are not affected by serious medical conditions.<sup>24-26</sup> Multiple applications may benefit a more dependent and at-risk older population.<sup>9,46</sup> Clinicians should use their clinical judgement about application frequency based on current evidence and individual caries risk factors.<sup>43,47</sup> More studies are required to determine effective application frequency for caries prevention and arrest rates in older adults, at different stages of dependency and risk.

The studies included in this report were conducted in locales with community water fluoridation. However, in the United States, water fluoridation is not uniform.

Black staining of carious lesions by SDF was reported to be acceptable by parents and young children,<sup>36,38</sup> possibly because primary teeth exfoliate. Future studies should evaluate aesthetic acceptability for older adults and ways to reduce staining in permanent dentition. Acceptability may also vary depending on patient expectations.

The few clinical trials focused on older adults indicate SDF is effective in the prevention and arrest of root caries for this population. However, additional clinical trials in heterogeneous populations of

older adults, investigating root, coronal, primary and secondary caries, would be beneficial to better establish the full range of optimal use.

## 7 | RECOMMENDATIONS

Our recommendations for the use of SDF in older adults are based on the current state of evidence found in this systematic review. The Seattle Care Pathway (SCP) provides an evidence-based approach to oral care for older adults.<sup>48</sup> SCP is a framework for dental providers to assess the risks, needs and barriers to oral health care for older adults and determine best practices for prevention and treatment based upon functional status.<sup>9</sup> The schema assists practitioners in appropriate assessment, prevention, treatment and communication strategies, based on functional dependency and is adaptable to patients' needs and population-based needs. The pathway provides an important framework through which standardised care can be delivered to patients throughout the dependency continuum with consistent outcomes.<sup>43</sup> Following SCP criteria and the results of this review, SDF is appropriate for a wide spectrum of seniors, from those who are independent with high to extreme caries risk<sup>47</sup> to highly dependent older adults with limited access to care and increased caries risk.<sup>43,46</sup> SDF could be used as a standalone measure or in conjunction with oral hygiene education<sup>25</sup> and other treatment.<sup>9,46</sup> Some states permit dental hygienists, dental assistants, physicians, nurses and their assistants to apply SDF for the control of caries, thereby increasing access to care for many older adults.<sup>9</sup> Communication between patients, care givers and healthcare providers, is crucial for setting expectations and achieving successful outcomes.<sup>43</sup> SDF is an appropriate option to manage dentin sensitivity and for caries prevention and management to optimise oral health across the life course.

## 8 | CONCLUSION

This systematic review evaluates the use of SDF for both root caries prevention and arrest in older adults. Existing reports of SDF trials support effectiveness in root caries prevention and arrest, remineralization of deep occlusal lesions and treatment of hypersensitive dentin.

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